

# An Analytical View of Generative AI Algorithms on Healthcare of Cancer Disease - A Review

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**Abstract:** Cancer remains one of the leading causes of mortality worldwide, requiring early diagnosis, accurate treatment planning, and continuous patient monitoring. Recent developments in Generative Artificial Intelligence (GenAI) have transformed healthcare by improving medical imaging, pathology, genomics, clinical decision support, and drug discovery. Unlike conventional machine learning algorithms that primarily perform prediction or classification, Generative AI models can generate realistic medical images, synthesize patient records, summarize clinical information, and assist clinicians in personalized treatment planning. This review analytically examines major Generative AI algorithms, including Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), Diffusion Models, Transformer Models, and Large Language Models (LLMs), with emphasis on their applications in cancer healthcare. The paper discusses advantages, limitations, ethical concerns, and future research directions. The review concludes that Generative AI has significant potential to revolutionize precision oncology while requiring careful clinical validation, transparency, and regulatory oversight before widespread deployment.

**Keywords:** Generative AI, Cancer Detection, Healthcare, Deep Learning, GAN, Large Language Models, Medical Imaging, Precision Oncology

## I. INTRODUCTION

Cancer is one of the world's most serious health problems, accounting for millions of new cases and deaths every year. Early diagnosis significantly improves survival rates, yet traditional diagnostic methods often rely on manual interpretation of imaging, pathology slides, and laboratory reports, making them time-consuming and prone to variability.

Artificial Intelligence (AI) has become a transformative technology in healthcare. Initially, AI systems focused on classification and prediction using machine learning and deep learning. More recently, **Generative AI** has emerged as a new paradigm capable of generating text, images, molecular structures, and synthetic medical data. These capabilities support cancer diagnosis, treatment planning, patient education, and biomedical research. Modern generative systems can integrate multimodal data—including radiology, pathology, genomics, and clinical records—making them particularly promising for precision oncology.

### Objectives of the Study

The major objectives are:

The main objectives of this review paper are:

1. **To study the concept of Generative Artificial Intelligence (GenAI)** and its role in modern healthcare, particularly in cancer diagnosis and treatment.
2. **To analyze the major Generative AI algorithms** such as Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), Diffusion Models, Transformers, and Large Language Models (LLMs) used in cancer healthcare.



3. **To review the applications of Generative AI in cancer care**, including early cancer detection, medical image analysis, histopathology, genomics, precision oncology, drug discovery, and clinical decision support.
4. **To compare the performance, strengths, and limitations** of different Generative AI algorithms in terms of accuracy, efficiency, scalability, and clinical applicability.
5. **To evaluate the impact of Generative AI on improving healthcare outcomes**, such as diagnostic accuracy, treatment planning, patient monitoring, and personalized medicine.
6. **To identify the challenges and ethical issues** associated with the adoption of Generative AI in cancer healthcare, including data privacy, bias, explainability, security, and regulatory compliance.
7. **To explore current research trends and future directions** for the integration of Generative AI into cancer diagnosis, treatment, and healthcare management.
8. **To provide a comprehensive analytical review** of existing literature on Generative AI algorithms in cancer healthcare and highlight research gaps for future investigation.

## II. RESEARCH METHODOLOGY

This study uses a **Systematic Literature Review (SLR)** approach based on secondary data. Relevant research papers on **Generative AI algorithms in cancer healthcare** were collected from reputed databases such as **IEEE Xplore, SpringerLink, ScienceDirect, PubMed, ACM Digital Library, and Google Scholar**. Studies published between **2019 and 2026** were selected using keywords including *Generative AI, Cancer Detection, GAN, VAE, Diffusion Models, Large Language Models (LLMs), Medical Imaging, and Precision Oncology*. The selected articles were screened using predefined inclusion and exclusion criteria. The collected literature was then analyzed and compared to evaluate the applications, advantages, limitations, and future scope of Generative AI algorithms in cancer diagnosis, treatment, and healthcare management. This methodology provides a comprehensive understanding of the current state of research and identifies future research opportunities.

### Review of Literature

The reviewed literature indicates that **Generative AI algorithms**, including **GANs, VAEs, Diffusion Models, Transformers, and Large Language Models (LLMs)**, have significantly advanced cancer healthcare through applications in medical imaging, early cancer detection, precision oncology, clinical decision support, and drug discovery. While these technologies improve diagnostic accuracy and support personalized treatment, challenges such as data privacy, model interpretability, computational complexity, ethical concerns, and clinical validation remain key research areas for future work.

**Table 1**

| Sr. No. | Author(s)          | Year | Title                                                                | Key Findings                                                                                               | Research Gap                                                        |
|---------|--------------------|------|----------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| 1       | Perez-Lopez et al. | 2024 | <i>A Guide to Artificial Intelligence for Cancer Researchers</i>     | Discussed the role of AI in cancer diagnosis, imaging, and precision oncology.                             | Limited discussion on real-world implementation and ethical issues. |
| 2       | Shokrollahi et al. | 2023 | <i>A Comprehensive Review of Generative AI in Healthcare</i>         | Reviewed applications of Generative AI in medical imaging, report generation, and synthetic data creation. | Limited focus on cancer-specific applications.                      |
| 3       | Buess et al.       | 2025 | <i>From Large Language Models to Multimodal AI: A Scoping Review</i> | Highlighted the potential of multimodal AI in clinical decision-making and medical documentation.          | Clinical validation remains insufficient.                           |



|    |                   |      |                                                                       |                                                                                                     |                                                                             |
|----|-------------------|------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| 4  | Elkefi et al.     | 2026 | <i>Generative AI Tools to Support Decision-Making in Cancer Care</i>  | Reviewed the use of LLMs in oncology for clinical support and patient communication.                | Concerns regarding hallucinations and reliability require further research. |
| 5  | Hamamoto et al.   | 2026 | <i>Implementing Generative AI in Precision Oncology</i>               | Explained the application of Generative AI in personalized cancer treatment and precision medicine. | Regulatory and ethical challenges need further investigation.               |
| 6  | Truhn et al.      | 2026 | <i>Artificial Intelligence Agents in Cancer Research and Oncology</i> | Demonstrated the growing role of AI agents in cancer research and clinical workflows.               | Requires large-scale clinical evaluation.                                   |
| 7  | Reddy et al.      | 2026 | <i>Artificial Intelligence and Transforming Cancer Care</i>           | Discussed AI applications in diagnosis, prognosis, and treatment planning.                          | Integration into routine healthcare systems is still limited.               |
| 8  | Goodfellow et al. | 2014 | <i>Generative Adversarial Networks</i>                                | Introduced GAN architecture for realistic data generation, later widely adopted in medical imaging. | Originally not designed for healthcare applications.                        |
| 9  | Kingma & Welling  | 2014 | <i>Auto-Encoding Variational Bayes</i>                                | Proposed the VAE framework for probabilistic data generation and representation learning.           | Produces lower-quality images compared to GANs and diffusion models.        |
| 10 | Ho et al.         | 2020 | <i>Denoising Diffusion Probabilistic Models</i>                       | Introduced diffusion-based image generation with superior image quality and stability.              | High computational cost and slow image generation.                          |

### III. GENERATIVE AI IN HEALTHCARE

Generative AI refers to computational models capable of learning data distributions and producing new, realistic outputs.

#### Characteristics

- Generates synthetic medical images
- Produces realistic patient records
- Supports medical report generation
- Enhances diagnostic decision-making
- Assists drug discovery
- Improves healthcare documentation
- Unlike traditional AI, which predicts labels, Generative AI creates new content while preserving learned clinical patterns.

#### Major Generative AI Algorithms

##### 3.1 Generative Adversarial Networks (GANs)

GANs consist of two competing neural networks:

- Generator
- Discriminator



The generator creates synthetic medical images, while the discriminator distinguishes real from generated images. Through adversarial training, image quality improves progressively.

#### **Cancer Applications**

- MRI enhancement
- CT image reconstruction
- Histopathology image synthesis
- Data augmentation
- Rare cancer image generation

#### **Advantages**

- High-quality image generation
- Reduces data scarcity
- Improves diagnostic model performance

#### **Limitations**

- Training instability
- Mode collapse
- High computational cost

### **3.2 Variational Autoencoders (VAEs)**

VAEs encode medical data into a latent space before reconstructing it.

#### **Applications include:**

- Tumor segmentation
- Medical image denoising
- Biomarker discovery
- Gene expression modeling

#### **Advantages:**

- Stable training
- Probabilistic learning
- Efficient latent representation

#### **Limitations:**

- Blurry image generation
- Lower realism than GANs

### **3.3 Diffusion Models**

Diffusion models generate images by progressively removing noise.

#### **Applications include:**

- Medical image synthesis
- MRI reconstruction
- Image super-resolution
- Cancer lesion generation

#### **Advantages:**

Excellent image quality

- Stable optimization
- Better diversity

#### **Limitations:**

- Slow generation
- High computational requirements



### 3.4 Transformer Models

Transformers utilize self-attention mechanisms for learning long-range dependencies.

#### Healthcare applications include:

- Medical report generation
- Clinical note summarization
- Genomic sequence analysis
- Clinical decision support

#### Advantages:

- Parallel processing
- Better contextual understanding
- Scalability

### 3.5 Large Language Models (LLMs)

#### Popular examples include:

- GPT
- Gemini
- LLaMA

#### Applications:

- Oncology question answering
- Clinical documentation
- Patient education
- Decision support
- Literature summarization

LLMs can help clinicians synthesize evidence but still require human oversight because of possible hallucinations and incomplete reasoning.

## IV. APPLICATIONS OF GENERATIVE AI IN CANCER HEALTHCARE

### 4.1 Early Cancer Detection

Generative AI improves detection of:

- Breast cancer
- Lung cancer
- Brain tumors
- Skin cancer
- Prostate cancer

Medical image enhancement increases diagnostic accuracy while reducing false negatives.

### 4.2 Medical Imaging

#### Applications include:

- MRI enhancement
- CT reconstruction
- PET image generation
- Noise removal
- Image super-resolution

### 4.3 Histopathology

Generative AI assists pathologists by:

- Segmenting tissues
- Detecting malignant cells



- Classifying tumors
- Generating synthetic pathology slides

#### **4.4 Precision Oncology**

##### **AI integrates:**

- Genomics
- Clinical records
- Radiology
- Laboratory reports

to recommend personalized treatment strategies.

#### **4.5 Drug Discovery**

##### **Generative AI accelerates:**

- Molecule generation
- Drug-target prediction
- Clinical trial optimization
- Biomarker discovery

#### **4.6 Clinical Documentation**

Large Language Models assist with:

- Discharge summaries
- Medical report writing
- Patient communication
- Clinical documentation automation

### **V. COMPARATIVE ANALYSIS OF GENERATIVE AI ALGORITHMS**

| <b>Algorithm</b> | <b>Main Strength</b>           | <b>Cancer Application</b>       | <b>Limitation</b>              |
|------------------|--------------------------------|---------------------------------|--------------------------------|
| GAN              | Realistic image generation     | MRI, CT, pathology              | Training instability           |
| VAE              | Stable latent learning         | Tumor modeling                  | Lower image quality            |
| Diffusion Model  | High-quality image synthesis   | Imaging reconstruction          | Slow inference                 |
| Transformer      | Sequence modeling              | Clinical reports, genomics      | Large computational resources  |
| LLM              | Natural language understanding | Decision support, documentation | Hallucinations, factual errors |

### **VI. BENEFITS**

- Early diagnosis
- Improved diagnostic accuracy
- Reduced clinical workload
- Personalized medicine
- Faster drug discovery
- Better patient engagement
- Automated documentation
- Enhanced medical education



## VII. CHALLENGES

Major challenges include:

- Limited annotated datasets
- Patient privacy concerns
- Algorithmic bias
- Lack of interpretability
- Hallucinated clinical outputs
- Regulatory compliance
- Ethical issues
- High computational cost

These limitations mean that current GenAI systems are best viewed as clinician-support tools rather than autonomous decision-makers.

## VIII. FUTURE RESEARCH DIRECTIONS

Future work should focus on:

- Explainable Generative AI
- Federated learning
- Privacy-preserving AI
- Multimodal foundation models
- Real-time clinical deployment
- Human-AI collaboration
- Regulatory frameworks
- Robust clinical validation through prospective studies

## IX. CONCLUSION

Generative Artificial Intelligence (GenAI) represents a significant advancement in the application of computational intelligence to cancer healthcare, with considerable potential to enhance cancer diagnosis, prognosis, treatment planning, drug discovery, medical imaging, and personalized patient care. The ability of generative models to learn complex patterns from heterogeneous clinical, imaging, pathological, and genomic datasets provides opportunities for developing more efficient and individualized approaches to cancer management. Nevertheless, the clinical adoption of GenAI remains constrained by challenges related to data quality, privacy and security, algorithmic bias, model interpretability, hallucinations, reproducibility, and the need for rigorous clinical validation. Consequently, future research should emphasize robust model evaluation, explainable and trustworthy AI, multimodal learning, privacy-preserving techniques, and appropriate ethical and regulatory frameworks. Overall, the responsible integration of GenAI with clinical expertise has the potential to strengthen precision oncology and contribute to improved diagnostic accuracy, therapeutic decision-making, and patient outcomes.

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