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Application of Artificial Intelligence in Healthcare: Global Trends, Opportunities, and Implementation Challenges in Iran — A Narrative Review

Mohammad Vahedian-shahroodi[1], Mehdi Sedaghatkar[2], *Mohammad Saeedi[3], Alireza Akhlaghi[4]

[1]Professor of Health Education and Promotion, School of Health, Mashhad University of Medical Sciences, Mashhad, Iran. [2]Electronics Engineer, Mashhad Municipality Fire and Safety Services Organization, Mashhad, Iran. [3]M.S. in Software Engineering, Information and Communication Technology Unit, Mashhad Municipality Fire and Safety Services Organization, Mashhad, Iran. [4]MSc in Health Education and Promotion, Bushehr University of Medical Sciences, Bushehr, Iran.

Abstract

Background: Artificial intelligence (AI) is a cornerstone of digital health with transformative potential in diagnosis, medical imaging, and clinical management. Clinical translation is constrained by data quality, interpretability issues, and ethical-legal gaps. This study maps the global AI landscape and evaluates opportunities, barriers, and the infrastructural readiness of Iran's healthcare system for AI implementation.

Materials and Methods*:* We conducted a structured narrative review of PubMed, Scopus, Web of Science, and Google Scholar for English and Persian sources to December 2025. Peer-reviewed articles, policy reports, and official documents on AI in diagnosis, imaging, health-systems management, and policymaking were independently screened by two reviewers. Data were synthesized using thematic analysis, and methodological quality was appraised with the SANRA scale.

Results: Five principal AI domains were identified: medical imaging, outcome prediction, personalized medicine, drug discovery, and health-systems management. Globally, deep learning attains specialist-level diagnostic performance in multiple tasks, but widespread clinical utility is limited by data heterogeneity, algorithmic bias, black-box interpretability, and regulatory gaps. In Iran, academic activity and pilot initiatives have risen, yet clinical integration is impeded by fragmented data sources, limited interoperability, absent regulatory and legal frameworks, workforce educational deficits, and weak governance. Deploying imported models without local validation increases risk of performance drift and patient safety concerns. Cross-cutting needs include improved data quality, interoperable infrastructure, ethical governance, and workforce capacity building.

Conclusion: For safe, effective adoption in Iran, AI should function as "augmented medicine," supporting clinicians. An ecosystem approach—upgrading digital infrastructure, ensuring data interoperability and local validation of models, and establishing ethical-legal frameworks—combined with interdisciplinary collaboration is required to move from research to responsible clinical practice.

Key Words: Artificial Intelligence, Digital Health, Iran, Health System, Machine Learning.

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Corresponding Author:

Mohammad Saeedi, Information and Communication Technology Unit, Mashhad Municipality Fire and Safety Services Organization, Mashhad, Iran.

Email: msaeedi884@yahoo.com

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1- INTRODUCTION

Healthcare systems worldwide face rising challenges: aging populations, growing chronic disease burdens, escalating costs, workforce shortages, and pressure to improve quality, safety, and access (1). Digital transformation is a leading strategy to address these challenges, with artificial intelligence (AI) playing a central role (2). AI's capacity to process large clinical, imaging, genomic, and managerial datasets makes it a powerful tool for optimizing decision-making, streamlining workflows, and supporting intelligent care delivery (3, 4).

AI applications have moved beyond theory into practice across diagnosis, outcome prediction, patient monitoring, clinical decision support, personalized medicine, and drug discovery (5, 6). For specific, well-defined tasks, deep learning models can achieve expert-level performance, reducing errors and improving speed and efficiency (6). However, such technical capability does not imply readiness for broad clinical deployment; implementation depends on resolving several critical issues (7).

Primary challenges include the need for high-quality, standardized, and complete data, since bias or heterogeneity in inputs undermines model performance and equity (7, 8). The "black-box" nature of some models and limited interpretability raise ethical and liability concerns, while privacy and governance shortcomings demand frameworks for "responsible AI" in healthcare (8, 9). Thus, the core challenge shifts from algorithmic performance to safe, transparent, and equitable integration into real-world systems (7–9).

International guidance reflects this view: the WHO's Global Strategy on Digital Health 2020–2025 calls for strengthened digital infrastructure, data governance, and alignment of technologies with health system needs (1). Evidence suggests the future of AI in health lies in augmenting—not replacing—clinical judgment through synergistic human-algorithm collaboration (2, 9, 10).

In Iran, research activity, education, and interest in digital health are growing, yet operational deployment of AI faces structural barriers: data fragmentation and silos, lack of standardized interoperable exchange, regulatory and privacy gaps, and financial and international constraints. At the same time, skilled personnel, expanding knowledge-based enterprises, and gradual EHR adoption offer opportunities for localized solutions (10). A comprehensive review of the evidence is therefore needed to inform a roadmap for responsible AI development and implementation in Iran. This narrative review aims to synthesize global AI applications in healthcare, clarify major implementation challenges, and assess opportunities and barriers for deploying AI within Iran's health system.

2- MATERIALS AND METHODS

2-1. Study Design

We conducted a structured narrative review to synthesize evidence on healthcare applications of artificial intelligence (AI), implementation challenges, and the status of AI adoption in Iran. A narrative approach is appropriate for interdisciplinary, rapidly evolving fields like digital health, where evidence is heterogeneous and includes original studies, reviews, policy documents, and technical reports (11, 12).

2-2. Search strategy and data sources

A systematic literature search was conducted across PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar, supplemented by a review of official policy and guidance documents from the World Health Organization and other relevant national and international health authorities. The search strategy combined controlled vocabulary (where available, such as MeSH and Emtree) with free-text terms, tailored to the syntax and indexing structure of each database. Key terms included "artificial intelligence," "machine learning," "deep learning," "digital health," "clinical decision support," "health system," "health policy," and "Iran." All databases were searched from inception to December 2025.

2-3. Eligibility criteria

We included peer-reviewed original research, systematic and narrative reviews, policy analyses, and official reports that addressed applications of AI in clinical medicine, healthcare delivery, health management, policy, ethics, or implementation. Eligible items were available in full text and published in English or Persian. We excluded duplicates, editorials without substantive data or analysis, conference abstracts lacking full text, articles focused solely on algorithmic or engineering development with no clear clinical, organizational, or policy implications, and records for which full text could not be obtained.

2-4. Study selection

After deduplication, two reviewers independently screened titles and abstracts against the eligibility criteria. Full texts of potentially eligible records were obtained and assessed independently by the same reviewers. Selection prioritized conceptual relevance to the review aims, specifically contributions to diagnostic, prognostic, personalized, therapeutic, managerial, ethical, or policy dimensions of AI in healthcare. Disagreements were resolved by discussion and consensus; a third reviewer adjudicated unresolved conflicts.

2-5. Data extraction and synthesis

A standardized data-extraction form was used to collect study characteristics: publication year, country/setting, study design, health domain, AI approach, target population, main findings, reported benefits and harms, implementation barriers and facilitators, and Iran-specific contextual issues. Evidence were synthesized using thematic analysis, with findings grouped under diagnostic applications, clinical prediction, personalized medicine, drug discovery, healthcare management, and challenges/opportunities for the Iranian health system. Given the narrative scope of the review, reporting followed the Scale for the Assessment of Narrative Review Articles (SANRA); emphasis was placed on conceptual integration rather than formal quantitative risk-of-bias assessment (12).

2-6. Ethical Considerations

As this study was based exclusively on the analysis and synthesis of previously published literature and publicly available policy documents, it did not involve human participants, patient data, or primary data collection; therefore, formal ethical approval was not required in accordance with standard research guidelines. Nonetheless, the study was conducted in line with established principles of research integrity and ethical scholarship. All sources were accurately cited and referenced to ensure proper attribution, and efforts were made to represent the original findings of included studies faithfully, without misinterpretation or selective reporting.

3- RESULTS

This review indicates that artificial intelligence (AI) has transitioned from conceptual experimentation to functional application across the healthcare continuum. As summarized in **Table 1**, five principal domains of AI deployment were identified: diagnostic imaging, clinical outcome prediction, personalized medicine, drug discovery, and health systems management. Overall, the literature suggests that AI has made the most progress in tasks with clearly defined inputs and outputs, while broader implementation remains constrained by data quality, interoperability, interpretability, and governance challenges (1, 4, 7). In the Iranian context, research activity and technical expertise are expanding, but adoption in routine care remains limited by structural fragmentation, regulatory gaps, and implementation barriers (10, 13–15).

3-1. Diagnostic Applications and Medical Imaging

Medical imaging emerged as the most mature and best-supported domain. Across the reviewed literature, AI consistently demonstrated strong performance in image-based tasks, with evidence of improved diagnostic accuracy and workflow support in specialties where rapid visual interpretation is essential (5, 6, 16–18). Its main value lies not in replacing clinicians, but in reducing diagnostic delay and strengthening specialist decision-making, particularly in resource-constrained settings. Despite this promise, concerns regarding external validity and population-level generalizability remain important.

3-2. Prediction of Clinical Outcomes and Risk Stratification

Clinical outcome prediction represented another major application area, particularly through the use of electronic health records and large-scale clinical datasets (19–21). The literature shows that AI can support dynamic risk assessment by integrating longitudinal and multi-source patient information, enabling earlier recognition of disease progression, readmission risk, and clinical deterioration (20, 21). However, the utility of these models depends heavily on data completeness, interoperability, and consistency across health information systems (7, 14, 20).

3-3. Personalized Medicine and Precision Health

AI was also identified as a key enabler of personalized medicine, where heterogeneous genomic, proteomic, and clinical data are combined to support individualized care (2, 13, 22). In this domain, the reviewed studies emphasize AI's ability to detect non-linear and patient-specific patterns that are not captured by conventional population-based approaches. This was especially evident in oncology, where AI-supported models were used to estimate prognosis and therapeutic response. Still, implementation remains limited by the complexity of integrating multi-layered biological data into routine practice.

3-4. Drug Discovery and Development

The literature also highlighted the growing role of AI in drug discovery and development, especially in the early phases of molecular design and target identification (23, 24). AI methods can accelerate compound screening, optimize molecular properties, and reduce development time and cost. Nevertheless, most applications remain preclinical, and the path to approved clinical therapies still requires stronger validation and clearer regulatory pathways.

3-5. Healthcare Management, Digital Health, and Surgery

Beyond direct clinical decision support, AI has begun to shape healthcare management, digital health, and surgical workflows (1, 10, 25, 26). The reviewed studies suggest that these applications may improve operational efficiency, patient flow, and selected aspects of surgical care. At the same time, successful translation into routine use depends on compatibility with existing systems, user acceptance, and standardized implementation pathways. Without these conditions, even technically sound tools are unlikely to achieve sustainable adoption.

3-6. Cross-cutting Challenges

Across all five domains, the literature indicates that implementation barriers extend beyond technical performance to include data, methodological, ethical, and governance issues. Poor data quality, incomplete records, lack of standardization, and heterogeneous data formats limit model development and external generalizability, while the “black-box” nature of many deep learning systems reduces interpretability and clinician trust, especially in high-stakes decisions such as diagnosis and treatment planning. Ethical and legal concerns—including privacy, accountability, liability for errors, and preservation of the human element in care—further complicate responsible adoption (7, 8, 10, 19, 27).

In Iran, these challenges are intensified by fragmented health information systems, data silos, weak interoperability, and infrastructural limitations that hinder the routine use of AI in clinical practice (13–15). Although the national electronic health record program (SEPAS) was designed to improve data integration, inconsistent data capture and limited computing resources continue to restrict advanced AI applications. At the same time, the literature highlights growing technical expertise and local innovation potential, suggesting that progress will depend on stronger governance, improved digital infrastructure, interoperability standards, and local validation of imported models before deployment (13–15).

Table-1: Integrated Summary of Artificial Intelligence Domains, Applications, Evidence, and Implementation Challenge.

Domain	Core Function	Key Applications & Examples	Key Value Proposition	Main Implementation Barriers	Status in Iran
Medical imaging	Image and signal interpretation	Image classification, lesion detection, radiology, pathology; skin cancer classification, diabetic retinopathy screening, arrhythmia detection (5, 6, 16, 17)	High diagnostic accuracy; reduced workload; faster diagnosis; workflow augmentation	Data quality; generalizability; validation across populations	Strong research activity; limited clinical integration
Clinical outcome prediction	Risk stratification and forecasting	Disease prediction, readmission forecasting; EHR-based predictive models (19–21)	Early intervention; proactive care; dynamic risk assessment	Data completeness; interoperability; model robustness	Fragmented HIS; limited integrated datasets
Personalized medicine	Individualized diagnosis and treatment	Genomic analysis, precision oncology; cancer prognosis and treatment response models (2, 22)	Targeted therapies; improved outcomes; precision care	Data complexity; integration of multi-omics data; clinical translation gaps	Emerging research; not yet routine

Domain	Core Function	Key Applications & Examples	Key Value Proposition	Main Implementation Barriers	Status in Iran
Drug discovery	Molecular design and prediction	Drug–target interaction modeling, molecule prediction, drug repurposing; kinase inhibitor discovery (23, 24)	Reduced time and cost; accelerated R&D	Predominantly preclinical; regulatory uncertainty	Limited infrastructure; constrained resources
Health systems management	Operational and system optimization	Workflow optimization, resource allocation, digital health tools, AI-assisted surgery; patient flow prediction (1, 10, 25, 26)	Improved efficiency; optimized resource use; enhanced care delivery	Integration into existing systems; adoption barriers; lack of standardization	Limited implementation; policy and governance gaps

Note: AI: Artificial intelligence, HER: Electronic health record, HIS: Health information system.

4- DISCUSSION

The findings of this narrative review indicate that artificial intelligence (AI) has evolved from an emerging computational innovation into an important component of modern healthcare, with applications spanning diagnostic triage, risk prediction, personalized medicine, drug discovery, and operational management (3, 4, 9). Rather than simply automating routine tasks, the main clinical value of AI lies in its capacity to support clinical reasoning and enable "augmented medicine," in which computational tools complement rather than replace human expertise (2, 27).

In diagnostic medicine, deep learning models have demonstrated specialist-level performance in tasks such as skin cancer classification, diabetic retinopathy detection, arrhythmia recognition, and medical image interpretation (5, 6, 16–18). Although these systems may help address specialist shortages and reduce triage delays in underserved settings (4, 5), technical accuracy alone does not ensure clinical effectiveness. Transitioning from controlled retrospective datasets to routine practice is often hindered by variability in real-world data quality, workflow integration difficulties, and patient heterogeneity (7, 26). Similarly, machine learning models integrated with electronic health records (EHRs) can improve risk stratification (19–21), but their reliability remains highly dependent on the completeness, consistency, and standardization of underlying data.

AI has also expanded personalized medicine and biomedical research. In data-intensive fields such as oncology, machine learning supports targeted therapy by integrating genomic, molecular, and clinical data to predict individual patient trajectories (2, 9, 22). In pharmaceutical research, AI accelerates target identification and molecular screening, reducing early-stage development timelines (23, 24). However, the broader clinical adoption of these systems is limited by the "black-box" nature of many advanced neural networks. Limited interpretability reduces physician trust, raises safety concerns, and complicates professional accountability (7, 8). For this reason, recent studies increasingly recommend inherently interpretable models for high-stakes clinical decision-making (8).

Implementation challenges extend beyond model performance. Recent reviews of medical AI have highlighted additional risks, including algorithmic bias, data insecurity, generative hallucination, legal liability, and the need for workforce retraining (13). In Iran, these challenges are intensified by structural and systemic limitations. Although academic interest and technical capacity are increasing, practical integration into the national healthcare system remains limited (13). This gap is driven largely by fragmented digital health systems, weak interoperability, and delays in fully implementing unified electronic health records (14, 15).

A qualitative study of the Iranian health system identified five major barriers to AI adoption: organizational and structural constraints, legal and policy gaps, data-related problems such as poor quality and lack of standardization, workforce and educational deficits, and governance concerns related to human oversight (28). Policy analyses similarly show that sustainable integration is limited by the absence of responsive ethical, legal, and administrative frameworks (29). Without clearer rules for algorithm validation, clinical responsibility, and data security, AI will likely remain confined to pilot projects and academic settings.

Data governance and local validation therefore appear to be the most important prerequisites for AI readiness in Iran. Fragmented digital systems and heterogeneous data structures limit the generation of high-quality training datasets and hinder local validation efforts (15, 28). Because imported models may perform differently across populations, disease patterns, and clinical workflows, local validation and iterative recalibration are essential to ensure safety and effectiveness (7, 26). This is particularly relevant in primary care, where AI could support early screening, decision support, and resource allocation, but only if robust data exchange standards and surveillance infrastructure are in place (30).

At the policy level, AI should not be treated as a standalone software solution. Instead, it must be embedded within a national digital health strategy that strengthens infrastructure, establishes adaptive regulation, and builds interdisciplinary capacity (1, 26). Addressing these foundational issues is essential for moving AI from an academic concept to a safe, equitable, and effective component of healthcare in Iran.

4-1. Study Limitations

This study has several limitations. First, as a narrative review, it is inherently subject to selection and interpretive bias, despite efforts to prioritize credible, influential, and methodologically relevant sources and to apply a structured review logic (11, 12). Second, much of the available literature on AI in healthcare is based on retrospective datasets, technical validation studies, or controlled research settings, which may not fully capture the complexity of routine clinical implementation. Third, the number of studies specifically addressing AI adoption in the Iranian health system remains limited, which constrains the depth of context-specific interpretation. Finally, because AI is a rapidly evolving field, new tools, governance frameworks, and implementation evidence may emerge faster than the publication cycle of narrative reviews can incorporate.

5- CONCLUSION

Artificial intelligence is increasingly positioned as a transformative force in healthcare, with demonstrated and emerging applications in diagnosis, prediction, personalized medicine, drug discovery, and service delivery. However, the shift from algorithmic promise to meaningful clinical value depends not only on technical performance, but also on data quality, interoperability, explainability, governance, and context-sensitive implementation.

In Iran, the evidence suggests that AI in healthcare is advancing at the conceptual and academic levels, but real-world integration remains limited by fragmented digital infrastructure, legal and policy gaps, weak data governance, and insufficient implementation readiness. Addressing these barriers will require coordinated national efforts to modernize health information systems, strengthen ethical and legal oversight, establish adaptive regulatory frameworks, and build interdisciplinary workforce capacity. Under these conditions, AI could become a meaningful contributor to improving the quality, accessibility, and efficiency of healthcare in Iran.

7- CONFLICT OF INTEREST: None.

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