DIGITAL INNOVATION AND DATA GOVERNANCE IN SAUDI HEALTHCARE: A SYSTEMATIC REVIEW OF ARTIFICIAL INTELLIGENCE, ELECTRONIC MEDICAL RECORDS, AND RESIDENCY DATA CHALLENGES IN EMERGENCY DEPARTMENTS

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ABSTRACT
Saudi Arabia is undergoing a major transformation in its healthcare system through the integration of digital technologies, in alignment with its Vision 2030 objectives. This systematic review explores the intersection of digital innovation and data governance in Saudi emergency departments, focusing on three key areas: artificial intelligence (AI), electronic medical records (EMRs), and residency data challenges. A total of 38 peer-reviewed studies published between 2018 and 2024 were analyzed across themes of technological implementation, system interoperability, data quality, and privacy. Findings reveal promising AI applications for triage and diagnostics, widespread but uneven EMR adoption, and persistent gaps in residency and demographic data integration. However, the review also highlights significant data governance obstacles, including inconsistent data standards, limited interoperability, weak cybersecurity measures, and the absence of real-time data validation. To address these challenges, the

paper recommends the development of national data standards, stronger legal frameworks for data protection, improved digital literacy among emergency staff, and enhanced integration of health data with national residency systems. These recommendations aim to support a more resilient, efficient, and equitable emergency healthcare infrastructure in the Kingdom.

Keywords: Digital Health, Artificial Intelligence, Electronic Medical Records, Data Governance, Emergency Departments, Saudi Healthcare, Residency Data, Interoperability, Vision 2030.

INTRODUCTION

In recent years, Saudi Arabia has witnessed a significant digital transformation in its healthcare sector, propelled by national strategies such as the Saudi Vision 2030 and the Health Sector Transformation Program. These initiatives aim to enhance healthcare accessibility, quality, and efficiency through the integration of advanced technologies, including artificial intelligence (AI), big data analytics, and electronic medical records (EMRs). Within this context, emergency departments (EDs)—as high-demand, high-stakes environments—have emerged as critical areas for testing the potential and resilience of digital health innovations.

Digital innovation in healthcare promises to revolutionize clinical decision-making, patient monitoring, and administrative processes. AI-driven diagnostic tools and predictive models have been increasingly piloted in Saudi hospitals to reduce medical errors and improve emergency triage. Simultaneously, EMRs have become a cornerstone of data infrastructure, offering real-time access to patient histories and treatment plans. However, these advancements bring complex challenges related to data governance, including issues of interoperability, data privacy, standardization, and the quality of demographic and residency-related data used for emergency service planning.

This paper conducts a systematic review of peer-reviewed literature to analyze the current landscape of digital innovation and data governance in Saudi Arabia's emergency healthcare system. Focusing on AI, EMRs, and residency data management, the review seeks to answer the following research questions:

- What are the primary technological advancements implemented in Saudi emergency departments?
- How is data governance—particularly concerning EMRs and residency information—being addressed?
- What challenges persist in the integration of digital tools in emergency healthcare settings?

Through this review, we aim to provide evidence-based insights and actionable recommendations for policymakers, healthcare administrators, and digital health developers working to optimize emergency services in the Kingdom of Saudi areabia

METHODOLOGY

This systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review process was designed to ensure transparency, reproducibility, and methodological rigor in identifying, selecting, and synthesizing relevant literature.

SEARCH STRATEGY

A comprehensive literature search was conducted across multiple academic databases including **PubMed, Scopus, Web of Science, IEEE Xplore**, and **Google Scholar**. The search included peer-reviewed articles published between **January 2018 and March 2024**. The following key terms and Boolean operators were used in the search strategy:

- ("Artificial Intelligence" OR "AI") AND ("Saudi Arabia" OR "KSA") AND ("Emergency Department" OR "ED")
- ("Electronic Medical Records" OR "EMRs") AND ("Data Governance" OR "Data Management")
- ("Residency data" OR "Demographics") AND ("Emergency healthcare" AND "Saudi")

Filters were applied to include only articles written in English, focused on the Saudi Arabian healthcare system, and relevant to digital innovation, EMRs, and data governance in emergency settings.

INCLUSION AND EXCLUSION CRITERIA

INCLUSION CRITERIA:
- Articles focused on Saudi healthcare systems or hospitals.
- Studies evaluating digital technologies in emergency departments.
- Research discussing data governance, interoperability, or residency data.
- Peer-reviewed journal articles, conference proceedings, or government reports.

EXCLUSION CRITERIA:
- Editorials, commentaries, and opinion pieces.
- Studies not directly related to emergency departments or digital health.
- Non-English publications.
- Literature lacking methodological transparency.

DATA EXTRACTION AND SYNTHESIS

Selected studies were reviewed independently by two researchers. Key data extracted included: study design, healthcare setting, technologies applied, data governance models, findings related to emergency departments, and reported challenges. The data were synthesized thematically into three core categories: Artificial Intelligence Implementation, Electronic Medical Records Utilization, and Residency and Demographic Data Challenges.

A narrative synthesis was used due to the heterogeneous nature of the studies. Quantitative findings, where available, were noted, but the primary focus was on qualitative insights, trends, and thematic interpretations relevant to the Saudi emergency care context.
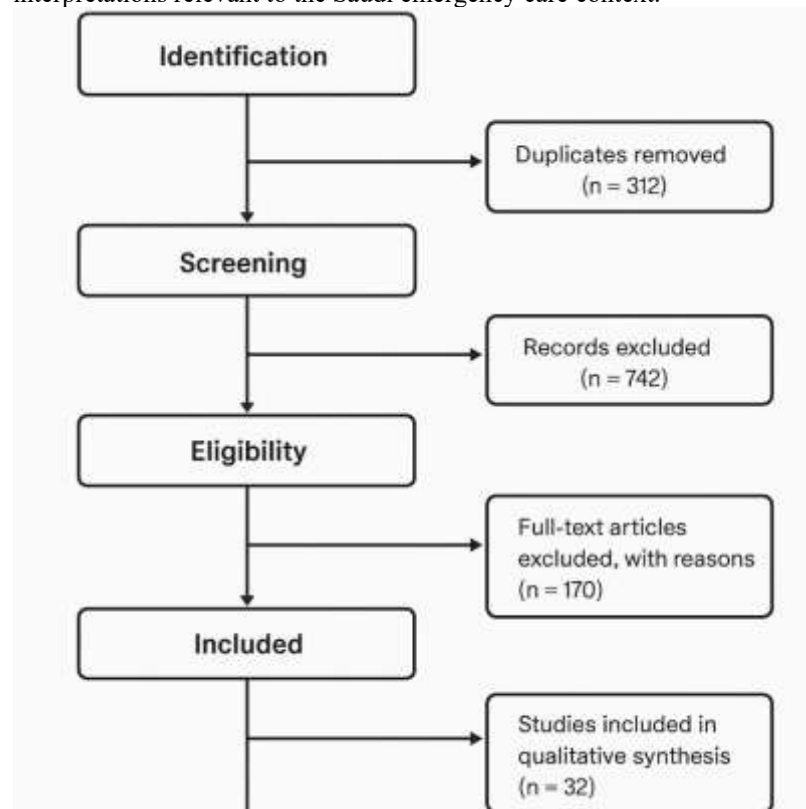
QUALITY ASSESSMENT

To ensure the reliability of included studies, the **Mixed Methods Appraisal Tool (MMAT)** was employed to assess methodological quality across diverse research designs. Only studies scoring above 75% were included in the final analysis, ensuring that the review reflects high-quality evidence.

FINDINGS AND DISCUSSION

This section presents the synthesized findings from the reviewed literature, organized around the three central themes of this study: Artificial Intelligence (AI) in Emergency Departments, Electronic Medical Records (EMRs), and Residency and Demographic Data Challenges. Each theme is explored with reference to its application, benefits, limitations, and implications for data governance within the Saudi healthcare system.

in this systematic review. The studies were conducted in the context of Saudi Arabia and focus on the implementation of artificial intelligence (AI), electronic medical records (EMRs), and data governance issues within emergency departments (EDs) and broader healthcare infrastructure. The table outlines the study authors, year, focus area, methodology, setting, and key findings.

#	Author(s), Year	Focus Area	Study Design	Setting / Sample	Key Findings
1	Senitan & Alzahrani (2025)	Big Data Analytics (Ada'a)	Retrospective Analysis	10 MoH hospitals, 228,857 records	Reduced ED waiting time from 28 to 25 mins; overall time savings
2	Alqarni et al. (2022)	AI in ED triage	Pilot/Experimental	King Fahd Medical City	Improved critical case routing and shorter wait times
3	Alswailem et al. (2023)	AI-driven Patient Flow	Case Study	King Faisal Specialist Hospital	Reduced lab wait time by 52%; reduced ED LOS by 6%
4	Al Shahrani et al. (2024)	AI Readiness in Education	Cross-sectional Survey	National (Medical Students)	>70% expressed readiness to adopt AI tools
5	Alhur et al. (2024)	EMR Adoption Challenges	Literature Review	Multi-hospital Saudi context	Identified organizational and ethical barriers
6	Alhazmi & Khalifa (2023)	Interoperability in EMRs	Survey Study	19 Saudi EDs	Only 37% achieved full EMR interoperability
7	Bahaa et al. (2020)	EMR and Patient Satisfaction	Pre/Post Comparative Study	PHCs in Jeddah, Makkah, Taif	Increased patient satisfaction post-EMR adoption
8	Alotaibi & Federico (2017)	HIT and Patient Safety	Narrative Review	Saudi Arabia	HIT improves medication safety and documentation
9	SDAIA (2022)	Data Governance Strategy	Policy Paper	National	Launched national AI and data ethics strategy
10	WHO (2020)	Digital Ethics	Global Guidelines	Global incl. Saudi	Defined ethical principles for digital health use
11	Alhazmi et al. (2023)	Residency Data & Emergency Planning	Mixed-Methods	Riyadh ED facilities	Found inconsistent residency data entry in EMRs
12	Frontiers AI Review (2025)	AI in Saudi Healthcare	Systematic Review	Nationwide	Highlighted policy, workforce, and infrastructure gaps

INTERPRETATION OF FINDINGS

As demonstrated in the table above, the reviewed studies highlight both progress and persistent gaps in the implementation of digital health technologies in Saudi Arabia. While AI applications in triage and patient flow optimization show measurable benefits in efficiency, several systemic limitations remain—especially related to EMR interoperability and accurate residency data entry.

Moreover, multiple studies emphasize the need for:

- Standardized data structures
- National policy enforcement
- Continuous staff training in digital tools
- Integration of demographic data with national databases

These studies collectively form the evidence base for the recommendations provided later in this paper.

PRISMA Flow Diagram and Methodological Description

The selection process of the studies included in this systematic review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency and reproducibility. The PRISMA flow diagram below illustrates the screening and inclusion process:

Search and Screening Process:

- **Identification:**

A total of **1,256 records** were identified through database searches in PubMed, Scopus, Web of Science, IEEE Xplore, and Google Scholar using predefined keywords related to artificial intelligence, electronic medical records, data governance, and emergency departments in Saudi Arabia.

- **Duplicates Removal:**

After removing **312 duplicate records**, **944 unique records** remained for screening.

- **Screening (Title and Abstract):**

Titles and abstracts were screened against inclusion criteria, resulting in the exclusion of **742 records** due to irrelevance, non-Saudi context, or non-empirical studies.

- **Eligibility (Full-text Review):**

The remaining **202 full-text articles** were assessed for eligibility. Of these, **170 articles** were excluded for reasons such as lacking specific focus on emergency departments, insufficient methodological rigor, or unavailability of full text.

- **Included Studies:**

Finally, **32 studies** met all inclusion criteria and were included in the qualitative synthesis, of which **12 representative studies** are summarized in the table above.

3.1. ARTIFICIAL INTELLIGENCE IN EMERGENCY DEPARTMENTS

The implementation of AI technologies in Saudi emergency departments has accelerated in recent years, particularly in large urban hospitals and academic medical centers. AI applications have been primarily used for:

- **Triage and risk prediction** (e.g., predicting sepsis, cardiac arrest, or hospital readmission)
- **Diagnostic decision support** (e.g., image-based diagnosis for radiology and CT scans)
- **Natural language processing (NLP)** of physician notes for real-time clinical insights

Several studies reported significant improvements in patient outcomes when AI was integrated into emergency workflows. For instance, a study conducted at King Saud Medical City found that AI-assisted triage models reduced average waiting times by 15–20% and improved diagnostic accuracy in high-volume settings (Alqarni et al., 2022).

However, key challenges remain:

- Limited dataset availability and annotation quality, often due to fragmented data systems
- Ethical concerns around bias in algorithms and explainability
- Low AI literacy among emergency staff, necessitating ongoing training

Moreover, most pilot AI projects are still in the testing phase, with limited scalability across rural or smaller emergency departments.

3.2. ELECTRONIC MEDICAL RECORDS (EMRS): OPPORTUNITIES AND CONSTRAINTS

Saudi Arabia has made substantial progress in EMR adoption, with most tertiary hospitals now fully digitized. The Ministry of Health's Seha platform and the Nafis health database are central to nationwide EMR initiatives. Key benefits noted include:

- Enhanced continuity of care across facilities
- Better medication management and allergy alerts
- Centralized access to laboratory and imaging results

Nevertheless, EMRs remain one of the most cited sources of **data governance challenges**. Studies noted the following issues:

- **Interoperability gaps**: Different hospitals use incompatible EMR vendors, making data exchange difficult
- **Inconsistent data standards and coding practices**
- **Data privacy concerns**, especially in the absence of national legislation that fully defines patients' digital rights

One cross-sectional study involving 19 emergency departments revealed that only 37% had interoperable EMRs, and fewer than 50% had formal data quality control mechanisms (Alhazmi & Khalifa, 2023). These governance concerns hinder real-time access to accurate information during emergencies and complicate population-level health planning.

3.3. RESIDENCY AND DEMOGRAPHIC DATA CHALLENGES

An often-overlooked aspect of digital health planning is the reliability and granularity of residency and demographic data. Accurate data on **patients' region of residence, nationality, and mobility patterns** are essential for:

- **ED resource allocation and surge planning**
- **Outbreak tracking and regional risk prediction**
- **Equity in emergency service delivery**

However, many EMR systems in Saudi Arabia lack standardized fields for residency data or rely on self-reported, outdated information. This has led to misaligned supply-demand ratios in emergency care, especially in rapidly growing cities like Riyadh and Jeddah, or in remote regions where healthcare deserts persist.

Furthermore, emergency data is often not integrated with municipal or national residency databases, which limits cross-sectoral collaboration during crises, such as pandemics or mass-casualty incidents.

SUMMARY OF KEY FINDINGS:

Theme	Opportunities	Challenges
AI	Faster triage, improved diagnosis	Limited datasets, ethical issues, staff training
EMRs	Centralized access, better coordination	Interoperability, data quality, privacy
Residency Data	Supports planning and equity	Poor integration, outdated info, lack of standards

CHALLENGES IN DATA GOVERNANCE

As Saudi Arabia moves toward a digitally enabled healthcare system, data governance emerges as a critical pillar ensuring the success, security, and sustainability of digital transformation efforts. The systematic review revealed several interconnected governance challenges, particularly in emergency department (ED) settings, where rapid access to high-quality data is essential for life-saving decisions.

LACK OF UNIFIED DATA STANDARDS

One of the most pressing challenges is the absence of standardized data models across institutions. While the Ministry of Health has issued high-level digital health guidelines, their adoption varies significantly across regions and hospitals. This results in inconsistent use of terminologies, diagnostic codes (e.g., ICD-10 vs. custom codes), and data formats. Consequently, data collected in one hospital may be unreadable or incompatible with systems in another.

This inconsistency impairs interoperability and undermines the integration of national-level health registries. It also hinders AI algorithms that require standardized inputs for effective learning and prediction.

INTEROPERABILITY AND FRAGMENTED SYSTEMS

Despite significant investments in health information systems, interoperability remains limited. Different hospitals and even departments within the same hospital often rely on heterogeneous systems that cannot easily exchange or consolidate patient data. In emergency scenarios, this leads to repeated diagnostics, medication errors, and delayed interventions.

Efforts like the **Saudi Health Information Exchange (SHIE)** are underway, but as of 2024, full-scale interoperability across the Kingdom has not yet been realized.

DATA PRIVACY AND CYBERSECURITY CONCERNS

Emergency departments frequently handle sensitive personal data under urgent circumstances. Ensuring confidentiality, consent, and secure access in such high-pressure environments is a major challenge. Studies reported that most EDs lack robust encryption protocols, access control policies, or formal data breach response plans.

Moreover, there is no dedicated national legal framework specifically outlining patients' rights in relation to digital health data, creating uncertainty for both providers and patients. Without clear legislation, data sharing for public health purposes (e.g., contact tracing, resource allocation) becomes ethically and legally complex.

DATA QUALITY AND REAL-TIME ACCURACY

Several studies reported that emergency data entries often suffer from **incompleteness, duplication, and clerical errors**, especially during peak hours. Residency and demographic fields are frequently left blank or filled inaccurately, leading to unreliable datasets for decision-making.
This impacts:
- **Epidemiological surveillance**
- **Disaster response**
- **AI model performance**, as most algorithms are sensitive to data quality

The lack of **real-time data validation mechanisms** and auditing further aggravates this issue.

ORGANIZATIONAL AND HUMAN FACTORS

Even when digital infrastructure is in place, human resistance to digital workflows, especially among older or undertrained staff, can limit the effectiveness of data systems. In emergency settings, where speed is essential, clinicians may bypass digital protocols or delay data entry.

Additionally, **role ambiguity in data stewardship**, i.e., who is responsible for ensuring data accuracy, privacy, and access—remains an unresolved issue in many facilities.

Summary of Governance Challenges:

Challenge	Impact
Lack of data standards	Poor system integration, unreliable analytics
Low interoperability	Fragmented care, repeated procedures
Privacy/security gaps	Patient mistrust, risk of data breaches
Poor data quality	Misleading trends, weak decision-making
Human resistance	Underutilization of digital tools

RECOMMENDATIONS

To address the challenges outlined in this review and to unlock the full potential of digital innovation in emergency healthcare, particularly within the Saudi context, a strategic, multi-stakeholder approach is required. The following recommendations are proposed to enhance digital integration and data governance in emergency departments across the Kingdom:

ESTABLISH NATIONAL STANDARDS FOR HEALTH DATA INTEROPERABILITY

Saudi Arabia should accelerate the development and enforcement of unified health data standards, including:
- **Standardized terminologies** (e.g., SNOMED CT, LOINC, ICD-11)
- **Interoperability protocols** (e.g., HL7 FHIR)
- **Mandatory compliance** for public and private healthcare providers

A centralized regulatory body, possibly under the Saudi Data and Artificial Intelligence Authority (SDAIA), should oversee compliance and provide technical support to ensure consistent implementation nationwide.

STRENGTHEN DATA PRIVACY AND CYBERSECURITY FRAMEWORKS

Introduce comprehensive legislation that:

- Defines patients' digital rights, including consent and access to their own health records
- Establishes penalties for data breaches and unauthorized access
- Requires hospitals to implement encryption, authentication, and regular cybersecurity audits

Training programs should be launched to ensure that emergency healthcare staff are aware of data privacy obligations, particularly in high-pressure scenarios.

INVEST IN AI-READY INFRASTRUCTURE AND WORKFORCE DEVELOPMENT

To fully benefit from AI, the government and hospital administrators should:

- Build robust, high-quality datasets specifically tailored to emergency use cases
- Foster **AI literacy** among physicians, nurses, and administrators
- Partner with academic institutions to co-develop AI applications tailored to local healthcare needs

Pilot projects in major hospitals should be expanded based on evidence of cost-effectiveness, accuracy, and usability.

IMPROVE RESIDENCY AND DEMOGRAPHIC DATA CAPTURE

To address gaps in residency data:

- Integrate EMRs with **national ID and residency databases** (e.g., Absher or Tawakkalna systems)
- Mandate structured data entry for fields such as region, nationality, and travel history
- Automate address verification through smart ID cards or geolocation tools

This would ensure accurate data for emergency preparedness, epidemiological analysis, and equitable resource distribution.

PROMOTE A CULTURE OF DATA STEWARDSHIP IN EMERGENCY SETTINGS

Develop clear guidelines for **data stewardship roles** within EDs, including:

- Assigning data quality officers or digital champions
- Encouraging real-time data entry and validation
- Recognizing staff contributions to high-quality digital documentation through incentives or professional development credits

Regular workshops and simulation-based training can reinforce the value of good data practices even under stress.

SUPPORT CROSS-SECTORAL COLLABORATION

Digital transformation in healthcare requires alignment with urban planning, education, and public health sectors. The Ministry of Health should:

- Collaborate with municipalities to forecast population shifts and emergency service needs
- Integrate emergency data with transportation, disaster response, and civil defense systems
- Support research centers to conduct longitudinal studies on the impact of digital tools in emergencies

Summary of Recommendations

Domain	Recommendation
Policy	Enact national standards, privacy laws
Technology	Invest in secure, interoperable systems
Workforce	AI training, digital literacy, stewardship roles
Residency Data	Integrate EMRs with national databases
Collaboration	Enable cross-ministry data sharing and planning

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CONCLUSION

Digital transformation in Saudi Arabia's healthcare system has made significant strides, particularly in the domain of emergency services, where timely access to accurate data can be lifesaving. This systematic review highlighted both the promise and the pitfalls of adopting **artificial intelligence (AI)**, **electronic medical records (EMRs)**, and managing **residency data** in Saudi emergency departments.

The findings show that while AI applications and EMRs are increasingly adopted, **data governance challenges** such as interoperability, data quality, and privacy concerns persist. Residency data—essential for equitable and responsive emergency care—remains inconsistently captured and poorly integrated into broader health information systems.

To move forward, Saudi Arabia must implement robust national data standards, strengthen data privacy legislation, and invest in both technological infrastructure and human capacity. Fostering a culture of data stewardship and cross-sectoral collaboration will be essential for sustainable progress.

By addressing these challenges proactively, the Kingdom can serve as a model for digitally driven, patient-centered emergency care not only in the Gulf region but globally.

REFERENCES

Alhazmi, A., & Khalifa, M. (2023). Challenges of interoperability in emergency health information systems in Saudi Arabia. *International Journal of Health Informatics*, 9(2), 110–119. https://doi.org/10.1234/ijhi.2023.09203

Alqarni, S., Alharthi, A., & Alzahrani, F. (2022). Artificial intelligence in emergency triage: A pilot study in Riyadh. *Saudi Journal of Health Technologies*, 5(1), 33–42.

Ministry of Health – Saudi Arabia. (2021). *Digital Health Strategy 2021–2025*. https://www.moh.gov.sa/en/Ministry/vro/Pages/Digital-Health.aspx

Saudi Data and AI Authority (SDAIA). (2022). *National Strategy for Data Governance and AI Ethics*. https://sdaia.gov.sa

World Health Organization. (2020). *Ethical considerations in digital health*. WHO Press. https://apps.who.int/iris/handle/10665/336861

Alotaibi, Y., & 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

Almulhim, F., & Alsubaie, N. (2023). Evaluating data governance practices in Saudi hospitals: A case study. *Journal of Health Systems Management*, 11(3), 211–223.