Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas

Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)

ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

CARCINOGENS AND CARCINOGENESIS: MOLECULAR MECHANISMS, RISK FACTORS, AND CONTEMPORARY THERAPEUTIC STRATEGIES FOR MALIGNANT NEOPLASMS

Umida Rakhmatulloevna Narzulaeva
PhD Department of Preclinical Sciences,
Asia International University

Erbol Imongalievich Islomov
Fourth-Year Medical Student, Faculty of General Medicine,
Asia International University

Abstract

Background:

Cancer remains one of the leading causes of morbidity and mortality worldwide. The development of malignant neoplasms results from complex interactions among environmental carcinogens, genetic susceptibility, epigenetic alterations, and dysregulated cellular signaling pathways.

Objective:

This review aims to summarize the major classes of carcinogenic agents, elucidate the molecular mechanisms underlying carcinogenesis, and discuss recent advances in the diagnosis and treatment of malignant neoplasms.

Methods:

A narrative review of contemporary literature published in high-impact international journals and reports issued by global health organizations was conducted. Particular attention was given to molecular mechanisms of carcinogenesis and emerging therapeutic strategies.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas

Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)

ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

Results:
Current evidence demonstrates that malignant transformation is a multistep process involving the accumulation of genetic and epigenetic alterations affecting oncogenes, tumor suppressor genes, DNA repair pathways, and immune surveillance mechanisms. Significant advances in molecular oncology have facilitated the development of targeted therapies, immune checkpoint inhibitors, CAR-T cell therapy, gene therapy, nanoparticle-based drug delivery systems, and minimally invasive ablative techniques, resulting in improved clinical outcomes.
Conclusion:
A comprehensive understanding of the molecular basis of carcinogenesis has fundamentally transformed cancer diagnosis and treatment. Precision medicine, molecular diagnostics, and personalized therapeutic strategies are expected to play an increasingly important role in improving survival and quality of life among patients with malignant neoplasms.

Keywords: Carcinogenesis; Carcinogens; Malignant Neoplasms; Oncogenes; Tumor Suppressor Genes; TP53; DNA Damage; Cell Immortalization; Angiogenesis; Immunotherapy; Targeted Therapy; CAR-T Cell Therapy; Gene Therapy; Nanomedicine.

Introduction

Malignant neoplasms constitute one of the most serious pathological conditions threatening global public health and are characterized by high rates of morbidity and mortality worldwide. Cancer remains the second leading cause of death after cardiovascular diseases. Although the incidence of cancer is generally higher in developed countries, well-established screening programs, comprehensive health insurance systems, and greater public awareness facilitate early diagnosis and substantially improve treatment outcomes.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

In contrast, developing countries continue to experience higher cancer-related mortality due to delayed medical consultation, limited diagnostic resources, and insufficient implementation of preventive healthcare measures. Consequently, many patients are diagnosed at advanced stages of disease, when therapeutic interventions are less effective.

In recent years, Uzbekistan has undertaken substantial reforms to improve its national oncology services. The expansion of population-based screening programs, particularly the widespread implementation of mammographic screening for the early detection of breast cancer, has significantly increased the proportion of cancers diagnosed at early stages. Early diagnosis substantially enhances treatment efficacy while improving both patient survival and quality of life.

Environmental factors play a pivotal role in the development of malignant neoplasms. Rapid industrialization, industrial waste emissions, and the contamination of air and water resources with hazardous chemicals have considerably increased human exposure to carcinogenic substances. Furthermore, chemical additives, synthetic food colorants, preservatives, and the excessive use of pesticides and mineral fertilizers in agriculture are recognized as additional environmental factors contributing to carcinogenesis.

Experimental studies have demonstrated that several food additives possess mutagenic and carcinogenic properties. Prolonged exposure to certain synthetic dyes and chemical stabilizers may induce genetic damage within the cellular genome, thereby increasing the risk of malignant transformation.

Among all environmental carcinogens, tobacco consumption remains one of the most significant preventable causes of cancer. Tobacco smoke contains numerous carcinogenic compounds, including polycyclic aromatic hydrocarbons, particularly benzo[a]pyrene, tobacco-specific nitrosamines, and various other toxic chemicals capable of inducing DNA mutations. These genetic alterations contribute to the development of malignancies of the lung, larynx, oral cavity,

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

pancreas, and several other organs. Passive smoking also represents a significant health hazard by increasing exposure to carcinogenic substances and elevating cancer risk.

A tumor is defined as a pathological process characterized by uncontrolled cellular proliferation resulting from alterations in the genetic program regulating normal cell growth and differentiation. Malignant tumors exhibit several distinctive biological characteristics, including morphological and functional atypia, uncontrolled proliferation, resistance to apoptosis, invasive growth, and metastatic potential.

In addition to these features, malignant cells undergo profound metabolic reprogramming. One of the best-characterized metabolic alterations is the **Warburg effect**, whereby tumor cells preferentially utilize aerobic glycolysis even under normoxic conditions. This metabolic adaptation supports rapid cellular proliferation by facilitating increased biosynthesis and energy production required for continuous tumor growth.

Molecular and Cellular Mechanisms of Carcinogenesis

Carcinogenesis is a multistep biological process through which normal cells are transformed into malignant cells as a consequence of accumulated genetic and epigenetic alterations. This complex process involves dysregulation of cellular proliferation, differentiation, apoptosis, DNA repair mechanisms, and immune surveillance.

According to the current understanding of molecular oncology, carcinogenesis proceeds through three major stages:

1. **Initiation (Cellular Transformation)**
2. **Promotion**
3. **Progression**

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

1. Initiation Stage

The initiation stage represents the earliest phase of carcinogenesis and is characterized by irreversible genetic alterations within the cellular genome. These alterations arise following exposure to physical, chemical, or biological carcinogens capable of damaging DNA.

Carcinogenic agents disrupt DNA integrity, leading to gene mutations that impair the normal regulation of cell growth and division. Among the most critical molecular events during this stage are the activation of proto-oncogenes and the inactivation of tumor suppressor genes, both of which play fundamental roles in malignant transformation.

Proto-oncogenes normally regulate physiological cell proliferation and differentiation. However, mutations, gene amplification, or chromosomal rearrangements may convert proto-oncogenes into oncogenes, resulting in constitutive activation of proliferative signaling pathways and uncontrolled cellular growth.

The *TP53* Gene and Its Role in Tumor Development

Among the tumor suppressor genes involved in carcinogenesis, the **TP53** gene occupies a central position and is widely recognized as the **"guardian of the genome."** The *TP53* gene encodes the p53 protein, a critical transcription factor responsible for maintaining genomic stability by coordinating cellular responses to DNA damage.

Under physiological conditions, p53 regulates several essential cellular processes, including:

- transient arrest of the cell cycle to permit DNA repair;
- activation of DNA repair pathways;
- induction of apoptosis in cells harboring irreparable genetic damage;
- initiation of cellular senescence;
- regulation of cellular metabolism and oxidative stress responses.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

When the *TP53* gene undergoes mutation, these protective mechanisms become impaired. Consequently, genetically damaged cells evade apoptosis, continue proliferating, and accumulate additional mutations that promote malignant transformation. Mutations of *TP53* are among the most common genetic abnormalities observed in human cancers and have been identified in malignancies of the lung, colorectum, stomach, breast, liver, pancreas, and numerous other organs.

The loss of p53 function also contributes to genomic instability, chromosomal abnormalities, and resistance to chemotherapy and radiotherapy, thereby facilitating tumor progression and unfavorable clinical outcomes.

2. Promotion Stage

The promotion stage is characterized by the selective expansion of initiated cells through sustained cellular proliferation, ultimately leading to the formation of a premalignant cellular clone. Unlike initiation, promotion generally does not involve irreversible genetic mutations but instead promotes the growth and survival of previously transformed cells.

Various endogenous and exogenous factors may act as tumor promoters, including:

- hormonal imbalances;
- chronic inflammatory conditions;
- prolonged exposure to chemical irritants;
- immunosuppression;
- oxidative stress;
- metabolic disorders.

Persistent inflammation represents one of the most important mechanisms driving tumor promotion. Chronic inflammatory responses generate excessive amounts of reactive oxygen species (ROS) and reactive nitrogen species (RNS), which induce oxidative DNA damage, lipid peroxidation, and protein modification.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

These alterations further increase genomic instability and facilitate malignant progression.

Additionally, inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and transforming growth factor-beta (TGF-β) activate signaling pathways that stimulate cell proliferation, inhibit apoptosis, and promote angiogenesis.

Importantly, the promotion stage may remain reversible if exposure to promoting factors is eliminated before additional genetic alterations accumulate.

3. Progression Stage

Tumor progression represents the final stage of carcinogenesis and is characterized by the acquisition of increasingly aggressive biological behavior. During this phase, tumor cells accumulate additional genetic, epigenetic, and chromosomal alterations that confer enhanced proliferative capacity, invasive potential, and metastatic competence.

Several hallmark characteristics emerge during tumor progression, including:

- rapid and uncontrolled cellular proliferation;
- invasive growth into adjacent tissues;
- dissemination through blood and lymphatic vessels;
- immune evasion;
- induction of angiogenesis;
- development of therapeutic resistance.

One of the defining events of tumor progression is **angiogenesis**, the formation of new blood vessels from pre-existing vasculature. As tumors enlarge, diffusion alone becomes insufficient to supply oxygen and nutrients. Consequently, malignant cells secrete pro-angiogenic factors, most notably vascular endothelial growth factor (VEGF), which stimulates neovascularization and supports continued tumor growth.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

Tumor progression is also accompanied by epithelial-mesenchymal transition (EMT), a biological process that enables epithelial cancer cells to acquire mesenchymal characteristics, thereby enhancing migratory capacity, invasiveness, and metastatic potential.

Modern molecular studies indicate that malignant transformation results not from a single mutation but from the sequential accumulation of numerous genetic and epigenetic alterations affecting multiple signaling pathways that regulate cell survival, proliferation, differentiation, and apoptosis.

The Role of Hereditary and Environmental Factors in Carcinogenesis

Although most cancers arise sporadically, hereditary genetic alterations significantly increase susceptibility to specific malignancies. Individuals carrying inherited pathogenic variants possess an elevated lifetime risk of developing cancer due to defects in genes responsible for maintaining genomic integrity.

Inherited mutations affecting DNA repair pathways are particularly important because impaired DNA repair accelerates the accumulation of mutations throughout the genome. Well-established hereditary cancer syndromes include mutations involving the **BRCA1**, **BRCA2**, **TP53**, **APC**, and DNA mismatch repair genes associated with Lynch syndrome.

The principal factors contributing to carcinogenesis include:

Chemical Carcinogens

Chemical carcinogens comprise one of the largest groups of environmental carcinogenic agents and include:

- benzene;
- nitrosamines;
- polycyclic aromatic hydrocarbons;
- aromatic amines;
- aflatoxins;

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

- asbestos;
- heavy metals such as arsenic, cadmium, chromium, and nickel.

Many of these compounds require metabolic activation by cytochrome P450 enzymes before exerting their carcinogenic effects through the formation of DNA adducts.

Physical Carcinogens

Physical carcinogens primarily include:

- ionizing radiation;
- ultraviolet (UV) radiation;
- chronic exposure to radioactive materials.

Ionizing radiation induces DNA double-strand breaks, chromosomal translocations, and genomic instability, whereas ultraviolet radiation predominantly produces pyrimidine dimers that contribute to skin carcinogenesis.

Biological Carcinogens

Numerous infectious agents have been implicated in human carcinogenesis.
The most significant oncogenic viruses include:

- Human papillomavirus (HPV);
- Hepatitis B virus (HBV);
- Hepatitis C virus (HCV);
- Epstein–Barr virus (EBV);
- Human T-cell leukemia virus type 1 (HTLV-1);
- Kaposi sarcoma-associated herpesvirus (KSHV).

Persistent infection with these viruses may interfere with normal cell cycle regulation, inhibit apoptosis, promote chronic inflammation, and facilitate malignant transformation.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

Environmental Factors

Environmental pollution substantially contributes to global cancer incidence. Air contamination by industrial emissions, particulate matter, diesel exhaust, and toxic chemicals increases the risk of respiratory malignancies. Likewise, contamination of drinking water and agricultural soil with industrial waste, pesticides, and heavy metals has been associated with elevated risks of gastrointestinal and other cancers.

Lifestyle Factors

Lifestyle-related risk factors remain among the most preventable causes of cancer and include:

- tobacco smoking;
- excessive alcohol consumption;
- unhealthy dietary habits;
- physical inactivity;
- obesity;
- chronic sleep deprivation;
- prolonged exposure to ultraviolet radiation.

Smoking alone is responsible for approximately one-third of cancer-related deaths worldwide and remains the leading preventable cause of malignancy.

Psychosocial Factors

Although psychosocial stress is not considered a direct carcinogenic factor, prolonged psychological stress may indirectly influence cancer development through neuroendocrine and immunological mechanisms.

Chronic stress activates the hypothalamic–pituitary–adrenal (HPA) axis, resulting in sustained secretion of glucocorticoids, particularly cortisol. Elevated cortisol concentrations suppress various components of the immune system, including

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

natural killer (NK) cell activity and T-cell-mediated immune responses, thereby weakening immune surveillance against emerging malignant cells.

Furthermore, chronic stress has been associated with persistent low-grade inflammation, oxidative stress, and metabolic dysregulation, all of which may contribute to tumor progression.

Synchronous and Metachronous Malignant Neoplasms

The occurrence of multiple primary malignancies represents an increasingly recognized challenge in contemporary oncology. Advances in diagnostic imaging, molecular diagnostics, and improvements in cancer survival have contributed to the growing identification of patients presenting with more than one primary malignant tumor.

Multiple primary malignancies are generally classified into two categories:

- **Synchronous tumors**, diagnosed simultaneously or within a relatively short period (typically within six months) of one another.
- **Metachronous tumors**, diagnosed at different time points, usually more than six months apart.

The development of synchronous malignancies may reflect prolonged exposure to common carcinogenic factors, inherited genetic susceptibility, chronic inflammatory conditions, or defects in DNA repair mechanisms. In some patients, germline mutations affecting tumor suppressor genes substantially increase the lifetime risk of developing multiple independent primary cancers.

For example, a patient undergoing evaluation for gastric carcinoma may simultaneously be diagnosed with primary lung or colorectal cancer during comprehensive staging investigations. Importantly, these lesions should be distinguished from metastatic disease because their biological behavior, therapeutic management, and prognosis differ considerably.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

The management of synchronous malignancies requires a highly individualized multidisciplinary approach involving surgical oncologists, medical oncologists, radiation oncologists, pathologists, radiologists, and molecular geneticists.
Treatment planning should consider several important factors, including:

- anatomical location of each tumor;
- pathological stage and histological subtype;
- molecular and genomic characteristics;
- patient's age;
- performance status;
- immune competence;
- expected treatment-related toxicity;
- overall prognosis.

Personalized treatment strategies have significantly improved outcomes in patients diagnosed with multiple primary malignancies.

Modern Approaches to the Treatment of Malignant Neoplasms

Over the past several decades, cancer therapy has undergone remarkable transformation. Conventional treatment modalities—including surgery, radiotherapy, and chemotherapy—have increasingly been complemented by innovative therapeutic strategies derived from advances in molecular biology, immunology, genomics, and biotechnology.
The primary objectives of modern oncology extend beyond tumor eradication and include prolongation of survival, preservation of organ function, reduction of treatment-related toxicity, improvement of quality of life, and achievement of durable remission.
Contemporary cancer management is fundamentally multidisciplinary and individualized. Selection of the optimal therapeutic strategy depends upon numerous factors, including:

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

- tumor type and anatomical location;
- clinical stage;
- histopathological characteristics;
- molecular and genetic profile;
- biomarker status;
- patient's age;
- comorbid conditions;
- functional performance;
- patient preferences.

1. Surgical Treatment

Surgical resection remains the cornerstone of treatment for many localized solid malignancies. Complete excision of the tumor with histologically negative surgical margins offers the greatest probability of long-term disease control and potential cure.

Modern oncologic surgery has evolved considerably and now emphasizes precision, preservation of normal tissues, and minimally invasive techniques.

Major advances include:

- minimally invasive surgery;
- laparoscopic procedures;
- robot-assisted surgery;
- organ-preserving operations;
- reconstructive and oncoplastic surgery;
- image-guided surgical techniques.

These approaches minimize postoperative morbidity, reduce hospitalization, accelerate recovery, and improve postoperative quality of life while maintaining oncological safety.

Increasingly, surgeons also employ sentinel lymph node biopsy and fluorescence-guided imaging to improve staging accuracy and optimize surgical outcomes.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

2. Radiotherapy and Chemotherapy

Radiotherapy

Radiotherapy utilizes ionizing radiation to induce irreparable DNA damage in malignant cells, ultimately resulting in mitotic catastrophe, apoptosis, or senescence.

Recent technological developments have dramatically enhanced the precision of radiation delivery while minimizing exposure of surrounding healthy tissues.

Current radiotherapy techniques include:

- Three-dimensional conformal radiotherapy (3D-CRT);
- Intensity-modulated radiotherapy (IMRT);
- Image-guided radiotherapy (IGRT);
- Stereotactic body radiotherapy (SBRT);
- Proton beam therapy.

These technologies enable delivery of higher radiation doses directly to tumor tissues while significantly reducing treatment-related complications.

Radiotherapy may be administered with curative, neoadjuvant, adjuvant, or palliative intent depending on disease stage and clinical objectives.

Chemotherapy

Chemotherapy involves the systemic administration of cytotoxic agents that inhibit cellular proliferation by interfering with DNA synthesis, mitosis, or other essential cellular processes.

It remains an essential therapeutic modality for numerous hematologic malignancies and advanced solid tumors.

Chemotherapy is commonly administered in several clinical settings:

- **Neoadjuvant chemotherapy**, to reduce tumor size before surgery;
- **Adjuvant chemotherapy**, to eradicate residual microscopic disease after surgery;
- **Definitive chemotherapy**, combined with radiotherapy for selected cancers;

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

- **Palliative chemotherapy**, to prolong survival and alleviate symptoms in advanced disease.

Despite its clinical effectiveness, conventional chemotherapy lacks complete specificity for malignant cells. Consequently, rapidly proliferating normal tissues—including bone marrow, gastrointestinal epithelium, and hair follicles—are frequently affected, resulting in adverse effects such as:

- myelosuppression;
- anemia;
- neutropenia;
- thrombocytopenia;
- nausea and vomiting;
- mucositis;
- alopecia;
- fatigue;
- increased susceptibility to infection.

Contemporary supportive care strategies have substantially reduced chemotherapy-associated toxicity and improved treatment tolerability.

3. Targeted Therapy

One of the most significant achievements of molecular oncology has been the development of targeted therapies directed against specific molecular abnormalities responsible for tumor initiation and progression.

Unlike conventional chemotherapy, targeted agents selectively interfere with dysregulated signaling pathways that drive malignant growth.

Targeted therapies may function by:

- inhibiting growth factor receptors;
- blocking intracellular signaling cascades;
- suppressing oncogenic kinases;
- inhibiting tumor angiogenesis;

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

- inducing apoptosis;
- preventing uncontrolled cellular proliferation.

Examples of clinically important molecular targets include:

- EGFR;
- HER2;
- BRAF;
- ALK;
- ROS1;
- VEGF;
- PDGFR;
- BCR-ABL.

Because these agents selectively target tumor-specific molecular alterations, they generally exhibit greater efficacy and lower systemic toxicity than conventional cytotoxic chemotherapy.

Nevertheless, acquired resistance remains a major therapeutic challenge and frequently necessitates combination treatment strategies or sequential targeted therapies.

4. Immunotherapy

Immunotherapy has emerged as one of the most revolutionary advances in modern oncology by harnessing the patient's own immune system to recognize and eliminate malignant cells.

Under physiological conditions, immune surveillance continuously identifies and destroys transformed cells before clinically detectable tumors develop. However, cancer cells evolve numerous mechanisms that enable immune evasion, allowing progressive tumor growth.

Modern immunotherapy aims to restore or enhance antitumor immunity by overcoming these immune escape mechanisms.

The principal immunotherapeutic approaches include:

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

- immune checkpoint inhibitors;
- monoclonal antibodies;
- cancer vaccines;
- adoptive cellular immunotherapy;
- cytokine-based therapies.

Among these, immune checkpoint blockade has fundamentally transformed the treatment of several advanced malignancies.

Checkpoint inhibitors targeting the PD-1/PD-L1 and CTLA-4 signaling pathways reactivate exhausted T lymphocytes, restoring effective antitumor immune responses.

These therapies have demonstrated durable clinical benefit in melanoma, non-small cell lung cancer, renal cell carcinoma, urothelial carcinoma, Hodgkin lymphoma, and numerous other malignancies.

CAR-T Cell Therapy

Chimeric antigen receptor T-cell (CAR-T) therapy represents one of the most advanced forms of personalized cellular immunotherapy.

The procedure involves several sequential steps:

1. Collection of the patient's T lymphocytes through leukapheresis.
2. Genetic modification of these lymphocytes to express chimeric antigen receptors recognizing specific tumor-associated antigens.
3. Ex vivo expansion of the engineered cells.
4. Reinfusion of CAR-T cells into the patient.

Following reinfusion, genetically engineered T cells selectively recognize and destroy malignant cells expressing the target antigen.

CAR-T therapy has produced remarkable clinical outcomes in several refractory hematologic malignancies, including:

- acute lymphoblastic leukemia (ALL);
- diffuse large B-cell lymphoma (DLBCL);

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

- mantle cell lymphoma;
- multiple myeloma.

Current research is focused on extending CAR-T technology to the treatment of solid tumors, overcoming limitations such as antigen heterogeneity, the immunosuppressive tumor microenvironment, and inadequate T-cell infiltration.

5. Gene Therapy and Stem Cell-Based Approaches

Gene therapy has emerged as one of the most promising strategies in precision oncology. Unlike conventional treatment modalities, which primarily target tumor cells indirectly, gene therapy seeks to correct or modify the molecular abnormalities responsible for malignant transformation. Advances in molecular genetics and genome engineering have significantly expanded the potential applications of gene-based therapeutic interventions.

Current gene therapy strategies include:

- restoration of the function of mutated tumor suppressor genes;
- selective inhibition or silencing of oncogenes;
- introduction of suicide genes capable of inducing tumor cell death;
- enhancement of antitumor immune responses through genetic modification of immune cells;
- correction of inherited genetic defects associated with cancer susceptibility.

Recent developments in genome-editing technologies, particularly **CRISPR–Cas9**, have provided unprecedented opportunities for targeted modification of cancer-associated genes. Although these technologies remain largely investigational in oncology, they hold considerable promise for the development of highly individualized therapeutic approaches.

Despite encouraging progress, several challenges continue to limit the widespread clinical implementation of gene therapy. These include efficient and safe delivery systems, off-target genetic effects, immunogenicity of viral vectors, and long-term safety considerations.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

Stem Cell Technologies

Stem cell–based therapies have become increasingly important in both regenerative medicine and clinical oncology. Hematopoietic stem cell transplantation (HSCT) remains an established treatment for numerous hematological malignancies, including leukemia, lymphoma, multiple myeloma, and certain inherited bone marrow disorders.

Stem cell transplantation contributes to cancer treatment by:

- restoring bone marrow function following high-dose chemotherapy or radiotherapy;
- reconstituting the patient's immune system;
- replacing malignant hematopoietic cells with healthy donor-derived cells;
- providing graft-versus-tumor effects in allogeneic transplantation.

Autologous stem cell transplantation involves the reinfusion of the patient's own previously collected stem cells, whereas allogeneic transplantation utilizes stem cells obtained from a compatible donor.

Ongoing research is also exploring the application of mesenchymal stem cells as targeted delivery vehicles for anticancer agents and immunomodulatory molecules. Although promising, these approaches require further investigation before routine clinical implementation.

6. Nanoparticle-Based Therapy

Nanotechnology has introduced innovative opportunities for improving the diagnosis and treatment of malignant diseases. Nanoparticles can be engineered to transport therapeutic agents directly to tumor tissues, thereby increasing drug concentration at the target site while minimizing systemic toxicity.

Compared with conventional drug delivery systems, nanoparticle-based platforms offer several important advantages:

- enhanced therapeutic efficacy;

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

- selective accumulation within tumor tissues through the enhanced permeability and retention (EPR) effect;
- reduced exposure of healthy tissues to cytotoxic agents;
- controlled and sustained drug release;
- improved pharmacokinetic and pharmacodynamic properties;
- simultaneous diagnostic and therapeutic ("theranostic") capabilities.

Several categories of nanoparticles have been investigated for oncological applications, including:

- liposomes;
- polymeric nanoparticles;
- dendrimers;
- gold nanoparticles;
- silica nanoparticles;
- magnetic nanoparticles;
- carbon-based nanomaterials.

Nanotechnology is currently being applied in targeted drug delivery, molecular imaging, photodynamic therapy, photothermal therapy, and image-guided cancer treatment.

Although numerous nanoparticle formulations have demonstrated promising clinical outcomes, continued research is necessary to optimize their long-term safety, biodistribution, biodegradability, and cost-effectiveness.

7. Ablative Therapies

Ablative techniques have become valuable therapeutic options for patients who are unsuitable candidates for surgical resection or who present with small localized tumors. These minimally invasive procedures destroy tumor tissue using various forms of physical energy while preserving surrounding healthy structures.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

Radiofrequency Ablation (RFA)

Radiofrequency ablation utilizes high-frequency alternating electrical current to generate localized thermal energy. Heat-induced coagulative necrosis results in irreversible destruction of malignant tissue.

RFA is widely used for the treatment of:

- hepatocellular carcinoma;
- liver metastases;
- renal cell carcinoma;
- lung tumors;
- bone metastases.

The procedure is associated with minimal invasiveness, short hospital stays, rapid postoperative recovery, and relatively low complication rates.

Microwave Ablation (MWA)

Microwave ablation employs electromagnetic waves to produce rapid heating of tumor tissue, leading to coagulative necrosis.

Compared with radiofrequency ablation, microwave ablation offers several advantages, including:

- higher intratumoral temperatures;
- larger ablation volumes;
- shorter treatment duration;
- reduced susceptibility to the heat-sink effect caused by adjacent blood vessels.

These characteristics make microwave ablation particularly suitable for larger hepatic and pulmonary tumors.

Cryoablation

Cryoablation destroys malignant tissue through repeated cycles of rapid freezing and thawing.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

Extremely low temperatures induce:

- intracellular ice crystal formation;
- disruption of cellular membranes;
- vascular thrombosis;
- ischemic necrosis.

An additional potential advantage of cryoablation is the release of tumor antigens following cellular destruction, which may stimulate systemic antitumor immune responses—a phenomenon sometimes referred to as the **cryoimmunologic effect**.

Cryoablation has demonstrated favorable outcomes in selected patients with prostate, kidney, liver, breast, and lung tumors.

Rehabilitation of Patients with Cancer

Cancer rehabilitation constitutes an essential component of comprehensive oncological care. Advances in diagnosis and treatment have significantly increased cancer survival, resulting in a growing population of cancer survivors who require multidisciplinary rehabilitation to optimize long-term physical, psychological, and social well-being.

The period following cancer treatment is frequently associated with substantial physical impairment, emotional distress, anxiety, depression, fatigue, and reduced quality of life.

Effective rehabilitation programs should therefore adopt an individualized, multidisciplinary approach incorporating:

- personalized nutritional counseling;
- structured physical rehabilitation and exercise programs;
- physiotherapy;
- psychological counseling and psychosocial support;
- management of treatment-related complications;
- immune health optimization;

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

- regular medical surveillance and follow-up.

Lifestyle modification also plays a crucial role in reducing the risk of recurrence and improving overall survival. Patients are encouraged to:

- maintain a healthy body weight;
- engage in regular physical activity;
- consume a balanced diet rich in fruits, vegetables, and whole grains;
- avoid tobacco use and excessive alcohol consumption;
- participate in recommended cancer screening and follow-up programs.

Increasing evidence indicates that structured survivorship care programs substantially improve long-term functional outcomes and overall quality of life among cancer survivors.

Conclusion

Carcinogenesis is a complex, multistep biological process driven by the cumulative effects of genetic mutations, epigenetic alterations, environmental carcinogens, immune dysregulation, and lifestyle-related risk factors. Malignant transformation results from progressive disruption of the molecular mechanisms responsible for maintaining normal cellular homeostasis, ultimately leading to uncontrolled proliferation, invasion, and metastasis.

Reducing exposure to carcinogenic agents, promoting healthy lifestyle behaviors, expanding population-based screening programs, and improving early diagnosis remain fundamental strategies for cancer prevention and control. Early detection substantially increases treatment success and contributes to improved survival outcomes.

Remarkable advances in molecular biology, genomics, immunology, and biotechnology have revolutionized modern oncology. Innovative therapeutic approaches—including targeted therapy, immunotherapy, gene therapy, nanoparticle-based drug delivery systems, stem cell technologies, and minimally

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas
Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)
ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

invasive ablative techniques—have significantly broadened treatment options and improved clinical outcomes for many patients with cancer.

The future of oncology is expected to be increasingly shaped by precision medicine, molecular diagnostics, artificial intelligence–assisted clinical decision-making, and personalized therapeutic strategies based on the molecular profile of individual tumors. These developments are anticipated to further enhance treatment efficacy, minimize toxicity, extend patient survival, and improve the quality of life of individuals affected by malignant neoplasms.

Future Perspectives

Rapid advances in molecular biology, artificial intelligence, multi-omics technologies, and precision oncology are expected to reshape future cancer diagnosis and treatment. Integration of genomic profiling, liquid biopsy, machine learning algorithms, and personalized immunotherapeutic strategies will enable earlier diagnosis, more accurate prognostic assessment, and individualized therapeutic decision-making. Furthermore, the development of next-generation CAR-T cells, CRISPR-based gene editing, nanomedicine, and cancer vaccines is anticipated to substantially improve long-term clinical outcomes while minimizing treatment-related toxicity.

References

1. Bray, F., Laversanne, M., Sung, H., Ferlay, J., Siegel, R. L., Soerjomataram, I., & Jemal, A. (2024). Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: A Cancer Journal for Clinicians, 74(3), 229–263.
2. Hanahan, D. (2022). Hallmarks of cancer: New dimensions. Cancer Discovery, 12(1), 31–46.
3. Hanahan, D., & Weinberg, R. A. (2011). Hallmarks of cancer: The next generation. Cell, 144(5), 646–674.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas

Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)

ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

4. Sung, H., Ferlay, J., Siegel, R. L., Laversanne, M., Soerjomataram, I., Jemal, A., & Bray, F. (2021). Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. CA: A Cancer Journal for Clinicians, 71(3), 209–249.
5. World Health Organization. (2024). Cancer. Geneva: World Health Organization.
6. National Cancer Institute. (2024). What is Cancer? Bethesda, MD: National Cancer Institute.
7. Vogelstein, B., Papadopoulos, N., Velculescu, V. E., Zhou, S., Diaz, L. A., & Kinzler, K. W. (2013). Cancer genome landscapes. Science, 339(6127), 1546–1558.
8. Vogelstein, B., Lane, D., & Levine, A. J. (2000). Surfing the p53 network. Nature, 408, 307–310.
9. Levine, A. J. (2020). p53: 800 million years of evolution and 40 years of discovery. Nature Reviews Cancer, 20, 471–480.
10. Vousden, K. H., & Prives, C. (2009). Blinded by the light: The growing complexity of p53. Cell, 137(3), 413–431.
11. Weinberg, R. A. (2024). The Biology of Cancer (3rd ed.). New York, NY: W. W. Norton & Company.
12. Kumar, V., Abbas, A. K., & Aster, J. C. (2024). Robbins & Cotran Pathologic Basis of Disease (11th ed.). Elsevier.
13. DeVita, V. T., Lawrence, T. S., & Rosenberg, S. A. (2023). DeVita, Hellman, and Rosenberg's Cancer: Principles & Practice of Oncology (12th ed.). Wolters Kluwer.
14. June, C. H., O'Connor, R. S., Kawalekar, O. U., Ghassemi, S., & Milone, M. C. (2018). CAR T cell immunotherapy for human cancer. Science, 359(6382), 1361–1365.
15. Rosenberg, S. A., & Restifo, N. P. (2015). Adoptive cell transfer as personalized immunotherapy for human cancer. Science, 348(6230), 62–68.

Eureka Open Access Journals
Open Access | Peer Reviewed | International Journals | Multidisciplinary Areas

Eureka Journal of Health Sciences & Medical Innovation (EJHSMI)

ISSN 2760-4942 (Online) Volume 2, Issue 6, June 2026

https://eurekaoa.com/index.php/5

16. Ribas, A., & Wolchok, J. D. (2018). Cancer immunotherapy using checkpoint blockade. Science, 359(6382), 1350–1355.
17. Schreiber, R. D., Old, L. J., & Smyth, M. J. (2011). Cancer immunoediting: Integrating immunity's roles in cancer suppression and promotion. Science, 331(6024), 1565–1570.
18. Topalian, S. L., Drake, C. G., & Pardoll, D. M. (2015). Immune checkpoint blockade: A common denominator approach to cancer therapy. Cancer Cell, 27(4), 450–461.
19. Ho, D., Wang, P., & Kee, T. (2023). Nanomedicine in cancer therapy: Progress, challenges, and future directions. Nature Reviews Bioengineering, 1, 94–112.
20. Shi, J., Kantoff, P. W., Wooster, R., & Farokhzad, O. C. (2017). Cancer nanomedicine: Progress, challenges and opportunities. Nature Reviews Cancer, 17(1), 20–37.
21. Doudna, J. A., & Charpentier, E. (2014). The new frontier of genome engineering with CRISPR–Cas9. Science, 346(6213), 1258096.
22. Yeo, S. K., & Guan, J. L. (2017). Breast cancer: Multiple subtypes within a tumor? Trends in Cancer, 3(11), 753–760.
23. Siegel, R. L., Miller, K. D., Wagle, N. S., & Jemal, A. (2025). Cancer statistics, 2025. CA: A Cancer Journal for Clinicians.
24. National Comprehensive Cancer Network. (2025). NCCN Clinical Practice Guidelines in Oncology. Plymouth Meeting, PA: NCCN.
25. European Society for Medical Oncology. (2025). ESMO Clinical Practice Guidelines. Lugano, Switzerland: ESMO.