



ADIGITAL TRANSFORMATION IN EMERGENCY MEDICINE: THE IMPACT OF HEALTH INFORMATION TECHNOLOGY IN SAUDI ARABIA

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DOI: <https://doi.org/10.5281/zenodo.18385006>

How to cite this Article: Abdulraouf Altaieb¹, Abdulaziz A. Alqahtani², Saad Alarifi³, ESSA H. Almutlaq⁴, Bader M. Al-Rashidi⁵, Adel Alzahrani⁶, Afrah Y. Saddeek⁷, Abdulrahim S. Althobaiti⁸, Sultan G. Althobaiti⁹, Mishal S. Al-Sayyali¹⁰, Saleh A. Alzahrani¹¹, Maryam A. Al Qannas^{12*}, Abed Althobaiti¹³, Nasser Alsufyani¹⁴, Mansour Alsufyani¹⁵, Bandar S. Alsharif¹⁶, Muteb H. Alharthi¹⁷ (2024). Adigital Transformation in emergency medicine: the impact of health information technology in saudi arabia. World Journal of Pharmaceutical and Life Science, 10(11), 566-583.

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Article Received on 21/10/2024

Article Revised on 09/11/2024

Article Published on 30/11/2024

ABSTRACT

This research paper provides a comprehensive examination of the transformative impact of digital health technologies on healthcare delivery in Saudi Arabia, with a particular focus on emergency department (ED) efficiency, telemedicine, artificial intelligence (AI), and health informatics. Through an extensive literature review of recent studies spanning the period 2020–2025, the paper highlights the roles of big data analytics, mobile health applications, telehealth services, AI-based decision support systems, and IoT innovations in improving patient care, operational efficiency, and accessibility. The review synthesizes empirical findings regarding the reduction of ED wait times, cost-effectiveness of telemedicine for chronic disease management, healthcare professional perceptions of digital tools, and patient satisfaction with virtual consultations. Key challenges are identified, including data security, privacy concerns, digital literacy gaps, infrastructural limitations, and workforce training needs. The study also highlights research gaps, emphasizing the scarcity of Saudi-specific empirical studies on AI triage, predictive analytics, integrated digital health ecosystems, and culturally tailored interventions. By proposing future research directions, including longitudinal evaluations, usability studies, and implementation science approaches, this paper provides a roadmap for leveraging digital innovations to achieve Saudi Vision 2030 objectives and foster an efficient, secure, and equitable healthcare system.

INDEXTERMS- Artificial Intelligence, Digital Health, Emergency Department Efficiency, Saudi Arabia, Telemedicine

I. INTRODUCTION

Emergency medicine is a critical component of modern healthcare systems, serving as the frontline for patients experiencing acute illnesses or injuries that require immediate attention.^[1,2] Globally, emergency departments (EDs) face persistent challenges, including overcrowding, delayed treatment, resource mismanagement, and variations in care quality (Bobardt-Hartshorn *et al.*, 2024). These challenges are further exacerbated by increasing population demands, aging populations, and the prevalence of chronic and complex diseases.^[3,4] Timely access to care is often constrained by structural limitations, such as inadequate staffing, limited bed availability, and suboptimal triage protocols. Moreover, emergency physicians and staff frequently confront high-stress environments, where rapid decision-making is required under conditions of uncertainty and incomplete patient information. Collectively, these factors contribute to inefficiencies in emergency care delivery, adversely affecting patient outcomes, satisfaction, and overall system performance.^[5]

In recent years, digital transformation has emerged as a pivotal strategy to address these pressing challenges in healthcare. Digital transformation encompasses the integration of information technology (IT) and innovative digital solutions to improve healthcare delivery, enhance patient safety, and optimize operational efficiency. In the context of emergency medicine, digital technologies—including electronic health records (EHRs), telemedicine platforms, clinical decision support systems, teleradiology, mobile health applications, and health information exchanges—have shown significant promise in mitigating traditional barriers to timely and high-quality care.^[6,7] For instance, EHRs facilitate the rapid retrieval and sharing of patient information, reducing diagnostic errors and enabling continuity of care across departments and facilities. Telemedicine applications allow patients in remote or underserved regions to receive timely consultations from emergency specialists, potentially reducing unnecessary hospital visits and improving care coordination. Additionally, clinical decision support tools can enhance triage accuracy, provide evidence-based treatment recommendations, and optimize resource allocation in real time, ultimately improving patient outcomes while reducing operational bottlenecks.^[8,9]

Despite these global advances, the adoption and impact of health information technology (HIT) in emergency medicine are context-dependent, influenced by regional infrastructure, regulatory frameworks, and cultural considerations. In Saudi Arabia, the national agenda for healthcare transformation is closely aligned with Vision 2030, a strategic initiative aimed at diversifying the economy, promoting technological innovation, and enhancing public service delivery, including healthcare.^[10,11] Vision 2030 emphasizes the development of a digitally enabled healthcare ecosystem that leverages cutting-edge technologies to improve

accessibility, quality, and efficiency. Under this framework, the Ministry of Health and other governmental bodies have introduced a variety of HIT initiatives, such as the implementation of EHRs across public hospitals, national telemedicine programs, mobile health platforms, and health information exchanges to enable seamless data sharing. These initiatives aim not only to improve routine care delivery but also to strengthen emergency services, enhance decision-making during critical events, and facilitate rapid response to public health crises, including mass casualty incidents and pandemics.^[12,13]

In Saudi Arabia, emergency medicine services are continually challenged by population growth, high rates of road traffic accidents, and a rising burden of chronic diseases such as diabetes, cardiovascular conditions, and respiratory disorders. Traditional emergency department workflows often struggle to accommodate the surge in patient volume while maintaining clinical quality and patient safety. Furthermore, variations in physician training, limited access to specialists in rural areas, and fragmented patient information contribute to delays in diagnosis and treatment. In this context, HIT offers an opportunity to transform emergency care by improving information accessibility, enabling remote consultations, streamlining clinical workflows, and enhancing coordination across different levels of care. For example, the integration of teleradiology allows radiologists to remotely review imaging studies, expediting diagnosis and facilitating timely interventions. Similarly, mobile health applications enable patients and first responders to transmit real-time clinical data to ED teams before arrival, supporting pre-hospital care and preparedness.^[14,15]

Beyond operational benefits, the adoption of HIT in emergency medicine is closely linked to broader policy and strategic objectives outlined in Vision 2030.^[16,17] The Kingdom's digital health agenda prioritizes interoperability, data-driven decision-making, patient-centered care, and evidence-based practices.^[18] By implementing standardized HIT solutions, Saudi healthcare institutions aim to reduce redundant procedures, enhance transparency, and promote accountability, while fostering a culture of continuous improvement. In emergency medicine, these objectives translate into tangible outcomes, such as reduced patient waiting times, improved triage accuracy, minimized medication errors, and enhanced overall patient satisfaction. Additionally, HIT facilitates the collection and analysis of large-scale health data, which can be used for predictive modeling, quality improvement initiatives, and policy planning, ensuring that emergency services are responsive to evolving population needs.^[19,20]

Several studies highlight the potential of HIT to address key challenges in emergency medicine within Saudi Arabia. Teleradiology, for instance, has demonstrated

high levels of satisfaction among healthcare professionals, improved diagnostic accuracy, and standardized imaging protocols, particularly in hospitals with limited specialist availability.^[21,22] Telemedicine and mobile health applications have been shown to enhance patient engagement, reduce unnecessary ED visits, and support chronic disease management, which indirectly alleviates pressure on emergency services. decision support systems and electronic triage tools contribute to more efficient resource utilization, helping prioritize high-risk cases and optimizing patient flow within the ED. Collectively, these findings underscore the transformative role of HIT in creating a more agile, data-driven, and patient-centered emergency care environment.^[23]

Nevertheless, the successful implementation of HIT in Saudi emergency medicine is not without challenges. Technical issues, including system interoperability, data security, and infrastructure limitations, can impede seamless technology adoption. Human factors, such as clinician resistance, limited digital literacy, and training gaps, may reduce the effective use of technology in high-pressure emergency settings. Additionally, ethical considerations, including patient privacy, informed consent, and equitable access to digital services, must be addressed to ensure safe and inclusive care. Cultural factors, including patient preferences for in-person consultations and trust in digital health systems, may also influence HIT uptake.^[24,25] To maximize the benefits of digital transformation, these challenges must be systematically identified and addressed through evidence-based strategies, policy guidance, and capacity-building initiatives.^[26,27]

Given the strategic importance of emergency medicine and the rapid expansion of HIT in Saudi Arabia, there is a pressing need to synthesize the available evidence on the impact of digital technologies in this domain. Systematic reviews provide a robust methodological approach to evaluating the effectiveness, benefits, and limitations of HIT interventions across diverse emergency care settings. By aggregating findings from multiple studies, systematic reviews can identify trends, knowledge gaps, and best practices, offering valuable guidance for policymakers, healthcare managers, and clinicians seeking to optimize emergency services. In the Saudi context, such a review is particularly relevant given the ongoing national transformation efforts, the growing population demands, and the imperative to align healthcare practices with Vision 2030 objectives.^[28,29]

The aim of this research, therefore, is to systematically review the impact of health information technology on emergency medicine in Saudi Arabia. Specifically, the study seeks to evaluate how digital tools, including telemedicine, teleradiology, electronic health records, mobile health applications, and clinical decision support systems, influence key aspects of emergency care, such as diagnostic accuracy, patient flow, resource utilization,

clinician satisfaction, and patient outcomes. By providing a comprehensive synthesis of current evidence, this research aims to inform strategic decision-making, identify opportunities for optimization, and guide future research and policy development in the intersection of HIT and emergency medicine. The findings are expected to contribute to the broader goal of establishing a digitally enabled, patient-centered, and efficient emergency healthcare system that is responsive to evolving needs and aligned with Saudi Arabia's Vision 2030 healthcare priorities.^[30,31]

Emergency medicine faces multifaceted challenges that demand innovative and effective solutions. Digital transformation, through the strategic adoption of health information technology, offers a promising avenue for enhancing care quality, operational efficiency, and patient outcomes in emergency settings. Saudi Arabia, guided by the principles of Vision 2030, is actively implementing HIT initiatives to support a more integrated, data-driven, and patient-centered healthcare system. This systematic review seeks to evaluate the impact of these technological interventions on emergency medicine, providing evidence-based insights to support informed policy, clinical practice, and future research. By examining the experiences, outcomes, and challenges associated with HIT in Saudi emergency care, this study aims to contribute to the Kingdom's vision of a modern, technologically advanced, and resilient healthcare system.^[32,33]

II. LITERATURE REVIEW

1. Impact of Big Data Analytics on Emergency Department Efficiency in Saudi Ministry of Health Hospitals

The study by Senitan and Alzahrani (2025) investigates the transformative role of big data analytics in enhancing operational efficiency in Saudi Ministry of Health (MOH) hospitals' emergency departments (EDs). Using a retrospective analysis of 228,857 patient records across ten hospitals, the research evaluated the effects of the Ada'a Health Program on key performance indicators such as Door-to-Doctor Time, Doctor-to-Decision Time, and Decision-to-Disposition Time. The results indicated significant improvements across all metrics, with strong correlations observed between clinical decision-making processes and patient flow efficiency. Regression analysis further confirmed that the program significantly reduced wait times ($p < 0.001$), underscoring the critical value of big data-driven operational decisions. The study emphasizes that continued investment in predictive modeling, workflow automation, and data-driven strategies is essential for sustaining ED efficiency, highlighting the potential scalability of such programs across diverse healthcare settings in Saudi Arabia.^[34]

2. The Role of Telemedicine Services in Changing Users' Intentions for Presenting to Emergency Departments in Saudi Arabia

Alfaleh *et al.* (2022) explore how telemedicine platforms, specifically the Sehha mobile application and the 937 medical call center, influence patients' decisions to visit emergency departments in Saudi Arabia. The cross-sectional study included 319 patients and analyzed their behavioral changes after teleconsultations. Findings revealed that 53 patients who initially intended to visit EDs did not do so following telemedicine advice, indicating a statistically significant reduction in unnecessary ED visits ($p < 0.01$). The study also highlighted differences between platforms, with the Sehha app demonstrating a higher influence on patient decision-making than the medical call center. These results suggest that telemedicine services can effectively reduce ED overcrowding, improve resource allocation, and enhance patient convenience by providing timely and accurate medical guidance for non-critical health issues.^[35]

3. Telehealth Role During the COVID-19 Pandemic: Lessons Learned from Health Care Providers in Saudi Arabia

Shehabe Eddine and Zedan (2021) examine the role of virtual clinics (VCs) in maintaining continuity of care during the COVID-19 pandemic in Saudi Arabia. Conducted in a hospital setting with 277 healthcare provider respondents, the study highlighted that 67.2% of providers deployed VCs, primarily serving chronically ill patients. The findings showed that most providers relied on mobile communication and integrated electronic prescriptions to facilitate care. Benefits included reduced appointment waiting times and increased patient satisfaction, while challenges were mainly linked to the lack of face-to-face interactions and limitations in physical examinations. This study underscores the critical need to integrate telehealth services effectively into existing healthcare systems while addressing operational, technological, and patient-centered challenges for optimal service delivery.^[36]

4. The Perception of Health Care Practitioners Regarding Telemedicine During COVID-19 in Saudi Arabia: Mixed Methods Study

Alqurashi *et al.* (2023) explore Saudi healthcare practitioners' perceptions and experiences with telemedicine during the COVID-19 pandemic using a mixed-methods approach. The study utilized 81 completed questionnaires and qualitative interviews to assess knowledge, awareness, and adoption of telemedicine systems. Results indicated high familiarity with telemedicine (83%) and highlighted that continuous training is crucial for effective usage. Practitioners reported teleconsultations and patient monitoring as the primary applications, with concerns regarding privacy and confidentiality (54%). Qualitative interviews revealed five themes: culture, barriers, communication, implementation, and evaluation. The study emphasizes

the importance of adopting national telemedicine standards, fostering a supportive organizational culture, and addressing ethical and privacy concerns to ensure sustainable telemedicine integration in Saudi Arabia.^[37]

5. Impact of Digital Transformation on Healthcare Accessibility in Saudi Arabia: A Systematic Review

Alsahmah and Alshammari (2025) conducted a systematic review to assess the influence of digital transformation on healthcare accessibility in Saudi Arabia, with a focus on telemedicine, electronic health records, and AI-driven diagnostic tools. The study, spanning literature from 2020 to 2024, found that digital health interventions significantly reduced consultation wait times (up to 40%) and improved continuity of care, especially in rural areas. However, implementation barriers such as digital literacy gaps, infrastructural limitations, and privacy concerns were identified. The study underscores the critical role of digital transformation in achieving Saudi Vision 2030 objectives, highlighting the need for strategic initiatives to enhance technological infrastructure, patient engagement, and long-term adoption of digital health solutions across diverse healthcare settings.^[38]

6. Digital Health Transformation in Saudi Arabia: A Cross-Sectional Analysis Using HIMSS Digital Health Indicators

Al-Kahtani *et al.* (2022) analyzed digital health readiness across ten healthcare facilities in Saudi Arabia's Eastern Province using the Healthcare Information and Management Systems Society (HIMSS) digital health indicators. The study assessed four dimensions: person-enabled health, predictive analytics, governance and workforce, and interoperability. Results indicated that private facilities scored higher than public ones, with governance and workforce being the most implemented dimension and predictive analytics the least. Tertiary hospitals showed lower readiness scores compared to primary and secondary facilities. This study provides valuable insights for policymakers and healthcare leaders, emphasizing the need for strategic planning to enhance digital maturity, improve workforce capabilities, and leverage technology for more efficient healthcare delivery in line with Saudi Vision 2030.^[39]

7. Security Awareness of End-Users of Mobile Health Applications: An Empirical Study

Aljedaani *et al.* (2020) investigated end-users' security awareness regarding mobile health (mHealth) applications in Saudi Arabia. Collaborating with two mHealth providers, the study surveyed 101 users and found that, despite possessing technical knowledge, many users failed to adopt adequate security practices, posing risks to health-critical data. The research highlighted the importance of security education, multi-step authentication, and app design that balances usability with security. Findings indicate that provider-led training and enforcement of best practices are critical to mitigating social, legal, and financial consequences

associated with improper use of mHealth apps, providing a framework for enhancing security awareness in the rapidly growing digital health ecosystem.^[40]

8. End-Users' Knowledge and Perception About Security of Mobile Health Apps: A Case Study with Two Saudi Arabian mHealth Providers

Aljedaani et al. (2021) further examined the security perceptions of end-users regarding mHealth applications in Saudi Arabia. Surveying 101 users, the study revealed that while users were aware of existing security features, they desired more user-friendly security measures such as biometric authentication. Concerns over privacy and data protection were prevalent, with end-users advocating for practices like session timeouts and two-factor authentication. The study emphasizes the importance of human-centric security design, highlighting that security awareness training, social guidance, and provider-led initiatives can enhance trust and adoption of mHealth apps, ensuring a balance between security and usability for sustainable digital health practices.^[41]

9. Assessing the Acceptance of Clinical Decision Support Tools Using an Integrated Technology Acceptance Model

Aljarboa and Miah (2020) explored factors influencing the acceptance of clinical decision support systems (CDSS) among general practitioners in Saudi Arabia. Using a qualitative approach with semi-structured interviews of 12 GPs, the study integrated the Unified Theory of Acceptance and Use of Technology (UTAUT) with a Task-Technology Fit (TTF) model. Results highlighted that performance expectancy, effort expectancy, facilitating conditions, technology-task fit, and system characteristics influenced CDSS acceptance. The study underscores the importance of understanding end-user perceptions and technology alignment to ensure successful implementation of digital health tools, offering a framework for promoting CDSS adoption in the context of Saudi healthcare systems aligned with Vision 2030 initiatives.^[42]

10. Internet of Things-Based Innovations in Saudi Healthcare Sector: A Methodological Approach for Investigating Adoption Issues

Masmali, Miah, and Mathkoor (2020) investigated the adoption of IoT-based innovations in Saudi Arabia's healthcare sector through a qualitative phenomenological approach. The study emphasized that despite the significant potential of IoT to improve real-time patient monitoring, reporting, and overall healthcare delivery, adoption rates lag behind other industries. The research identified barriers such as organizational readiness, user acceptance, and infrastructural limitations, and proposed a structured methodology for understanding adoption challenges. Findings suggest that integrating IoT into healthcare services requires strategic planning, stakeholder engagement, and a focus on human-centric design to overcome technological and organizational

challenges for effective deployment in Saudi healthcare settings.^[43]

11. Patient Opinions on Virtual Consultations in Saudi Arabia

AlShareef and AlWabel (2024) conducted a nationwide cross-sectional study in Saudi Arabia to explore patient perspectives on virtual consultations, aiming to identify the factors that influence patient satisfaction and perceptions of telehealth services. Utilizing a convenience sample of 916 adults, participants completed a questionnaire gathering demographic information, virtual consultation experiences, and technology usability based on the Telehealth Usability Questionnaire. Findings revealed that over 90% of participants found virtual consultations convenient, useful, and satisfactory, with a marked preference for video calls over telephone consultations. Satisfaction was lower among younger patients, urban residents, those attending specialty clinics, patients consulting psychologists, and individuals preferring in-person visits. The study highlights the potential for expanding telehealth services, particularly through video consultations, and underscores the importance of educational initiatives to optimize patient engagement and satisfaction, ultimately supporting the broader integration of telehealth in Saudi healthcare.^[44]

12. Tele-Oral Medicine Effectiveness and Specialist Experiences

Akeel et al. (2023) investigated tele-oral medicine in Saudi Arabia, focusing on specialists' experiences and the tool's effectiveness in managing oral diseases amid a shortage of oral medicine specialists. In this pilot cross-sectional study, 49 participants evaluated 16 preselected cases of oral lesions, including clinical histories and images, primarily through WhatsApp consultations. Results demonstrated high diagnostic accuracy ranging from 73.5% to 100% and management accuracy between 51% and 98%, indicating tele-oral medicine's ability to enhance patient care in rural regions with limited specialist access. The study emphasizes the tool's applicability for bridging gaps in healthcare delivery and recommends further studies with larger sample sizes and international collaboration to validate findings, refine strategies, and optimize tele-oral medicine implementation.^[45]

13. Cost-Effectiveness of Telemedicine in Managing Uncontrolled Diabetes

AlMutairi et al. (2021) assessed the cost-effectiveness of telemedicine care for patients with uncontrolled type 2 diabetes mellitus during the COVID-19 pandemic in Saudi Arabia. A retrospective chart review was conducted on 200 patients divided equally between telemedicine and traditional care models, evaluating HbA1c reduction and total healthcare costs. Patients in the telemedicine arm achieved a greater mean HbA1c reduction (1.82 vs. 1.54), albeit at higher costs, resulting in an incremental cost-effectiveness ratio (ICER) of SAR

2372.52 per 1% HbA1c reduction. The study concludes that telemedicine is a cost-effective approach for managing poorly controlled diabetes, supporting its adoption in routine care to improve clinical outcomes and reduce the burden of chronic disease management.^[46]

14. Telemedicine Training for Family Medicine Residents

AlFawaz and Alrasheed (2023) examined the experiences of family medicine residents at King Saud University Medical City during the COVID-19 pandemic with telemedicine training. A cross-sectional survey of 60 residents indicated that most preferred in-person visits but accepted telemedicine as part of training if limited to 25% of clinical exposure. The findings highlighted that telemedicine clinics were associated with reduced clinical experience, supervision, and discussion time, though 68.3% of residents reported improvement in communication skills. The study underscores the need for structured integration of telemedicine into residency programs to maintain educational quality while leveraging digital healthcare tools for effective patient care.^[47]

15. Telemedicine Perspectives During the COVID-19 Era in Saudi Arabia

Al-Hazmi, Sheerah, and Arafa (2021) reviewed telemedicine adoption and perspectives in Saudi Arabia during the COVID-19 pandemic. The study emphasized telemedicine's applications in triage, direct care, follow-up, and consultation, delivered through synchronous, asynchronous, or mixed modalities. Benefits included improved accessibility and cost-effectiveness, while challenges encompassed diagnostic reliability, ethical concerns, technical barriers, and cultural considerations. The authors advocated for robust legislation, secure digital infrastructure, and systematic policies to facilitate telemedicine adoption. The review aligns telemedicine strategies with Saudi Vision 2030, highlighting their potential to improve healthcare delivery while addressing systemic challenges.^[48]

16. Teleradiology in Saudi Arabia: National Survey and MRI Review

Alruwaili *et al.* (2024) investigated teleradiology services in Saudi Arabia via a national survey of Ministry of Health employees and retrospective analysis of 212 MRI reports. The study assessed service value, user satisfaction, quality assurance, and technical challenges. Findings revealed high user satisfaction (90%), recognition of service effectiveness (96.2%), and consensus on standardized imaging protocols (93%). However, variability in report quality pointed to areas needing improvement. The study illustrates teleradiology's transformative role in streamlining diagnostic workflows, enhancing service quality, and emphasizes ongoing enhancements for quality assurance, security, and standardization.^[49]

17. Patient-Reported Factors Influencing Emergency Department Referrals

Bobardt-Hartshorn *et al.* (2024) examined patient-reported factors affecting emergency department (ED) referrals from a co-located out-of-hours walk-in clinic in Germany. In a cross-sectional observational study involving 2574 participants, ten factors were significantly associated with ED referral likelihood, including trauma, eye symptoms, abdominal pain, diabetes history, neurological symptoms, and perceived urgency. Conversely, respiratory, neck/back, urinary tract symptoms, and health problems lasting more than four days reduced referral probability. The study suggests that gathering patient-reported information at registration could optimize resource allocation, improve patient flow, and inform triage tool development for urgent care, ultimately enhancing healthcare efficiency and patient outcomes.^[50]

18. Usability Evaluation of mHealth Apps

Shen *et al.* (2024) developed a usability evaluation model for mHealth applications, integrating task analysis and eye movement data to assess and improve user-friendliness. Using a blood glucose recording app as a test case, modifications based on task analysis reduced interaction errors by 24%, while eye movement-informed improvements increased information access usability by 15%. The study presents a validated, systematic methodology for evaluating mHealth app usability, demonstrating how combining behavioral and physiological metrics can enhance patient engagement, optimize app design, and promote the effective self-management of chronic diseases, particularly diabetes.^[51]

19. Health Informatics in Saudi Arabia

Alotaibi *et al.* (2024) reviewed the transformative role of health informatics in Saudi Arabia, focusing on digital technology adoption and data-driven practices to improve patient care. The study examined applications such as electronic health records, telemedicine, health information exchange, and mobile health apps, highlighting their impact on care coordination, accessibility, and healthcare efficiency. Challenges including data privacy, interoperability, workforce training, and financial limitations were discussed, alongside government strategies to address them. The review emphasized alignment with Saudi Vision 2030 and the potential for health informatics to advance precision medicine and position Saudi Arabia as a leader in digital healthcare innovation.^[52]

20. Role of Health Technology in Enhancing Healthcare Services

Almansour *et al.* (2024) discussed the pivotal role of health technology in improving healthcare delivery in Saudi Arabia, highlighting telemedicine, electronic health records, mobile applications, AI, and data analytics. These technologies enhance access, efficiency, and patient-centered care, especially in remote regions, while reducing wait times and administrative burdens.

Digital training tools, including VR simulations and e-learning platforms, support healthcare professional development and up-to-date skills. The study emphasizes that integrating technology facilitates personalized care, improves provider-patient communication, and promotes

adherence to treatment plans. Continued investment in innovative healthcare solutions aligns with Vision 2030, with promising outcomes for patient satisfaction, health outcomes, and system efficiency.^[53]

No	Authors / Year	Study Focus	Methods	Key Findings	Implications for Saudi Healthcare
1	Senitan & Alzahrani, 2025	Big data analytics in ED efficiency	Retrospective study, 228,857 patient records, 223 personnel surveys	Significant reduction in wait times; improved KPIs; strong correlation between clinical decisions and patient flow	Supports investment in predictive analytics and workflow automation to enhance ED efficiency
2	Alfaleh et al., 2022	Telemedicine impact on ED visits	Cross-sectional, 319 patients	53 patients avoided ED visits; Sehha app more effective than call center	Telemedicine reduces ED overcrowding and optimizes resource utilization
3	Shehabe Eddine & Zedan, 2021	Virtual clinics during COVID-19	Cross-sectional survey, 277 providers	High deployment of virtual clinics; improved patient satisfaction; reduced waiting times	Telehealth integration can maintain care continuity during crises
4	Alqurashi et al., 2023	Health practitioner perception of telemedicine	Mixed methods, 81 questionnaires + interviews	High awareness; continuous training needed; privacy concerns	Emphasizes training, national standards, and culture for telemedicine adoption
5	Alsahmah & Alshammari, 2025	Digital transformation and healthcare accessibility	Systematic review, 2020–2024	Telemedicine and AI improve access; 40% reduction in wait times; barriers include digital divide	Highlights digital transformation aligned with Vision 2030, emphasizing infrastructure and literacy
6	Al-Kahtani et al., 2022	Digital health readiness using HIMSS indicators	Cross-sectional, 10 facilities	Private facilities scored higher; predictive analytics least implemented	Provides roadmap for improving digital maturity and policy planning
7	Aljedaani et al., 2020	Security awareness in mHealth apps	Empirical study, 101 users	Low adoption of security practices; need for training and best practices	Emphasizes user education and secure design for mHealth adoption
8	Aljedaani et al., 2021	End-users' perception of mHealth security	Empirical study, 101 users	Desire for biometric authentication; privacy concerns; training improves trust	Guides design of secure and usable mHealth applications
9	Aljarboa & Miah, 2020	Acceptance of clinical decision support systems	Qualitative, 12 GPs	Factors affecting CDSS acceptance: performance expectancy, effort expectancy, facilitating conditions, TTF	Supports strategic implementation of CDSS in Saudi healthcare
10	Masmali et al., 2020	IoT adoption in healthcare	Qualitative phenomenological approach	IoT adoption slow; barriers include organizational readiness and infrastructure	Suggests strategic planning and stakeholder engagement for IoT implementation
11	AlShareef & AlWabel, 2024	Patient opinions on virtual consultations	Cross-sectional, n=916, questionnaire	>90% found teleconsultations useful; satisfaction influenced by age, location, clinic type, consultation mode	Supports telehealth expansion, especially video calls
12	Akeel et al., 2023	Tele-oral medicine effectiveness	Pilot cross-sectional, n=49	Diagnostic accuracy 73.5–100%; management 51–98%	Tele-oral medicine effective in rural regions; further studies needed
13	AlMutairi et al., 2021	Cost-effectiveness of telemedicine in diabetes	Retrospective chart review, n=200	HbA1c reduction higher in telemedicine; ICER SAR 2372.52	Telemedicine is cost-effective; supports routine use
14	AlFawaz &	Telemedicine	Cross-sectional	Preference for in-person	Structured integration

	Alrasheed, 2023	training experiences for residents	survey, n=60	visits; telemedicine limited to 25%; reduced clinical experience	needed in residency programs
15	Al-Hazmi, Sheerah & Arafa, 2021	Telemedicine perspectives during COVID-19	Literature review	Telemedicine useful for triage, care, follow-up; cultural/technical barriers	Requires legislation, ethical oversight, and secure infrastructure
16	Alruwaili et al., 2024	Teleradiology adoption and effectiveness	National survey + MRI report review, n=212	High satisfaction; quality variability; recognized service value	Enhances workflow; quality/security improvements needed
17	Bobardt-Hartshorn et al., 2024	Patient-reported ED referral factors	Cross-sectional observational, n=2574	10 factors identified affecting referral likelihood	Supports triage tool development; optimizes resource utilization
18	Shen et al., 2024	mHealth app usability	Task analysis + eye tracking	Task-based improvements 24%; eye movement improvements 15%	Provides validated usability evaluation model for mHealth apps
19	Alotaibi et al., 2024	Health informatics adoption	Literature review	EHRs, telemedicine, HIE, mHealth improve access, coordination, efficiency	Strategic alignment with Vision 2030; supports digital healthcare transformation
20	Almansour et al., 2024	Health technology impact on healthcare	Review	Telemedicine, AI, EHR, mobile apps enhance access, efficiency, training, patient engagement	Supports Vision 2030 goals; enhances healthcare quality and patient satisfaction

Gaps in Literature

Despite the substantial body of research on health information technology and digital transformation in Saudi healthcare, several critical gaps remain. Most studies focus primarily on telemedicine, teleradiology, and mHealth applications, while limited attention has been given to the integration of multiple HIT systems, such as clinical decision support, IoT devices, and predictive analytics, specifically within emergency department workflows. Evidence on the long-term clinical and operational impacts of these technologies is scarce, and studies often employ small sample sizes or pilot designs, limiting generalizability. Additionally, research addressing barriers to adoption—such as interoperability, security, ethical considerations, digital literacy, and cultural acceptance—remains fragmented. Few studies provide comprehensive frameworks for HIT implementation that align with Saudi Arabia's Vision 2030 objectives, particularly in emergency medicine. Furthermore, while patient satisfaction and clinician perceptions have been explored, quantitative outcomes on patient safety, care quality, and ED efficiency remain underreported. Addressing these gaps through large-scale, multi-center, and longitudinal studies could inform evidence-based policies, optimize resource allocation, and enhance emergency care delivery within the Saudi healthcare system.

III. METHODOLOGY

Research Design

This study employed a systematic review design to critically evaluate the impact of Health Information Technology (HIT) on emergency medicine within the context of Saudi Arabia. A systematic review is a rigorous, structured approach to synthesizing existing evidence, which allows researchers to identify, appraise,

and summarize relevant literature to address a clearly defined research question. This methodology was chosen due to its ability to provide comprehensive insights into HIT adoption, implementation, and outcomes, while highlighting gaps in the current knowledge base. The review focuses specifically on the intersection of emergency medicine and digital transformation initiatives in Saudi healthcare, in line with Vision 2030 objectives to enhance healthcare quality, accessibility, and efficiency through technological innovations.

Databases Searched

A comprehensive literature search was conducted across multiple reputable databases to ensure exhaustive coverage of relevant studies. The primary databases included **PubMed, Scopus, Web of Science, and the Saudi Digital Library (SDL)**. PubMed was selected for its extensive collection of biomedical literature and peer-reviewed clinical studies, offering high-quality research on healthcare technology and emergency medicine. Scopus and Web of Science were included to provide multidisciplinary coverage, capturing studies from both clinical and information technology perspectives. The Saudi Digital Library was particularly valuable for accessing region-specific publications, theses, and governmental reports, enabling the inclusion of local studies that directly address the Saudi healthcare system and national HIT initiatives. In addition, manual searches of reference lists from selected articles were performed to identify further relevant studies that might not have been indexed in the primary databases.

Keywords and Search Strategy

The search strategy was developed to ensure specificity and relevance to the research focus. Keywords were constructed using both controlled vocabulary (e.g.,

MeSH terms in PubMed) and free-text terms, combining concepts related to emergency medicine, HIT, and Saudi Arabia. The primary search string used was: (“Emergency Medicine” AND “Health Information Technology” AND “Saudi Arabia” AND “Digital Transformation”) Alternative keywords and synonyms were also considered to maximize retrieval, including “ED” or “Emergency Department” for emergency medicine, “eHealth” or “digital health” for HIT, and “telemedicine,” “mHealth,” and “clinical information systems” for specific HIT applications. Boolean operators (AND, OR) were employed to combine terms effectively. Truncation and wildcard symbols were applied to capture variations in spelling and terminology, and filters were applied to restrict results to studies published between 2018 and 2025 to reflect the most recent advancements in digital transformation initiatives.

Inclusion and Exclusion Criteria

The inclusion criteria were developed to ensure the selection of studies directly relevant to the research aim. Studies were included if they met the following conditions:

1. Focused on **emergency medicine or emergency departments** in the context of HIT or digital transformation.
2. Conducted in **Saudi Arabia** or included data specific to Saudi healthcare facilities.
3. Evaluated **HIT interventions**, including telemedicine, electronic health records (EHR), clinical decision support systems (CDSS), teleradiology, mHealth applications, predictive analytics, or workflow automation.
4. Published in **peer-reviewed journals, conference proceedings, or official reports** accessible through the selected databases.
5. Available in **English** to ensure accurate interpretation of technical and clinical information.

Studies were excluded if they

1. Focused solely on **general healthcare settings** without a clear link to emergency medicine.
2. Were **editorials, opinion pieces, or letters to the editor** lacking empirical data.
3. Were **duplicated across databases**, in which case only the most comprehensive version was retained.
4. Investigated HIT in **countries other than Saudi Arabia** without providing comparative insights relevant to the Saudi context.
5. Were published **before 2018**, as older studies might not reflect current HIT capabilities and national digital transformation policies.

Data Extraction and Analysis

For the included studies, relevant data were extracted using a standardized data extraction form. Information collected included authorship, year of publication, country/setting, study objectives, study design and methods, sample size, type of HIT intervention, key findings, and implications for emergency medicine in

Saudi Arabia. This structured extraction facilitated the synthesis of evidence across studies, allowing comparisons of interventions, outcomes, and reported challenges.

A narrative synthesis approach was used to summarize findings due to the heterogeneity of study designs, HIT interventions, and outcome measures. Quantitative results, such as ED wait times, diagnostic accuracy, patient satisfaction, and cost-effectiveness, were presented descriptively, while qualitative findings, including perceptions of healthcare practitioners and barriers to adoption, were thematically analyzed. This approach enabled the identification of recurring themes, successful strategies, and persistent gaps in the literature.

Quality Assessment

To ensure reliability and validity, each study was assessed for quality using established checklists appropriate to its design. Cross-sectional studies were evaluated using the AXIS tool, retrospective chart reviews were appraised using the Joanna Briggs Institute (JBI) checklist, and qualitative studies were assessed with the Critical Appraisal Skills Programme (CASP) checklist. Factors considered included clarity of research objectives, adequacy of sampling, appropriateness of methodology, completeness of outcome reporting, and consideration of ethical aspects. Studies scoring low in methodological quality were noted, and their findings were interpreted with caution in the synthesis.

Limitations of the Methodology

While the systematic review methodology allows a comprehensive synthesis of existing evidence, certain limitations must be acknowledged. First, the inclusion of only English-language studies may have excluded relevant Arabic-language publications, potentially introducing language bias. Second, reliance on published literature may have introduced **publication bias**, as studies reporting significant positive outcomes are more likely to be published. Third, the diversity in study designs, outcome measures, and HIT technologies limited the ability to perform quantitative meta-analysis, necessitating a narrative synthesis approach. Despite these limitations, the systematic review provides a rigorous overview of HIT adoption, utilization, and impact on emergency medicine in Saudi Arabia, offering valuable insights for policy, practice, and future research.

IV. FINDING

1. Impact of Big Data Analytics on Emergency Department Efficiency

The study by Senitan and Alzahrani (2025) highlights the transformative potential of big data analytics in improving operational efficiency within Saudi Ministry of Health (MOH) hospitals' emergency departments (EDs). By analyzing 228,857 patient records across ten hospitals, the research assessed the effects of the Ada'a Health Program on critical performance indicators, including Door-to-Doctor Time, Doctor-to-Decision

Time, and Decision-to-Disposition Time. The findings demonstrated substantial improvements across all metrics, with regression analysis confirming that predictive data-driven interventions significantly reduced wait times ($p < 0.001$). The study also revealed strong correlations between the quality of clinical decisions and patient flow efficiency, underscoring the importance of integrating analytical tools into decision-making processes. The implications for Saudi healthcare are significant, suggesting that sustained investment in big data and predictive modeling can enhance ED efficiency, optimize resource allocation, and provide scalable solutions applicable across diverse hospital settings.

2. Telemedicine Services and ED Utilization

Alfaleh *et al.* (2022) investigated the influence of telemedicine platforms—specifically the Sehha mobile application and the 937 medical call center—on patient behavior regarding emergency department visits. The cross-sectional study of 319 patients found that 53 patients who initially intended to visit EDs refrained from doing so after teleconsultation, representing a statistically significant reduction in unnecessary ED utilization ($p < 0.01$). Moreover, the Sehha app demonstrated a higher influence on patient decision-making compared to the call center, highlighting the effectiveness of mobile-based telehealth platforms. These findings underscore telemedicine's role in alleviating ED overcrowding, optimizing healthcare resources, and providing convenient, timely medical guidance for non-critical cases. For Saudi Arabia, telemedicine integration aligns with Vision 2030 goals by enhancing access to healthcare, particularly in geographically dispersed regions.

3. Virtual Clinics During COVID-19

The role of virtual clinics (VCs) in maintaining care continuity during the COVID-19 pandemic was explored by Shehabe Eddine and Zedan (2021). The study surveyed 277 healthcare providers and revealed that 67.2% deployed VCs, mainly for managing chronically ill patients. Mobile communication and electronic prescriptions facilitated clinical interactions, reducing appointment waiting times and improving patient satisfaction. However, challenges included limitations in physical examinations and the absence of face-to-face interactions. The study emphasizes the critical need to integrate telehealth services effectively, considering operational, technological, and patient-centered factors to optimize service delivery. These lessons are particularly relevant to Saudi healthcare systems seeking resilient, adaptable ED models capable of maintaining high-quality care during emergencies or crises.

4. Healthcare Practitioner Perceptions of Telemedicine

Alqurashi *et al.* (2023) examined Saudi healthcare practitioners' perceptions of telemedicine during the COVID-19 pandemic using mixed methods. Data from 81 questionnaires and qualitative interviews revealed

high telemedicine awareness (83%) and highlighted the importance of continuous training to ensure effective utilization. Practitioners predominantly used teleconsultations and remote monitoring but expressed concerns about privacy and confidentiality (54%). Qualitative analysis identified themes such as cultural influence, barriers to adoption, communication issues, implementation challenges, and evaluation strategies. The study underscores the need for national telemedicine standards, supportive organizational culture, and clear ethical and privacy guidelines, which are essential for the sustainable adoption of digital health technologies within Saudi Arabia.

5. Digital Transformation and Healthcare Accessibility

Alsahmah and Alshammari (2025) conducted a systematic review assessing the impact of digital transformation on healthcare accessibility in Saudi Arabia. Their review focused on telemedicine, electronic health records (EHRs), and AI-driven diagnostic tools, highlighting substantial reductions in consultation wait times (up to 40%) and improvements in continuity of care, particularly in rural areas. Nevertheless, barriers such as digital literacy gaps, infrastructural limitations, and privacy concerns were reported. The study emphasizes that strategic initiatives enhancing technological infrastructure, patient engagement, and long-term adoption are critical to achieving the accessibility and efficiency goals of Saudi Vision 2030.

6. Digital Health Readiness Using HIMSS Indicators

Al-Kahtani *et al.* (2022) evaluated digital health readiness in ten Saudi healthcare facilities using Healthcare Information and Management Systems Society (HIMSS) digital health indicators. Dimensions assessed included person-enabled health, predictive analytics, governance and workforce, and interoperability. Findings indicated that private facilities generally scored higher than public ones, while predictive analytics was the least implemented dimension. Tertiary hospitals exhibited lower readiness compared to primary and secondary facilities. These insights provide a roadmap for policymakers to enhance digital maturity, strengthen workforce capabilities, and leverage HIT tools for more efficient healthcare delivery in alignment with Vision 2030 objectives.

7–8. Security Awareness and Perceptions in mHealth

Aljedaani *et al.* (2020, 2021) explored end-users' security awareness and perceptions regarding mobile health applications in Saudi Arabia. Surveying 101 users, the studies identified a gap between technical knowledge and the adoption of adequate security practices, including weak authentication and insufficient attention to privacy protocols. Users expressed preferences for biometric authentication, session timeouts, and two-factor verification. These findings underscore the importance of provider-led training, user education, and human-centric security design to foster trust, promote

adoption, and mitigate risks associated with digital health tools.

9–10. Clinical Decision Support and IoT Adoption

Aljarboa and Miah (2020) examined the acceptance of clinical decision support systems (CDSS) among general practitioners, highlighting performance expectancy, effort expectancy, facilitating conditions, and task-technology fit as key determinants of adoption. Similarly, Masmali *et al.* (2020) addressed IoT adoption in healthcare, identifying organizational readiness, infrastructure limitations, and user acceptance as barriers. Both studies suggest that successful deployment of advanced HIT tools requires strategic planning, stakeholder engagement, and alignment with user needs, emphasizing that technology alone is insufficient without organizational and cultural support.

11–16. Telehealth, Tele-Oral Medicine, and Teleradiology

Several studies focused on patient-centered applications of digital health. AlShareef and AlWabel (2024) reported that over 90% of patients found virtual consultations useful, particularly video calls, although satisfaction varied with age, location, and clinic type. Akeel *et al.* (2023) demonstrated that tele-oral medicine achieved high diagnostic (73.5–100%) and management (51–98%) accuracy, improving access in underserved regions. AlMutairi *et al.* (2021) found telemedicine to be cost-effective in managing uncontrolled diabetes, achieving greater HbA1c reductions. AlFawaz and Alrasheed (2023) emphasized structured integration of telemedicine in residency training to maintain educational quality. Al-Hazmi *et al.* (2021) reviewed telemedicine perspectives during COVID-19, advocating legislation, ethical oversight, and secure infrastructure. Alruwaili *et al.* (2024) reported high satisfaction with teleradiology, though variability in report quality highlighted the need for standardization.

17–20. Patient Factors, mHealth Usability, and Health Technology Impact

Bobardt-Hartshorn *et al.* (2024) identified ten patient-reported factors affecting ED referral likelihood, which could inform triage tool development and improve resource utilization. Shen *et al.* (2024) presented a validated usability evaluation model for mHealth apps, demonstrating how task analysis and eye-tracking data can enhance patient engagement and self-management. Alotaibi *et al.* (2024) reviewed health informatics adoption, highlighting EHRs, telemedicine, HIE, and mHealth as improving access, care coordination, and efficiency. Finally, Almansour *et al.* (2024) emphasized that health technology, including AI, mobile apps, and EHRs, enhances access, efficiency, training, and patient engagement, aligning with Saudi Vision 2030 goals to improve healthcare quality and patient satisfaction.

Synthesis of Findings

The reviewed literature consistently demonstrates that HIT interventions—including big data analytics, telemedicine, teleradiology, CDSS, mHealth applications, and IoT—enhance emergency medicine efficiency, patient satisfaction, and care continuity in Saudi Arabia. Telehealth services effectively reduce ED overcrowding, optimize resource allocation, and improve access, particularly in rural regions. Big data analytics and predictive modeling significantly improve workflow efficiency and decision-making. Security, usability, and training are recurrent themes, highlighting the need for human-centered design, privacy safeguards, and continuous workforce development. Alignment with Saudi Vision 2030 initiatives emerges as a unifying goal, with digital transformation serving as a catalyst for improved healthcare quality, accessibility, and operational efficiency.

V. DISCUSSION

The findings of this systematic review provide compelling evidence that health information technology (HIT) and digital transformation initiatives have significantly influenced emergency medicine and broader healthcare delivery in Saudi Arabia, aligning with the objectives of Vision 2030 to create a more efficient, accessible, and patient-centered healthcare system. Across multiple studies, big data analytics has emerged as a transformative tool in optimizing emergency department (ED) workflows, as demonstrated by Senitan and Alzahrani (2025), where the application of the Ada'a Health Program led to measurable reductions in Door-to-Doctor, Doctor-to-Decision, and Decision-to-Disposition times, underscoring the capacity of predictive modeling to streamline patient flow, enhance clinical decision-making, and reduce operational bottlenecks. This evidence supports the notion that ED efficiency can be significantly improved through the integration of data-driven insights into routine hospital management, highlighting an urgent need for investment in scalable analytics infrastructures across Ministry of Health hospitals. Similarly, the deployment of telemedicine services, including mobile applications like Sehha and call center-based platforms, has demonstrated substantial potential in modifying patient behavior concerning ED utilization, as Alfaleh *et al.* (2022) reported a significant reduction in unnecessary ED visits following teleconsultations. This not only alleviates overcrowding—a persistent challenge in Saudi emergency medicine—but also optimizes resource allocation, allowing healthcare providers to prioritize critical cases while ensuring non-urgent patients receive timely advice. The implications of such findings extend beyond operational efficiency to patient satisfaction and convenience, as virtual consultations minimize travel requirements and waiting times, especially in rural or underserved regions, aligning with Vision 2030's goal of equitable healthcare access nationwide. The COVID-19 pandemic further emphasized the value of virtual clinics (VCs) and telehealth, with Shehabe Eddine and Zedan

(2021) highlighting that 67.2% of surveyed healthcare providers deployed VCs to maintain continuity of care for chronically ill patients, demonstrating both feasibility and adaptability of telehealth solutions under crisis conditions. Providers leveraged mobile communication and electronic prescriptions to facilitate care, reducing appointment waiting times and enhancing patient satisfaction, though challenges related to physical examination limitations and the absence of in-person interactions were noted, underscoring the need for hybrid care models that integrate both virtual and face-to-face services. Complementing these findings, Alqurashi *et al.* (2023) provided insight into healthcare practitioners' perceptions of telemedicine, revealing high awareness but emphasizing the critical need for continuous training, robust privacy protocols, and culturally sensitive implementation strategies. This highlights that successful HIT integration is not solely a matter of technological adoption but also requires addressing human factors, organizational culture, ethical considerations, and professional competencies to ensure sustainable and effective use. Furthermore, Alsahmah and Alshammari (2025) demonstrated through a systematic review that digital transformation, encompassing telemedicine, electronic health records (EHRs), and AI-based diagnostic tools, has significantly improved accessibility and continuity of care, with up to a 40% reduction in wait times, particularly benefiting rural populations; however, challenges such as digital literacy gaps, infrastructural limitations, and privacy concerns remain prevalent, suggesting that technological adoption must be accompanied by comprehensive policy, educational, and infrastructural interventions to maximize impact. Al-Kahtani *et al.* (2022) further quantified the state of digital health readiness across Saudi facilities using HIMSS indicators, identifying variability between private and public institutions and highlighting predictive analytics as the least implemented dimension, suggesting disparities in digital maturity that may hinder uniform HIT integration. These findings collectively emphasize that while HIT provides substantial operational and clinical benefits, national strategies are essential to standardize adoption, ensure interoperability, and enhance workforce competencies, ultimately enabling a cohesive digital ecosystem that supports both emergency and routine care. Security and privacy, particularly in mHealth applications, remain critical concerns, as studies by Aljedaani *et al.* (2020, 2021) revealed that users often lack sufficient security practices despite technical knowledge and express preferences for biometric authentication, session timeouts, and two-factor verification. These findings underscore that human-centric design, provider-led education, and clear regulatory frameworks are imperative to foster trust and encourage adoption, particularly given the sensitive nature of health data and the expanding reliance on mobile platforms. Moreover, acceptance of clinical decision support systems (CDSS) and IoT-based innovations, as highlighted by Aljarboa and Miah (2020) and Masmali *et al.* (2020), illustrates that end-user

perceptions, organizational readiness, infrastructural capacity, and technology-task fit are pivotal determinants of successful implementation. These studies indicate that technology implementation without attention to organizational, cultural, and workflow alignment may result in suboptimal utilization and reduced impact, suggesting that HIT strategies must adopt a holistic approach encompassing human, technological, and systemic factors. Patient-centered digital health applications, including tele-oral medicine, virtual consultations, and teleradiology, have also demonstrated significant contributions to improving access and clinical outcomes. For instance, AlShareef and AlWabel (2024) reported that over 90% of patients found virtual consultations convenient and effective, particularly favoring video calls over telephone interactions, while Akeel *et al.* (2023) demonstrated high diagnostic and management accuracy in tele-oral medicine, effectively bridging gaps in specialist availability in rural regions. These findings reinforce that digital health can mitigate geographical barriers, extend specialist reach, and enhance overall patient experience, though attention to patient demographics, consultation modes, and clinical contexts is necessary to optimize satisfaction and efficacy. AlMutairi *et al.* (2021) confirmed the cost-effectiveness of telemedicine for managing uncontrolled diabetes, indicating that remote care can achieve superior clinical outcomes with reasonable incremental costs, suggesting that telemedicine may provide both financial and operational benefits when strategically deployed. AlFawaz and Alrasheed (2023) further emphasized the importance of integrating telemedicine into residency training programs, highlighting the need for structured, balanced exposure to ensure residents develop practical clinical skills without compromising educational quality. In parallel, Al-Hazmi *et al.* (2021) and Alruwaili *et al.* (2024) highlighted the utility of telemedicine and teleradiology in enhancing triage, care delivery, and workflow efficiency, while identifying areas for improvement in standardization, legislation, and quality assurance. Patient-reported factors affecting ED referrals, as examined by Bobardt-Hartshorn *et al.* (2024), illustrate the value of collecting patient input to inform triage algorithms, optimize resource allocation, and reduce unnecessary ED visits, supporting a data-informed approach to emergency care planning. Furthermore, Shen *et al.* (2024) demonstrated that usability improvements in mHealth applications through task analysis and eye-tracking data can enhance patient engagement, promote self-management of chronic diseases, and optimize health outcomes, illustrating that digital health interventions must consider both clinical and behavioral factors to maximize effectiveness. Health informatics adoption in Saudi Arabia, as reviewed by Alotaibi *et al.* (2024), and the broader role of health technology in enhancing care delivery, as discussed by Almansour *et al.* (2024), further reinforce that integrating telemedicine, EHRs, AI, and mobile applications improves access, operational efficiency, patient engagement, and professional training. Collectively,

these findings suggest that HIT interventions provide a multifaceted framework for transforming emergency medicine, improving both process efficiency and patient-centered outcomes. Despite these successes, several gaps remain in the literature. Studies often focus on isolated technologies or single-center experiences, limiting the generalizability of findings, and longitudinal evidence on long-term impacts is scarce. Integration of multiple HIT systems within emergency department workflows—combining predictive analytics, CDSS, IoT, telemedicine, and EHRs—is rarely addressed, leaving a critical evidence gap regarding how these technologies synergize to improve outcomes. Barriers related to interoperability, ethical considerations, security, digital literacy, and cultural acceptance remain fragmented, and comprehensive implementation frameworks aligned with Saudi Vision 2030 objectives are limited. Additionally, while patient satisfaction and clinician perceptions are frequently explored, quantitative metrics on patient safety, care quality, clinical outcomes, and operational efficiency are underreported. These gaps underscore the need for large-scale, multi-center, longitudinal studies that not only evaluate technological efficacy but also examine systemic, human, and organizational factors to inform evidence-based policy, optimize resource allocation, and establish best practices for HIT adoption in emergency medicine. Overall, the synthesis of existing research indicates that HIT and digital transformation hold substantial promise for Saudi Arabia's emergency care system, offering opportunities to enhance efficiency, access, and quality, but effective implementation requires integrated strategies, robust infrastructure, workforce training, patient engagement, and governance frameworks that address the complex socio-technical landscape of healthcare delivery. This discussion highlights that the convergence of technological innovation, policy alignment, and human-centered implementation is essential for realizing the full potential of digital health, ultimately improving emergency medicine outcomes and advancing Saudi Arabia's healthcare vision.

I. RESEARCH GAPS & FUTURE DIRECTIONS

Despite the rapidly growing body of literature examining the impact of digital health interventions, telemedicine, big data analytics, and health informatics in Saudi Arabia, several critical research gaps persist that must be addressed to optimize emergency department (ED) efficiency, patient outcomes, and broader healthcare delivery. One notable limitation across current studies is the scarcity of empirical research specifically grounded in the Saudi healthcare context, particularly large-scale, multi-center investigations. While studies such as Senitan and Alzahrani (2025) provide valuable insight into the transformative potential of big data analytics in Ministry of Health hospitals, their retrospective design and focus on select facilities limit the generalizability of findings. Similarly, Alfaleh *et al.* (2022) demonstrated that telemedicine platforms like the Sehha mobile application and the 937 call center influence patient

decisions to visit EDs, yet these studies largely rely on small cross-sectional samples and self-reported behavioral measures, which may be subject to recall bias or social desirability effects. As a result, a gap exists in longitudinal, prospective studies that systematically evaluate the sustained effects of telehealth interventions on patient flow, ED utilization, and health outcomes over extended periods. The integration of predictive analytics and workflow automation, while promising, remains underexplored in real-world operational settings beyond pilot implementations, leaving a need for evidence on scalability, cost-effectiveness, and adaptability across diverse hospital contexts. In addition, while the COVID-19 pandemic catalyzed the widespread adoption of virtual clinics (VCs) and telemedicine (Shehabe Eddine & Zedan, 2021; Alqurashi *et al.*, 2023), many studies have predominantly focused on provider perceptions, satisfaction, and reported challenges without systematically assessing clinical outcomes, patient safety, or long-term adherence to telehealth protocols. This highlights a critical research gap: evaluating not only user acceptance and convenience but also the tangible impacts on health metrics, chronic disease management, and continuity of care. Another recurring theme in the literature is the need for research on artificial intelligence (AI) applications in triage, clinical decision-making, and diagnostic support. While Alsahmah and Alshammari (2025) and Al-Kahtani *et al.* (2022) underscore the potential of AI-driven tools to enhance healthcare accessibility and operational efficiency, the empirical evidence evaluating their performance, accuracy, and integration into existing workflows remains sparse. In particular, studies exploring the effectiveness of AI-assisted triage systems in EDs, their influence on patient prioritization, and their potential to reduce bottlenecks are limited in the Saudi context. Future research should rigorously assess AI algorithms against traditional triage approaches, examining metrics such as time-to-treatment, patient safety, diagnostic concordance, and staff satisfaction to establish evidence-based guidelines for adoption. Data security and privacy represent another significant domain requiring further exploration. Aljedaani *et al.* (2020, 2021) revealed that end-users of mobile health (mHealth) applications often possess technical knowledge but fail to implement adequate security measures, expressing preferences for features such as biometric authentication, two-factor verification, and session timeouts. These findings indicate that despite regulatory frameworks and technical safeguards, human behavior remains a primary factor in data vulnerability. Consequently, research is needed to develop comprehensive, context-specific interventions that combine user education, human-centered design, and policy measures to enhance data security in mHealth, telemedicine, and EHR systems. Additionally, while security and privacy issues have been examined from the patient perspective, limited research investigates healthcare provider awareness, organizational policies, and systemic approaches to safeguarding digital health data, representing a critical

gap that must be addressed to ensure safe and compliant deployment of health technologies. Training programs for healthcare professionals constitute another underexplored area. Studies such as AlFawaz and Alrasheed (2023) highlight that family medicine residents experience reduced clinical exposure and supervision when engaging in telemedicine clinics, despite recognizing improvements in communication skills. Similarly, Alqurashi *et al.* (2023) emphasize the importance of continuous training for effective telemedicine adoption. However, comprehensive evaluations of structured digital health curricula, competency-based assessments, and the long-term impact of training on clinical proficiency, workflow efficiency, and patient outcomes are lacking. Future studies should develop, implement, and assess targeted educational interventions for physicians, nurses, and allied health professionals, integrating AI, telemedicine, big data analytics, and security best practices to ensure that workforce development aligns with the increasing digitalization of Saudi healthcare. Moreover, while several studies examine patient perspectives on telehealth services (AlShareef & AlWabel, 2024; Akeel *et al.*, 2023), there is limited research addressing diverse patient populations, including underserved, rural, elderly, or digitally marginalized groups. Evidence indicates that factors such as age, geographic location, clinical specialty, and technology familiarity influence satisfaction and engagement, yet systematic analyses quantifying disparities and identifying strategies to mitigate inequities are sparse. This represents a significant knowledge gap, as equitable access to digital health is essential for achieving the Saudi Vision 2030 objectives of improving healthcare accessibility and reducing disparities. Similarly, usability studies like those conducted by Shen *et al.* (2024) offer valuable insights into optimizing mHealth applications using task analysis and eye-tracking data, but research assessing the generalizability of these findings across different types of apps, conditions, and patient populations is limited. Investigations are required to establish standardized methodologies for usability evaluation and to identify design features that maximize patient engagement, adherence, and self-management capabilities across diverse contexts. Another critical area for future research involves cost-effectiveness analyses. While AlMutairi *et al.* (2021) demonstrated the economic viability of telemedicine for managing uncontrolled diabetes, evidence for other chronic conditions, acute care interventions, and broader digital health programs remains fragmented. Robust economic evaluations incorporating direct and indirect costs, quality-adjusted life years (QALYs), and system-level savings are essential to inform policymakers and hospital administrators about the financial implications of scaling digital health interventions. In parallel, implementation science approaches remain underutilized in Saudi healthcare research. Studies often report outcomes without systematically examining the barriers and facilitators of technology adoption, including

organizational culture, leadership support, interoperability challenges, and stakeholder engagement. For example, while Aljarboa and Miah (2020) and Masmali *et al.* (2020) highlight factors affecting CDSS and IoT adoption, there is a need for longitudinal, mixed-methods research to identify actionable strategies for overcoming resistance, aligning technology with workflow, and fostering sustainable adoption. Developing standardized implementation frameworks tailored to Saudi healthcare settings could accelerate the integration of AI, telemedicine, and digital health solutions, ensuring alignment with national priorities and regulatory requirements. Furthermore, there is a paucity of research addressing the integration of multiple digital health interventions into cohesive care pathways. Many studies examine telemedicine, AI, CDSS, or big data analytics in isolation, limiting our understanding of their combined effects on patient flow, decision-making, and clinical outcomes. Future investigations should explore the synergistic effects of integrated digital health ecosystems, assessing how combined interventions influence triage accuracy, care coordination, resource utilization, and patient satisfaction. This integrative approach would provide more actionable insights for healthcare administrators seeking to optimize efficiency and quality of care in EDs and across hospital departments. Additionally, cultural and behavioral factors influencing technology adoption require further study. Existing literature identifies privacy concerns, ethical considerations, and cultural attitudes as barriers to telemedicine adoption (Alqurashi *et al.*, 2023; Al-Hazmi *et al.*, 2021), yet systematic evaluations of strategies to address these factors in the Saudi context are limited. Research is needed to develop culturally sensitive interventions, patient engagement initiatives, and communication strategies that promote trust, transparency, and sustained use of digital health tools. In parallel, while teleradiology (Alruwaili *et al.*, 2024) and tele-oral medicine (Akeel *et al.*, 2023) demonstrate high effectiveness and user satisfaction, longitudinal studies evaluating clinical accuracy, diagnostic concordance, workflow integration, and patient safety across multiple institutions are lacking, representing another area for future exploration. Moreover, despite evidence of improved ED efficiency through digital interventions, patient-reported factors influencing referral patterns, as highlighted by Bobardt-Hartshorn *et al.* (2024), remain underexplored in Saudi Arabia. Studies incorporating patient-reported outcome measures, real-time symptom tracking, and digital triage tools could inform predictive models to optimize ED utilization, prioritize high-risk patients, and enhance overall care quality. In terms of technology assessment, while HIMSS indicators (Al-Kahtani *et al.*, 2022) provide a snapshot of digital readiness, further research is needed to establish standardized metrics for evaluating the impact of digital health interventions on clinical, operational, and patient-centered outcomes. Such metrics could facilitate benchmarking across hospitals, guide policy decisions, and track progress toward national digital health

objectives. Taken together, the current literature underscores a clear need for more Saudi-specific empirical studies employing rigorous designs, large sample sizes, and longitudinal follow-up. Future research should prioritize the evaluation of AI applications in triage, predictive analytics, and decision support; the development of robust data security frameworks and user-centric privacy interventions; and the implementation and assessment of structured training programs for healthcare professionals. Additionally, integrated, multi-modal digital health interventions, longitudinal usability studies, cost-effectiveness analyses, and culturally tailored adoption strategies represent key avenues to advance knowledge and practice. Addressing these gaps will enable healthcare systems to leverage digital innovations more effectively, improve ED efficiency, enhance patient outcomes, and support the strategic objectives of Saudi Vision 2030 by fostering a safe, equitable, and technologically advanced healthcare environment. Ultimately, a coordinated research agenda that emphasizes empirical evidence, implementation science, and stakeholder engagement is critical to translating digital health potential into measurable improvements in healthcare delivery, patient satisfaction, and system resilience, ensuring that emerging technologies are adopted sustainably, securely, and equitably across Saudi Arabia's healthcare landscape.

II. CONCLUSION

The findings from this comprehensive review underscore the substantial potential of digital health technologies to transform healthcare delivery in Saudi Arabia, particularly in emergency departments and chronic disease management. Evidence from studies on big data analytics, telemedicine platforms, mobile health applications, AI-assisted clinical decision support systems, and IoT-based innovations consistently highlights improvements in patient flow, operational efficiency, accessibility, and satisfaction. For instance, the implementation of the Ada'a Health Program demonstrated significant reductions in Door-to-Doctor and Decision-to-Disposition times, indicating that data-driven workflow optimization can meaningfully enhance ED efficiency. Similarly, telemedicine platforms such as the Sehha mobile app and 937 call center effectively reduce unnecessary ED visits, providing timely guidance for non-critical health concerns while alleviating pressure on overburdened facilities. Virtual clinics and tele-oral medicine services further highlight the ability of digital interventions to bridge gaps in specialist access, especially in rural areas, and to maintain continuity of care during disruptive events such as the COVID-19 pandemic. Moreover, the cost-effectiveness of telemedicine for managing uncontrolled diabetes reinforces the value of integrating digital health tools into routine clinical practice, with benefits for both patients and healthcare systems.

Despite these positive outcomes, several challenges

persist, highlighting areas that require further research and strategic intervention. Data security and privacy concerns remain prominent, with end-users often unaware of or inadequately prepared to implement security best practices when using mobile health applications. Workforce training gaps have also been identified, as healthcare professionals frequently report reduced clinical exposure and the need for continuous education to effectively utilize telemedicine and AI-enabled tools. Additionally, current research often lacks longitudinal perspectives, large-scale empirical evidence, and evaluations of integrated digital health ecosystems, limiting the ability to generalize findings and fully assess long-term outcomes. Patient perspectives, particularly among underserved, rural, or digitally marginalized populations, are also underrepresented, highlighting the need for culturally sensitive, equitable approaches to digital health adoption. Implementation barriers, including organizational readiness, technological infrastructure, interoperability challenges, and cultural attitudes, further constrain the widespread and sustainable adoption of innovative health technologies.

Future research should therefore prioritize empirical studies that assess the efficacy, safety, and cost-effectiveness of AI-assisted triage systems, predictive analytics, and decision support tools in real-world Saudi healthcare settings. Longitudinal studies and mixed-methods approaches can provide deeper insights into the sustained impacts of digital interventions on patient outcomes, workflow efficiency, and healthcare accessibility. Usability evaluations and human-centered design strategies should be applied to mHealth and telemedicine applications to enhance patient engagement, adherence, and satisfaction, while also addressing privacy and ethical concerns. Furthermore, structured training programs and competency-based curricula for healthcare professionals will be critical to ensure that the workforce is adequately prepared to leverage emerging technologies. Research exploring integrated, multi-modal digital health interventions, as well as culturally tailored adoption strategies, will be essential for optimizing healthcare delivery in line with Saudi Vision 2030 objectives.

In conclusion, digital health technologies—including telemedicine, AI, big data analytics, IoT, and clinical decision support systems—offer transformative opportunities for improving healthcare delivery, patient satisfaction, and operational efficiency in Saudi Arabia. However, realizing this potential requires addressing persistent gaps related to data security, workforce preparedness, patient engagement, longitudinal evaluation, and systemic implementation barriers. By strategically addressing these challenges, policymakers, healthcare administrators, and researchers can foster a secure, efficient, and patient-centered healthcare ecosystem that not only meets current demands but also anticipates future needs. The integration of innovative digital health solutions, underpinned by rigorous

empirical research and culturally sensitive practices, will enable Saudi Arabia to achieve a technologically advanced, accessible, and sustainable healthcare system, supporting the broader goals of national development and the Vision 2030 framework. Ultimately, the success of digital health initiatives will depend on a coordinated effort to combine technological innovation, workforce development, patient engagement, and policy alignment, ensuring that digital tools translate into measurable improvements in health outcomes, resource optimization, and equitable care delivery.

REFERENCES

- Al Baalharith, I., Al Sherim, M., Almutairi, S. H. G., & Albaqami, A. S. A. (2022). Telehealth and Transformation of Nursing Care in Saudi Arabia: A Systematic Review. *International Journal of Telemedicine and Applications*, 2022; 8426095. <https://doi.org/10.1155/2022/8426095>
- Al Mutair, A., Saha, C., Alhuqbani, W., Alhuqbani, M. N., AlQahtani, M. N., Abogosh, A. K., Alsedrah, A. M., Alhindi, A. H., Alfehaid, R. H., & Al-Omari, A. (2023). Utilization of Telemedicine during COVID-19 in Saudi Arabia: A Multicenter Study. *Cureus*, 15(7): e41541. <https://doi.org/10.7759/cureus.41541>
- AlAli, N., AlKhudairy, Y., AlSafadi, K., Abduljabbar, B., Aljerian, N., Albeshry, A. M., & Alshahrani, N. Z. (2023). The Usage of Digital Health Mobile-Based Applications among Saudi Population. *Healthcare (Basel, Switzerland)*, 11(10): 1413. <https://doi.org/10.3390/healthcare11101413>
- Alanezi, F. (2021). Factors affecting the adoption of e-health system in the Kingdom of Saudi Arabia. *International Health*, 13(5): 456–470. <https://doi.org/10.1093/inthealth/ihaa091>
- Albaghdadi, A. T., & Al Daajani, M. M. (2023). Perceptions, Satisfaction, and Barriers to Telemedicine Use: A Community-Based Study From Jeddah, Saudi Arabia. *Cureus*, 15(6): e40738. <https://doi.org/10.7759/cureus.40738>
- Albarrak, A. I., Mohammed, R., Almarshoud, N., Almujalli, L., Aljaeed, R., Altuwaijiri, S., & Albohairy, T. (2021). Assessment of physician's knowledge, perception and willingness of telemedicine in Riyadh region, Saudi Arabia. *Journal of Infection and Public Health*, 14(1): 97–102. <https://doi.org/10.1016/j.jiph.2019.04.006>
- Al-Hanawi, M. K., Alsharqi, O., Almazrou, S., & Vaidya, K. (2018). Healthcare Finance in the Kingdom of Saudi Arabia: A Qualitative Study of Householders' Attitudes. *Applied Health Economics and Health Policy*, 16(1): 55–64. <https://doi.org/10.1007/s40258-017-0353-7>
- Al-Hanawi, M. K., Khan, S. A., & Al-Borie, H. M. (2019). Healthcare human resource development in Saudi Arabia: Emerging challenges and opportunities-a critical review. *Public Health Reviews*, 40: 1. <https://doi.org/10.1186/s40985-019-0112-4>
- Aljedaani, B., Ahmad, A., Zahedi, M., & Babar, M. A. (2021). End-Users' Knowledge and Perception about Security of Mobile Health Apps: A Case Study with Two Saudi Arabian mHealth Providers (arXiv:2101.10412). *arXiv*. <https://doi.org/10.48550/arXiv.2101.10412>
- Alkadi, S. H. (2016). The Healthcare System in Saudi Arabia and its Challenges: The Case of Diabetes Care Pathway. *Journal of Health Informatics in Developing Countries*, 10(1): Article 1. <https://www.jhidc.org/index.php/jhidc/article/view/142>
- Almalawi, A., Khan, A. I., Alsolami, F., Abushark, Y. B., Alfakeeh, A. S., & Mekuriyaw, W. D. (2022). Analysis of the Exploration of Security and Privacy for Healthcare Management Using Artificial Intelligence: Saudi Hospitals. *Computational Intelligence and Neuroscience*, 2022; 4048197. <https://doi.org/10.1155/2022/4048197>
- Alotaibi, Y. K., & Federico, F. (2017). The impact of health information technology on patient safety. *Saudi Medical Journal*, 38(12): 1173–1180. <https://doi.org/10.15537/smj.2017.12.20631>
- Alqurashi, H., Mohammed, R., AlGhanmi, A. S., & Alanazi, F. (2023). The Perception of Health Care Practitioners Regarding Telemedicine During COVID-19 in Saudi Arabia: Mixed Methods Study. *JMIR Formative Research*, 7: e47065. <https://doi.org/10.2196/47065>
- Alsulame, K., Khalifa, M., & Househ, M. (2016). E-Health status in Saudi Arabia: A review of current literature. *Health Policy and Technology*, 5(2): 204–210. <https://doi.org/10.1016/j.hlpt.2016.02.005>
- Alzghaibi, H. (2023). The gap between bachelor's degree graduates in health informatics and employer needs in Saudi Arabia. *BMC Medical Education*, 23(1): 475. <https://doi.org/10.1186/s12909-023-04442-7>
- Alzghaibi, H., Mughal, Y. H., Alkhamees, M., Alasqah, I., Alhlail, A. S., Alwheeb, M. H., & Alrehiely, M. (2022). The impact financial resources on implementation of large-scale electronic health records in the Saudi Arabia's primary healthcare centers: Mixed methods. *Frontiers in Public Health*, 10: 1037675. <https://doi.org/10.3389/fpubh.2022.1037675>
- Chowdhury, S., Mok, D., & Leenen, L. (2021). Transformation of health care and the new model of care in Saudi Arabia: Kingdom's Vision 2030. *Journal of Medicine and Life*, 14(3): 347–354. <https://doi.org/10.25122/jml-2021-0070>
- Haleem, A., Javaid, M., Singh, R. P., & Suman, R. (2021). Telemedicine for healthcare: Capabilities, features, barriers, and applications. *Sensors International*, 2: 100117. <https://doi.org/10.1016/j.sintl.2021.100117>
- Roberts, S., Chaboyer, W., Gonzalez, R., & Marshall, A. (2017). Using technology to engage hospitalised patients in their care: A realist review.

- BMC Health Services Research*, 17(1): 388. <https://doi.org/10.1186/s12913-017-2314-0>
20. Saeed, A., Bin Saeed, A., & AlAhmri, F. A. (2023). Saudi Arabia Health Systems: Challenging and Future Transformations With Artificial Intelligence. *Cureus*, 15(4): e37826. <https://doi.org/10.7759/cureus.37826>
 21. Yogesh, M. J., & Karthikeyan, J. (2022). Health Informatics: Engaging Modern Healthcare Units: A Brief Overview. *Frontiers in Public Health*, 10, 854688. <https://doi.org/10.3389/fpubh.2022.854688>
 22. Tanberry, B. Telemedicine: barriers and opportunities in the 21st century. *Journal of Internal Medicine*, 2000 Jun; 247(6): 615–628.
 23. Alasiri, A. A., & Mohammed, V. Healthcare transformation in Saudi Arabia: An overview since the launch of Vision 2030. *Health Services Insights*, 15: 11786329221121214. 2022 Sep.
 24. Maita, K. C., Maniaci, M. J., Haider, C. R., Avila, F. R., Torres-Guzman, R. A., Borna, S., Lunde, J. J., Coffey, J. D., Demaerschalk, B. M., & Forte, A. J. The impact of digital health solutions on bridging the health care gap in rural areas: A scoping review. *The Permanente Journal*, 2024 Aug 13; 28(3): 130.
 25. Uraif, A. Developing Healthcare infrastructure in Saudi Arabia using smart technologies: Challenges and opportunities. *Communications and Network*, 2024 Jul 31; 16(3): 51–73.
 26. Alkhalifah, J. M., Seddiq, W., Alshehri, B. F., Alhaluli, A. H., Alessa, M. M., & Alsulais, N. M. The role of the COVID-19 pandemic in expediting digital health-care transformation: Saudi Arabia's experience. *Informatics in Medicine Unlocked*, 2022 Jan 1; 33: 101097.
 27. Coombs, N. C., Campbell, D. G., & Caringi, J. A qualitative study of rural healthcare providers' views of social, cultural, and programmatic barriers to healthcare access. *BMC Health Services Research*, 2022 Apr 2; 22(1): 438.
 28. Maita, K. C., Maniaci, M. J., Haider, C. R., Avila, F. R., Torres-Guzman, R. A., Borna, S., Lunde, J. J., Coffey, J. D., Demaerschalk, B. M., & Forte, A. J. The impact of digital health solutions on bridging the health care gap in rural areas: A scoping review. *The Permanente Journal*, 2024 Aug 13; 28(3): 130.
 29. Palozzi, G., Schettini, I., & Chirico, A. Enhancing the sustainable goal of access to healthcare: Findings from a literature review on telemedicine employment in rural areas. *Sustainability*, 2020 Apr 19; 12(8): 3318.
 30. Brunetti, F., Matt, D. T., Bonfanti, A., De Longhi, A., Pedrini, G., & Orzes, G. Digital transformation challenges: Strategies emerging from a multi-stakeholder approach. *The TQM Journal*, 2020 Jul 21; 32(4): 697–724.
 31. Kemp, E., Trigg, J., Beatty, L., Christensen, C., Dhillon, H. M., Maeder, A., Williams, P. A., & Koczwar, B. Health literacy, digital health literacy and the implementation of digital health technologies in cancer care: The need for a strategic approach. *Health Promotion Journal of Australia*, 2021 Feb; 32: 104–114.
 32. Fitzpatrick, P. J. Improving health literacy using the power of digital communications to achieve better health outcomes for patients and practitioners. *Frontiers in Digital Health*, 2023 Nov 17; 5: 1264780.
 33. Jimenez, G., Spinazze, P., Matchar, D., Huat, G. K., van der Kleij, R. M., Chavannes, N. H., & Car, J. Digital health competencies for primary healthcare professionals: A scoping review. *International Journal of Medical Informatics*, 2020 Nov 1; 143: 104260.
 34. Senitan, M., & Alzahrani, B. J. (2025). Impact of big data analytics on emergency department efficiency in Saudi Ministry of Health hospitals: A retrospective data analysis. *Risk Management and Healthcare Policy*, 18: 775–784. <https://doi.org/10.2147/RMHP.S503744>
 35. Alfaleh, A., Alkattan, A., Alageel, A., Salah, M., Almutairi, M., Sagor, K., & Alabdulkareem, K. (2022). The role of telemedicine services in changing users' intentions for presenting to the emergency departments in Saudi Arabia. *Digital Health*, 8: 20552076221091358. <https://doi.org/10.1177/20552076221091358>
 36. Shehabe Eddine, I., & Zedan, H. S. (2021). Telehealth role during the COVID-19 pandemic: Lessons learned from health care providers in Saudi Arabia. *Telemedicine and e-Health*, 27(11): 1249–1259. <https://doi.org/10.1089/tmj.2020.0489>
 37. Alqurashi, H., Mohammed, R., AlGhanmi, A. S., & Alanazi, F. (2023). The perception of health care practitioners regarding telemedicine during COVID-19 in Saudi Arabia: Mixed methods study. *JMIR Formative Research*, 7: e47065. <https://doi.org/10.2196/47065>
 38. Alsahmah, M. M., & Alshammari, S. A. (2025). Impact of digital transformation on healthcare accessibility in Saudi Arabia: A systematic review. *International Journal of Pharmacy Research & Technology*, 15(1): 390–399. <https://www.ijprt.org/index.php/pub/article/view/391>
 39. Al-Kahtani, N., Alruwaie, S., Al-Zahrani, B. M., Abumadani, R. A., Aljaafary, A., Hariri, B., Alissa, K., Alakrawi, Z., & Alumran, A. (2022). Digital health transformation in Saudi Arabia: A cross-sectional analysis using Healthcare Information and Management Systems Society' digital health indicators. *Digital Health*, 8: 20552076221117742. <https://doi.org/10.1177/20552076221117742>
 40. Aljedaani, B., Ahmad, A., Zahedi, M., & Babar, M. A. (2020). Security awareness of end-users of mobile health applications: An empirical study. *arXiv preprint arXiv:2008.13009*. <https://doi.org/10.48550/arXiv.2008.13009>
 41. Aljedaani, B., Ahmad, A., Zahedi, M., & Babar, M. A. (2021). End-users' knowledge and perception about security of mobile health apps: A case study

- with two Saudi Arabian mHealth providers. *arXiv preprint arXiv: 2101.10412*. <https://doi.org/10.48550/arXiv.2101.10412>
42. Aljarboa, S., & Miah, S. J. (2020). Assessing the acceptance of clinical decision support tools using an integrated technology acceptance model. In *2020 IEEE Asia-Pacific Conference on Computer Science and Data Engineering (CSDE)* (pp. 370–379). IEEE. <https://doi.org/10.1109/CSDE50874.2020.9411594>
 43. Masmali, F. H., Miah, S. J., & Mathkoor, N. Y. (2020). Internet of Things-based innovations in Saudi healthcare sector: A methodological approach for investigating adoption issues. *arXiv preprint arXiv: 2012.04970*. <https://doi.org/10.48550/arXiv.2012.04970>
 44. AlShareef, S. M., & AlWabel, A. A. (2024). Patient opinions about virtual consultations in Saudi Arabia: A nationwide cross-sectional study. *Healthcare (Basel)*, *12*(10): 1001. <https://doi.org/10.3390/healthcare12101001>
 45. Akeel, S., Almazrooa, S., Ali, S. A., Alhindi, N. A., Alhamed, S., Felemban, O. M., Mansour, G., Sabbahi, D., Binmadi, N., & Mawardi, H. (2023). Assessing tele-oral medicine in Saudi Arabia: A cross-sectional study on specialists' experiences and effectiveness in oral healthcare. *Healthcare (Basel)*, *11*(23): 3089. <https://doi.org/10.3390/healthcare11233089>
 46. AlMutairi, M. F., Tourkmani, A. M., & AlRuthia, Y. (2021). Cost-effectiveness of telemedicine care for patients with uncontrolled type 2 diabetes mellitus during the COVID-19 pandemic in Saudi Arabia. <https://doi.org/10.1177/20406223211042542>
 47. AlFawaz, I., & Alrasheed, A. A. (2023). Experiences with telemedicine among family medicine residents at King Saud University Medical City during the COVID-19 pandemic: A cross-sectional study. *BMC Medical Education*, *23*: 313. <https://doi.org/10.1186/s12909-023-04250-8>
 48. Al-Hazmi, A. M., Sheerah, H. A., & Arafa, A. (2021). Perspectives on telemedicine during the era of COVID-19: What can Saudi Arabia do? *International Journal of Environmental Research and Public Health*, *18*(20): 10617. <https://doi.org/10.3390/ijerph182010617>
 49. Alruwaili, A. R., Alshammari, A. A., Alsalhi, F. M., Aldamen, S. A., & Alamri, H. S. (2024). Teleradiology in Saudi Arabia: A national survey and retrospective review of associated MRI reports. *BMC Health Services Research*, *24*: 1327. <https://doi.org/10.1186/s12913-024-1327-0>
 50. Bobardt-Hartshorn, J. S., Peters, P.-S., Schmalstieg-Bahr, K., Bessert, B., Schäfer, I., Scherer, M., & Oltrogge-Abiry, J. H. (2024). Patient-reported factors associated with emergency department referrals from a co-located out-of-hours walk-in clinic in Germany: A cross-sectional observational study. *BMJ Open*, *14*: e094312. <https://doi.org/10.1136/bmjopen-2024-094312>
 51. Shen, Y., Wang, S., Shen, Y., Tan, S., Dong, Y., Qin, W., & Zhuang, Y. (2024). Evaluating the usability of mHealth apps: An evaluation model based on task analysis methods and eye movement data. *Healthcare (Basel)*, *12*(13): 1310. <https://doi.org/10.3390/healthcare12131310>
 52. Alotaibi, S. F., Al-khuraym, A. M. A., AlShehri, K. M. A., Al Fuhayd, J. H. J., Alotaibi, A. A., Alrabiah, H. A., Buges, R. A., Alghahtani, M. S., Alhuwaykim, Z. E., Alsweed, F. J. H., Shuwayl, K. M. A., Qadh, A. I. N., Alreshidi, H., Alreshidi, M. A., & Almogisib, S. A. (2024). Health informatics in Saudi Arabia: Transforming patient care through technology. *Journal of International Crisis and Risk Communication Research*, *7*(S9): 3044–3055.
 53. Almansour, M. M., Al-mansour, H. M., Almansour, F. H. H., Al-Yami, H. H., Almansour, H. H., Almansour, S. H., Almansour, S. H., Almansour, M. H., Al Hannan, H. H., Alshaman, F. N., & Almaqbul, M. S. (2024). The role of health technology in improving healthcare services in Saudi Arabia. *Journal of International Crisis & Risk Communication Research*, *7*: 812.