TITLE: Generative Artificial Intelligence: Transforming Healthcare Delivery, Education, and Research

AUTHOR:
Dr Revant H Chole
Assistant Professor
Department of Oral and Maxillofacial Surgery and Diagnostic Sciences, Faculty of Dentistry, Najran University, Saudi Arabia.

Abstract

Background: Artificial intelligence (AI) is increasingly embedded in healthcare, supporting diagnostics, decision support, education, and administration. A recent development, generative artificial intelligence (GAI), exemplified by large language models (LLMs) such as ChatGPT, has demonstrated the ability to generate human-like text, synthesize data, and automate tasks across healthcare.

Objective: To review the applications, opportunities, challenges, and future directions of GAI in healthcare with attention to ethical, legal, and social implications.

Methods: A narrative review of PubMed, Scopus, and Web of Science was conducted (2018–2025), identifying peer-reviewed studies on GAI applications in healthcare. Inclusion criteria were English-language studies addressing clinical, educational, or operational applications of GAI. Data were synthesized thematically.

Results: GAI shows utility in clinical decision support, radiology, patient communication, medical education, research, and administrative efficiency. Benefits include reduced documentation burden, improved accessibility, and enhanced knowledge synthesis. However, risks include hallucinations, bias, privacy concerns, unclear accountability, and integration challenges.

Conclusion: GAI holds transformative potential as an augmentative technology in healthcare. Its success depends on responsible implementation, regulatory oversight, and clinician training. Future directions include multimodal AI, digital twins, federated learning, and deployment in low-resource settings.

Keywords: Artificial intelligence, Generative AI, ChatGPT, Large language models, Clinical decision support, Radiology, Medical education, Digital health.

Introduction

Artificial intelligence (AI) is rapidly transforming the global healthcare ecosystem, reshaping clinical decision-making, patient engagement, medical education, and research. Over the past decade, AI has evolved from proof-of-concept experiments to deployed systems in diagnostic imaging, electronic health record (EHR) systems, predictive analytics, and administrative support. Healthcare, as a data-rich domain, is especially poised to benefit from the advances in computational power, algorithmic complexity, and availability of large datasets. Traditional AI systems have already demonstrated utility in interpreting imaging data, risk stratification, and automation of routine tasks, thus enhancing workflow efficiency and diagnostic precision.

Within the broader AI landscape, Generative Artificial Intelligence (GAI) has emerged as one of the most disruptive innovations. Unlike conventional AI models—which are largely constrained to classification, regression, or pattern recognition—GAI systems are capable of generating novel content, whether in the form of text, images, structured reports, or interactive dialogue. This generative capacity stems from training on massive corpora of text (and in some instances multimodal data) and leveraging contextual embeddings to produce coherent, context-aware outputs. The Generative Pre-trained Transformer (GPT) family of models is the most prominent example: these models, such as ChatGPT, have demonstrated an ability to converse, draft documents, summarize complex literature, and assist with knowledge retrieval.

Healthcare systems globally are beginning to explore the integration of GAI into both clinical and non-clinical workflows. Early investigations report potential in automating radiology report generation, summarizing lengthy clinical notes, facilitating patient communication, and enriching medical education. In research settings, GAI has been applied to accelerate literature synthesis, generate synthetic clinical datasets, and assist in drafting manuscripts or grant proposals [1,2,3]. These applications suggest that GAI can function as a force multiplier for clinicians, alleviating cognitive load and streamlining knowledge access.

However, the excitement surrounding GAI must be tempered by a rigorous understanding of its limitations and risks. One of the principal concerns is "hallucination", in which the model generates plausible but factually incorrect or misleading content. In medicine, such errors can carry significant clinical consequences, making it imperative that human clinicians validate AI-generated outputs. Ethical dimensions including patient privacy, data security, informed consent, and liability are likewise critical. Many generative models are trained on vast datasets with limited transparency regarding data provenance, which raises questions around privacy compliance (e.g., HIPAA, GDPR) and data governance [4,5]. Moreover, the "black box" nature of many generative models complicates interpretability and accountability, potentially undermining clinician trust.

The role of GAI in the healthcare workforce is another area warranting careful reflection. Concerns linger about whether AI could displace certain roles or deskill clinicians. However, prevailing expert opinion frames GAI as a complementary tool—one that should free clinicians from repetitive tasks (such as documentation, summarization, or literature retrieval) and enable them to focus more on higher-level cognitive and interpersonal work [6]. This aligns with the concept of "human-centered AI," where synergy, rather than replacement, is prioritized.

Several contextual trends make the integration of GAI especially timely. The COVID-19 pandemic accelerated digital adoption—telehealth, remote monitoring, and AI-enabled triage became ubiquitous, exposing the potential for AI in scaling healthcare access. Meanwhile, healthcare systems worldwide face pressures such as workforce scarcity, rising costs, and increasing complexity of care. GAI offers one path to streamline operations, reduce administrative burden, and empower patient self-management. In parallel, patient expectations are evolving: modern patients often expect more personalized, on-demand, and interactive healthcare experiences—areas in which GAI-powered conversational systems may excel.

From a scientific standpoint, GAI also offers new opportunities for knowledge discovery and synthesis. Large language models can rapidly scan and integrate vast biomedical literature, generate hypotheses, and help in meta-analysis or evidence synthesis. In the realm of medical education, GAI is already being used as a tutor—capable of explaining complex topics, generating case scenarios, formulating practice questions, and simulating patient dialogues [2,7,8]. For educators and researchers, it offers tools to structure content, summarize findings, and draft manuscripts more efficiently.

Yet, integrating GAI into healthcare must be pursued with a critical lens. Over-reliance on model outputs may lead to automation bias, where clinicians accept AI suggestions uncritically—an issue of growing concern in medical education and clinical practice [9,10]. Bias in training data may result in inequitable model performance across demographic or clinical subgroups, reinforcing existing health disparities. The opacity of many generative models also pose challenges for transparency, trust, and legal accountability—especially in high-stakes care decisions.

Regulatory agencies and professional bodies are beginning to confront these challenges. The U.S. Food and Drug Administration (FDA) has introduced AI/ML-based medical device guidelines, while professional societies emphasize the need for model validation, transparency, and clinician oversight. Auditing frameworks, bias mitigation techniques, and clinician training curricula are essential to build responsible adoption pathways [5,11,12].

In light of these developments, the purpose of this review is to provide a structured and balanced examination of GAI in healthcare. Specifically, we aim to (1) define the conceptual foundations of GAI (LLMs, NLP, generative capabilities), (2) review real-world and emerging applications of GAI in clinical decision support, imaging, patient communication, education, and research, (3) identify key ethical, legal, and social considerations, (4) explore barriers to adoption in healthcare systems, and (5) discuss future directions—such as multimodal AI, federated learning, and GAI in low- and middle-income settings.

By combining expansive capabilities with a cautious evaluative stance, we argue that GAI should not be seen as a replacement for clinicians but as a potent augmentative tool. When integrated thoughtfully, GAI has the potential to enhance clinical practice, democratize access to medical knowledge, reduce clinician burden, and ultimately improve patient outcomes.

Table 1. Comparison of Traditional AI and Generative AI in Healthcare

Feature	Traditional AI	Generative AI(LLMs, GPT)
Function	Classification, prediction	Content generation, synthesis
Input	Structured Data	Structure+ Unstructured Data
Output	Label, Probabilities	Text, Report, Dialogue
Example	Detecting tumor on CT	Drafting Radiology Report
Limitation	Narrow Task Scope	Hallucinations, Interpretability

3. Methods / Approach

This paper adopts a narrative review methodology to synthesize the current state of knowledge on generative artificial intelligence (GAI) in healthcare. Given the novelty and rapid evolution of the field, a traditional systematic review approach was deemed less suitable; instead, we aimed to capture both peer-reviewed evidence and emerging perspectives from recent literature.

3.1 Literature Search

A structured literature search was conducted across PubMed, Scopus, and Web of Science between January 2018 and September 2025. The search strategy combined keywords including “Generative artificial intelligence,” “large language models,” “ChatGPT,” “healthcare,” “Clinical decision support,” “medical education,” and “digital health.” Boolean operators and MeSH terms were applied where applicable.

3.2 Inclusion and Exclusion Criteria

Inclusion:

a. Peer-reviewed articles published in English.
b. Studies describing applications of GAI in healthcare delivery, education, patient
c. communication, or biomedical research.
d. Reviews, commentaries, and perspective papers in high-impact medical or
e. informatics journals.

Exclusion:

a. Non-healthcare applications (e.g., AI in finance or entertainment).
b. Studies focusing exclusively on non-generative AI methods (e.g., purely diagnostic CNNs).
c. Preprints without peer review (unless highly cited and influential).

3.3 Data Extraction and Synthesis

Relevant data were extracted, including study objectives, AI model type, healthcare domain, application use-case, reported outcomes, and limitations. Findings were synthesized thematically into domains such as clinical decision support, radiology, patient communication, education, administration, and research. Ethical, regulatory, and social considerations were also coded as recurring themes.

3.4 Scope and Limitations

As a narrative review, this approach prioritizes breadth of coverage and conceptual mapping rather than quantitative meta-analysis. While comprehensive, some relevant preprints or non-indexed studies may not have been included. Nonetheless, this methodology provides a robust overview of how GAI is being explored, evaluated, and applied across healthcare systems worldwide [1,3,7].

4. Applications of Generative AI in Healthcare

GAI has demonstrated versatility across clinical, administrative, educational, and research domains. Below, we synthesize the most prominent applications, highlighting both opportunities and limitations.

4.1 Clinical Decision Support

One of the most promising roles of GAI lies in clinical decision support (CDS). By synthesizing unstructured text (e.g., physician notes, radiology reports) and structured data (e.g., laboratory values, vital signs), LLMs can generate evidence-based recommendations and highlight differential diagnoses [2,6,11].

Examples:

a. Early pilot studies demonstrate ChatGPT’s ability to draft treatment plans aligned with clinical guidelines in oncology and cardiology [2,8].

b. Predictive modeling has been applied to forecast renal impairment, hematologic disorders, and cardiovascular risk using structured patient data [6].

c. Integration into EHR systems enables automated chart summarization and preliminary clinical note drafting.

Advantages: Reduced physician workload, rapid access to literature, and improved diagnostic efficiency.

Challenges: Risk of hallucinated recommendations, limited transparency in reasoning, and medicolegal liability [5,12].

4.2 Radiology and Imaging

Radiology is among the earliest fields to adopt AI, and GAI further extends these applications. By combining imaging data with textual generation, GAI systems can produce structured radiology reports, summarize findings, and flag potential abnormalities for review.

Examples:

a. AI-assisted reporting in chest radiographs has reduced reporting time while maintaining diagnostic accuracy [9].

b. Generative models integrated with PACS have been trialed for triaging urgent scans, such as identifying pulmonary embolisms or intracranial hemorrhage [13].

Advantages: Improved efficiency in high-volume departments, consistency of reporting, and support in under-resourced settings.

Challenges: Dependence on annotated training data, risk of over-reliance by junior radiologists, and potential bias in datasets [3,16].

4.3 Patient Communication and Engagement

GAI-powered conversational agents offer patient-facing support, ranging from answering medical questions to providing adherence reminders and health education. These systems can generate personalized, understandable explanations of complex medical conditions and facilitate follow-up care [6,14].

Examples:

a. Chatbots providing diabetes education have improved patient satisfaction and adherence [18].

b. AI systems have been trialed in oncology clinics to provide supportive counseling for newly diagnosed patients [13].

Advantages: Enhanced accessibility, especially for patients with low health literacy or in remote settings.

Challenges: Risk of misinformation, need for cultural and linguistic adaptation, and privacy concerns [15,19].

4.4 Medical Education and Training

Medical students and trainees increasingly use GAI tools for study support. ChatGPT, for example, has been evaluated in simulated medical licensing examinations and has demonstrated performance near the passing threshold [7,20].

Applications:

a. Drafting case-based scenarios for problem-based learning.
b. Generating exam questions and providing formative feedback.
c. Simulating patient interviews for communication training [21].

Advantages: Personalized learning, scalability, and improved access to resources.

Challenges: Risks of plagiarism, over-reliance, and accuracy of generated content [22].

4.5 Administrative and Operational Efficiency

Administrative burden contributes significantly to clinician burnout. GAI can automate EHR documentation, discharge summaries, billing code generation, and correspondence [17].

Examples:

a. Digital scribes powered by LLMs reduce time spent on note-taking, allowing clinicians to focus on patient interaction.

b. Automated insurance claim summaries and coding systems are under pilot testing.[12].

Advantages: Time savings, reduced burnout, improved accuracy of records.

Challenges: Integration with legacy IT systems, data security, and cost of implementation.

4.6 Research and Knowledge Discovery

GAI also accelerates biomedical research. By processing large volumes of scientific literature, models can summarize findings, generate hypotheses, and assist in systematic reviews [1,3].

Examples:

a. Synthetic patient datasets have been generated to train predictive models while preserving privacy [23].
b. AI-assisted literature screening has reduced workload in systematic reviews by up to 50% [16].

Advantages: Increased research efficiency, democratization of access to knowledge.

Challenges: Risk of bias amplification, intellectual property issues, and need for rigorous validation [25].

Table 2. Current and Emerging Applications of GAI in Healthcare

DOMAIN	APPLICATION	BENIFITS	CHALLENGES
Clinical Decision Support	Summarizing EHRs, Risk predictions	Efficiency, Accuracy	Hallucinations, Liability
Radiology	Automated Reporting	Consistency, reduced workload	Dataset Bias
Patient Communication	Chatbots, health education	Accessibility,	Misinformation Risk
Education	Exam preps, Simulations	Personalized learning	Over reliance
Research	Literature synthesis, synthetic data	Efficiency, scalability	Bias, Validation

5. Ethical, Legal, and Social Considerations

The adoption of generative artificial intelligence (GAI) in healthcare introduces not only technical opportunities but also profound ethical, legal, and social implications (ELSI). These considerations are central to ensuring safe, equitable, and trustworthy integration of AI technologies into patient care.

5.1 Bias, Fairness, and Equity

Bias in training data can result in discriminatory outputs that exacerbate existing health disparities. If LLMs are trained predominantly on data from high-income countries or overrepresented populations, their recommendations may be less accurate for minority groups, women, or individuals from low-resource settings [1,5,12]. In healthcare, where disparities already exist, biased AI outputs may amplify inequities in diagnosis, treatment, and outcomes. Mitigation strategies include bias auditing, dataset diversification, and fairness-aware model design [2,11].

5.2 Transparency and Explainability

Unlike traditional rule-based systems, LLMs function as “black boxes,” making it difficult for clinicians to trace how outputs are generated. In medicine, where accountability is paramount, the lack of explainability undermines trust and hinders adoption [4,10]. Researchers are increasingly advocating for explainable AI (XAI) frameworks that provide interpretable rationales for model decisions without compromising performance [19].

5.3 Privacy and Data Security

Healthcare data are among the most sensitive forms of personal information. GAI systems that process EHRs or patient queries must comply with strict legal frameworks such as the Health Insurance Portability and Accountability Act (HIPAA) in the United States and the General Data Protection Regulation (GDPR) in Europe [6,14]. Risks include unauthorized data access, data leakage during model training, and potential misuse of synthetic patient data. Ensuring robust encryption, anonymization, and secure federated learning frameworks will be key to mitigating these risks [22].

5.4 Accountability and Liability

When AI-generated recommendations contribute to adverse outcomes, it is unclear who bears responsibility—the clinician, the institution, or the AI developer. Current legal frameworks are not fully equipped to allocate liability in such cases [9,15]. A proposed solution involves shared accountability models, where clinicians remain the final decision-makers, but institutions and developers share responsibility for AI system validation and safe deployment.

5.5 Professional Identity and Workforce Implications

The integration of GAI raises concerns about workforce disruption. Clinicians may fear replacement, while students may worry about diminished training opportunities if AI tools automate key tasks [3,20]. A balanced perspective frames GAI as an augmentative technology that should reduce clerical burden and cognitive load rather than erode professional expertise. Policies and training programs must ensure clinicians are equipped to use AI responsibly while preserving critical thinking and patient-centered care [7,21].

5.6 Patient Trust and Acceptance

Successful adoption depends not only on clinician acceptance but also on patient trust. Studies show that patients may be hesitant to rely on AI-generated advice, especially in high-stakes conditions like cancer care or surgery [18]. Transparent communication about AI's role, limitations, and safeguards is crucial to fostering trust. Co-designing AI tools with patient input can also enhance cultural sensitivity and acceptability [13].

6. Challenges and Barriers to Adoption

Despite the rapid progress of GAI, several systemic and practical barriers may hinder its widespread integration into healthcare systems.

6.1 Technical Limitations

Generative models remain prone to hallucinations, producing factually incorrect outputs that appear convincing [8]. In healthcare, such errors could misinform treatment decisions. Furthermore, most LLMs lack access to real-time, institution-specific data, limiting their clinical utility without integration into secure EHR systems. Resource-intensive training requirements also restrict accessibility in low-resource settings [16].

6.2 Regulatory Uncertainty

Regulatory frameworks for AI in healthcare remain under development. While the U.S. FDA has introduced guidelines for AI/ML-enabled devices, generative models that provide narrative outputs (e.g., clinical notes, patient instructions) often fall outside existing classifications [5]. Ambiguities regarding validation standards, risk categorization, and ongoing monitoring create uncertainty for developers and institutions.

6.3 Integration with Clinical Workflows

AI systems must fit seamlessly into existing workflows to be adopted. If poorly integrated, they may increase clinician burden rather than reduce it [7,12]. Issues include interoperability with legacy IT systems, clinician training requirements, and workflow redesign. Successful adoption will require co-design with end-users, ensuring usability and alignment with clinical practice.

6.4 Cost and Resource Barriers

Developing, implementing, and maintaining GAI systems is resource-intensive. High infrastructure demands (e.g., GPU clusters, secure data storage) and licensing fees may limit adoption, especially in smaller hospitals and low- and middle-income countries (LMICs) [22]. Cost-benefit analyses and equitable pricing models are needed to ensure broad accessibility.

6.5 Workforce Preparedness and Education

Most clinicians lack formal training in AI. Without proper education, there is a risk of automation bias or misuse of AI outputs [9]. Medical curricula must evolve to include AI literacy, covering topics such as model limitations, ethical considerations, and best practices for human-AI collaboration [20,21]. Continuing education for practicing clinicians will also be essential.

6.6 Cultural and Institutional Resistance

Healthcare organizations are traditionally cautious adopters of new technologies, especially those that may disrupt established roles and hierarchies. Resistance may stem from concerns about job displacement, erosion of clinical autonomy, or skepticism about AI reliability [14]. Overcoming these barriers requires transparent governance, pilot testing, and evidence-based demonstration of benefits.

7. Future Directions

The trajectory of generative artificial intelligence (GAI) in healthcare is rapidly evolving, and several emerging trends suggest how these technologies may transform medicine in the coming decade.

7.1 Multimodal AI Integration

Most current GAI systems rely primarily on text, but the future lies in multimodal AI capable of integrating clinical text, imaging, laboratory values, genomic data, and even wearable sensor outputs. Such systems could provide holistic, patient-specific insights, enabling personalized risk prediction and treatment planning. For example, multimodal AI could integrate MRI imaging with genetic biomarkers to tailor oncology therapies [1,11].

7.2 AI-Driven Digital Twins

The concept of digital twins—virtual models of individual patients—offers a promising frontier. By simulating disease progression and treatment responses, digital twins could allow clinicians to test therapeutic interventions virtually before applying them in real life [2,13]. Coupled with GAI, these systems could generate patient-specific narratives, visualizations, and predictions, supporting precision medicine.

7.3 Federated and Privacy-Preserving Learning

To address concerns regarding data privacy, the future of GAI will increasingly incorporate federated learning and privacy-preserving training techniques. These approaches allow models to learn from distributed datasets without transferring sensitive patient data, thereby maintaining compliance with regulations such as GDPR and HIPAA while still leveraging diverse data sources [5,16].

7.4 Global Health and Low-Resource Settings

GAI may play a transformative role in low- and middle-income countries (LMICs) where specialist availability is limited. Lightweight, locally adapted LLMs could support triage, patient education, and basic diagnostic guidance. By embedding GAI into mobile health platforms, underserved regions could gain access to scalable, low-cost medical expertise [7,18]. Ensuring culturally sensitive and linguistically diverse models will be essential for global equity.

7.5 Continuous Validation and Regulation

As healthcare increasingly adopts AI, regulatory frameworks will evolve toward continuous post-market validation. Instead of static approvals, adaptive regulation may require ongoing audits, bias checks, and transparency reporting. Future GAI systems are likely to incorporate explainability features, making outputs more interpretable to both clinicians and patients [12,20].

7.6 Collaborative Human-AI Practice

The most impactful future applications will be those that foster collaborative intelligence, where human expertise and AI capabilities complement each other. In such models, AI handles repetitive or data-heavy tasks while clinicians provide context, empathy, and ethical oversight. This approach reinforces the idea that GAI should serve as a co-pilot, not a replacement, in clinical care [9,21].

8. Conclusion

Generative artificial intelligence represents a paradigm shift in healthcare, with the potential to revolutionize clinical practice, patient engagement, education, and biomedical research. By leveraging large language models and multimodal architectures, GAI can synthesize vast data sources, automate routine tasks, and provide context-aware clinical insights. Early applications in radiology, decision support, patient communication, and education demonstrate both feasibility and utility.

Yet, alongside these opportunities lie significant challenges. Issues of bias, transparency, privacy, liability, and integration must be addressed to safeguard patient safety and maintain trust. Importantly, GAI is not a substitute for clinicians but an augmentative technology that should enhance efficiency, accuracy, and patient-centered care. Regulatory frameworks, professional training, and ethical governance will determine whether GAI fulfills its promise responsibly.

Looking ahead, the future of GAI in healthcare will likely be shaped by multimodal integration, digital twins, privacy-preserving models, and global health applications. By adopting a human-centered, ethically guided approach, healthcare systems can harness GAI to reduce disparities, improve outcomes, and create more sustainable models of care delivery.

In conclusion, GAI offers an unprecedented opportunity to reimagine the practice of medicine. If implemented thoughtfully and responsibly, it has the potential not only to augment clinical expertise but also to democratize access to knowledge and reshape healthcare delivery for the better.

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