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Cancer and its Treatment: An Overview

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Abstract: *Cancer is a complex group of diseases characterized by uncontrolled cell growth and the ability to invade or metastasize to distant organs. It arises from genetic mutations influenced by lifestyle factors, environmental exposures, and inherited predispositions. Globally, cancer remains a major health burden, with increasing incidence and mortality, particularly in developing countries like India. Cancer types vary widely by cell origin and organ involvement, encompassing carcinomas, sarcomas, leukemias, lymphomas, melanomas, and myelomas. Traditional treatments such as surgery, chemotherapy, and radiotherapy continue to play essential roles; however, limitations like toxicity and resistance have accelerated the development of advanced modalities. Innovations including immunotherapy, targeted therapy, gene therapy, personalized medicine, and nanotechnology have significantly improved therapeutic precision and outcomes. Despite these advancements, challenges such as tumor heterogeneity, late diagnosis, metastasis, and limited access to modern therapies persist. Pharmacists and pharmacy students contribute substantially to cancer care through medication management, counseling, and support in precision medicine and clinical research. This review highlights the biology, epidemiology, treatments, challenges, and evolving roles in cancer management.*

Keywords: Cancer, Immunotherapy, Targeted Therapy, Drug Resistance, Precision Medicine

I. INTRODUCTION

Cancer refers to a group of diseases characterized by uncontrolled cell growth and the potential to invade or spread (metastasize) to other parts of the body. Normally, cell division and death are tightly regulated. In cancer, genetic mutations (in oncogenes, tumor suppressor genes, DNA repair genes, etc.) disrupt this regulation, leading to abnormal proliferation. These mutations may be inherited (germline) or acquired (somatic) and can be driven by multiple risk factors such as tobacco use, diet, infections, radiation, and environmental exposures.[1,2] Cancer progression typically involves multiple steps:

- **Initiation**: Mutations occur in normal cells.
- **Promotion**: Mutant cells proliferate**.**
- **Progression**: Cells acquire further changes, leading to invasive and metastatic disease.

Cancer is a complex group of diseases characterized by uncontrolled and abnormal cell growth with the ability to invade surrounding tissues and metastasize to distant organs. Under normal conditions, cell division and death are tightly regulated; however, mutations in oncogenes, tumor-suppressor genes, and DNA-repair genes disrupt this balance, leading to continuous proliferation. These mutations may be inherited or acquired due to environmental and lifestyle factors such as tobacco use, diet, infections, chemical exposure, and radiation. Cancer develops in multiple stages—**initiation,** where initial mutations occur**; promotion,** where mutated cells begin to proliferate; and **progression,** where they become invasive and metastatic.

Globally, cancer remains a major public health burden. According to recent reports, around **20 million new cancer cases**and**over 10 million deaths** occur annually. India also faces a rising cancer incidence, with approximately **100 cases per 100,000 population**, reflecting increasing risk factors and improved detection. Despite the rising burden, advancements in science and technology have contributed to declining mortality rates through improved prevention, early diagnosis, and modern therapies.Cancer can arise in almost any tissue, but all share the hallmark of uncontrolled

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cell division. Types of cancer vary widely—from carcinomas and sarcomas to leukemias, lymphomas, melanomas, and myelomas—and may also be categorized based on the organ involved, such as breast, lung, colorectal, prostate, or liver cancer. Numerous lifestyle, genetic, and environmental factors contribute to cancer development, including poor diet, tobacco exposure, radiation, pathogens like HPV and H. pylori, and inherited mutations. Common warning signs include unexplained weight loss, persistent fatigue, abnormal bleeding, non-healing sores, and changes in bowel habits or skin appearance. Understanding the causes, types, burden, and symptoms of cancer is essential for improving prevention, early detection, and therapeutic outcomes.

Major Types of Cancer

Classification	Type	Origin	Examples
By Cell Origin	Carcinoma	Epithelial cells	Lung, breast, colorectal cancer
	Sarcoma	Connective tissue	Osteosarcoma, liposarcoma
	Leukemia	Bone marrow / blood-forming tissue	Acute/chronic leukemias
	Lymphoma	Lymphatic system	Hodgkin & Non-Hodgkin lymphoma
	Melanoma	Melanocytes	Skin melanoma
	Myeloma	Plasma cells	Multiple myeloma
By Organ/System	–	Specific organs	Breast, lung, prostate, liver, stomach, colorectal, kidney, brain cancers

Global and Indian Burden

Cancer remains a major public health challenge worldwide. According to the *AACR Cancer Progress Report 2025*, there are an estimated ~20 million new cancer cases and over 10.3 million cancer-related deaths globally in 2025. In India, the burden is also rising sharply. A recent government report noted that there are around 100 cancer cases per 100,000 population, and the number of new diagnoses continues to increase.[3,4]These statistics highlight the urgency for not just treating cancer but also improving prevention, early detection, and access to advanced therapy in both developed and low/middle-income countries.

Table: 01 Cancer Types – Causes – Symptoms

Cancer Type	Main Causes	Common Symptoms
Lung Cancer	Smoking, pollution, asbestos, radon gas	Chronic cough, chest pain, breathlessness, coughing blood
Breast Cancer	Genetics (BRCA), obesity, alcohol, estrogen exposure	Breast lump, nipple discharge, breast pain, skin changes
Colorectal Cancer	Low fiber diet, red meat, obesity, alcohol, family history	Blood in stool, abdominal pain, constipation/diarrhea, weight loss
Prostate Cancer	Age >50, obesity, genetics	Frequent urination, weak urine flow, pelvic pain
Cervical Cancer	HPV infection, smoking, early sexual activity	Abnormal vaginal bleeding, pelvic pain, discharge
Liver Cancer	Hepatitis B/C, alcohol, fatty liver disease	Abdominal swelling, jaundice, weight loss
Stomach Cancer	H. pylori infection, smoking, salty foods	Stomach pain, nausea, indigestion, vomiting
Skin Cancer (Melanoma)	UV radiation (sun), tanning beds	Mole changes, skin lesions, bleeding spots
Leukemia	Radiation, benzene exposure, genetic mutations	Fatigue, infections, bleeding, bone pain
Lymphoma	Immune weakness, viral infections	Swollen lymph nodes, fever, night sweats
Pancreatic Cancer	Smoking, diabetes, chronic pancreatitis	Abdominal pain, jaundice, weight loss
Kidney Cancer	Smoking, obesity, high blood pressure	Blood in urine, side pain, lump near kidney

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Ovarian Cancer	Genetics (BRCA), age, infertility	Bloating, pelvic pain, appetite loss
Brain Tumors	Radiation, genetic disorders	Headache, vision problems, seizures
Oral Cancer	Tobacco, alcohol, HPV	Mouth sores, difficulty chewing, lumps

Cancer treatment today spans both traditional and advanced modalities, beginning with surgery, radiation therapy, and chemotherapy—core approaches that physically remove tumors, destroy cancer cells with targeted radiation, or use systemic cytotoxic drugs despite their side effects. Modern innovations have transformed the field, especially immunotherapies such as checkpoint inhibitors, CAR-T cells, CAR-NK cells, and the recently approved TCR T-cell therapy afamitresgene autoleucel, which empower the immune system to recognize and attack cancer. Targeted therapies like inavolisib inhibit specific molecular drivers of tumor growth, while personalized mRNA cancer vaccines train the immune system using tumor-specific antigens. Additional advances include targeted radionuclide (alpha-particle) therapies and precision medicine approaches that use genomic profiling and AI to guide individualized treatment, predict tumor evolution, and enhance diagnostics. Despite this progress, significant challenges persist, including high costs and limited access—particularly in lower- and middle-income countries such as India—along with issues of treatment resistance, toxicity, metastasis, and complex regulatory and manufacturing demands for cell-based therapies.

Sr. No.	Cancer type	Treatment / Modality	Author(s)	Paper title	Journal (Year)	Conclusion / Key finding
1	Multiple cancers (hematologic: MM, leukemia, lymphoma)	CAR-T (immunotherapy)	— (meta-analysis)	*Heterogeneity and efficacy of immunotherapy in multiple cancer: insights from a meta-analysis*	*Biological Procedures Online* (2025)	The meta-analysis found varied objective response rates (ORR): ~86.8% in multiple myeloma, ~84.9% in leukemia, ~67.9% in lymphoma — supporting strong efficacy of immunotherapy (especially CAR-T) in blood cancers; also notes variation by population (e.g. higher response rates in Chinese vs American cases).
2	Pan-cancer (various solid tumors) undergoing immunotherapy	Immunotherapy + AI-based diagnostics for prognostics	MeldaYeghaian, ZuhirBodalal, Daan van den Broek, John B.A.G. Haanen, Regina G.H. Beets-Tan, Stefano Trebeschi, Marcel A.J. van Gerven	*Multimodal Integration of Longitudinal Noninvasive Diagnostics for Survival Prediction in Immunotherapy Using Deep Learning*	(preprint 2024)	The study showed that combining noninvasive longitudinal data (blood measurements, medications, CT imaging) via a transformer-based deep learning model predicted 3-, 6-, 9-, 12-month survival with good accuracy (AUC ~ 0.81–0.84), highlighting the potential of AI to guide immunotherapy prognostication.
3	Blood cancers	CAR-T and cancer	Hushmandi K., Imani Fooladi	*Next-generation immunotherapeutic*	*Experimental*	The review outlines that next-gen immunotherapies (CAR-

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	(general)	vaccines (next-gen immunotherapy)	A.A., Reiter R.J., et al.	*approaches for blood cancers: Exploring the efficacy of CAR-T and cancer vaccines*	*Hematology & Oncology* (2025)	T, vaccines) are showing promise for blood cancers, offering potential improved efficacy and durability over traditional therapies.
4	Breast cancer (both early and metastatic)	CAR-T cell therapy (immunotherapy)	Marei H.E., Bedair K., Hasan A., et al.	*Current status and innovative developments of CAR-T-cell therapy for the treatment of breast cancer*	*Cancer Cell International* (2025)	The review highlights ongoing developments for CAR-T therapy in breast cancer, discusses in-vivo challenges (tumor microenvironment, antigen heterogeneity), but suggests potential future applicability.
5	Solid tumors (various)	CAR-T cell therapy (immunotherapy)	Chen T., Wang M., Chen Y., et al.	*Current challenges and therapeutic advances of CAR-T cell therapy for solid tumors*	*Cancer Cell International* (2024)	The paper outlines key challenges (antigen heterogeneity, T-cell exhaustion, toxicity) but also therapeutic advances, underlining that CAR-T for solid tumors remains promising with further optimization.
6	General / multiple cancer types	$CD8^+$ T-cell–based immunotherapy / cellular immunotherapy	Chen Y., Yu D., Qian H., et al.	*CD8+ T cell-based cancer immunotherapy*	*Journal of Translational Medicine* (2024)	This review synthesizes evidence that $CD8^+$ T-cell–based therapies (including CAR-T and checkpoint inhibitors) are promising, especially when combined with strategies to overcome immunosuppressive tumor microenvironments.
7	Metastatic colorectal cancer (mCRC)	Targeted therapy & immunotherapy (systemic treatment)	P.W. Underwood, S.M. Ruff, T.M. Pawlik	*Update on Targeted Therapy and Immunotherapy for Metastatic Colorectal Cancer*	*Cells* (2024)	The review notes that combining targeted therapy (e.g., based on molecular subtypes) and immunotherapy is promising for mCRC — representing a move beyond standard chemotherapy, though efficacy depends on tumor genetics and patient selection.
8	Colorectal cancer (immunotherapy context)	Immunotherapy (checkpoint inhibitors, immune	Y. Li, et al.	*Immunotherapy in colorectal cancer: Statuses and strategies*	(2025)	The paper concludes that immunotherapy for colorectal cancer is evolving: while success is limited in some subtypes, novel strategies

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		strategies)				(combination therapies, biomarkers, personalized approaches) give hope for improved outcomes.
9	Acute lymphoblastic leukemia (B-cell ALL)	CAR-T (CD19-targeted)	Myers R.M., Li Y., Barz Leahy A., Barrett D.M., Teachey D.T., et al.	*Clinical Variables Associated with Improved Outcomes for CD19 CAR T-cell Therapy in B-Cell Acute Lymphoblastic Leukemia*	*ASTCT Journal* (2023)	Analysis identified patient and disease-related variables (e.g., lower disease burden before infusion) associated with better long-term outcomes — emphasizing the importance of timing and patient selection in CAR-T therapy.
10	B-cell acute lymphoblastic leukemia (ALL) / B-cell malignancies	CAR-T (CD19/CD22 cocktail)	Wang N., Hu X., Cao W., Li C., Xiao Y., Cao Y., et al.	*Efficacy and safety of CAR19/22 T-cell cocktail therapy in patients with refractory/relapsed B-cell Malignancies*	*Blood* (2020)	The study demonstrated that combining CAR-T cells targeting both CD19 and CD22 antigens achieved good efficacy in heavily pretreated patients, with manageable safety profile — offering a strategy to reduce relapse due to antigen escape.

Cancer treatment encompasses a wide range of modalities, each designed to target cancer in different ways depending on the type, stage, and biology of the disease. Traditional approaches such as **surgery, chemotherapy, and radiotherapy** remain foundational. Surgery is highly effective for localized tumors, aiming to remove cancerous tissue along with a margin of healthy cells to reduce recurrence. Chemotherapy uses cytotoxic drugs that kill rapidly dividing cells and is valuable for metastatic cancers, though it affects healthy tissues and causes significant side effects. Radiotherapy employs high-energy radiation to damage cancer cell DNA and is used alone or in combination with surgery or chemotherapy. **Hormone therapy** is used for hormone-dependent cancers such as breast and prostate cancer, while **stem cell or bone marrow transplantation** enables treatment of blood cancers by replacing destroyed marrow with healthy stem cells. Newer modalities such as **nanotechnology-based therapy** and **gene therapy** are emerging, offering targeted drug delivery and the potential to correct genetic mutations, though both remain limited by regulatory and technical challenges.

In recent years, cancer treatment has shifted toward **precision and biological therapies**, driven by advancements in molecular understanding and biotechnology. **Targeted therapies** use drugs that interfere with specific molecules like HER2 or EGFR, offering higher precision and fewer side effects compared to chemotherapy. **Immunotherapy**, including checkpoint inhibitors, CAR-T cell therapy, and cancer vaccines, harnesses the immune system to recognize and eliminate cancer cells, often producing durable responses. **Personalized medicine** tailors treatment to the genetic profile of each patient and tumor, while **nanotechnology** enhances drug delivery and reduces toxicity. Advances in radiation techniques such as IMRT and stereotactic radiosurgery have increased precision, and combination therapies integrating multiple modalities are becoming more common. Innovations like **liquid biopsies** and biomarker-based diagnostics are improving early detection and real-time monitoring, further transforming cancer care.

Despite progress, significant challenges persist in achieving consistently effective outcomes. **Drug resistance**, tumor heterogeneity, and the complex tumor microenvironment often limit therapeutic success. Many cancers are diagnosed late, reducing treatment options, and metastasis remains the leading cause of cancer-related mortality. Side effects and toxicity restrict treatment intensity, while immune evasion can reduce the effectiveness of immunotherapies. Additionally, advanced treatments are costly and not universally accessible, creating disparities in care. Psychological,

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social, and economic factors also affect patient adherence and overall outcomes, emphasizing the need for holistic cancer management alongside scientific advancements.

II. RESULT AND DISCUSSION

The findings highlight that cancer remains a major global and national health challenge, driven by uncontrolled cell growth, genetic mutations, and diverse risk factors such as tobacco, dietary habits, infections, chemical exposures, and radiation. The global burden, with ~20 million new cases and more than 10 million deaths annually, and the rising incidence in India reflect increasing exposure to risk determinants and improved diagnostic capabilities. Classification of cancer by cell origin and organ system underscores its heterogeneity, further complicated by varied symptoms, progression patterns, and treatment responses. Conventional treatments including surgery, chemotherapy, radiotherapy, and hormone therapy continue to form the foundation of cancer care, yet their limitations—mainly toxicity, non-specificity, and resistance—highlight the need for more advanced approaches. Recent developments such as immunotherapy (notably CAR-T cells, checkpoint inhibitors, and personalized cancer vaccines), targeted therapies, AI-guided diagnostics, precision medicine, nanotechnology, and genomic-based interventions show significant promise in improving survival, especially in hematologic malignancies where high response rates have been documented. However, challenges like tumor heterogeneity, immune evasion, therapeutic toxicity, high cost, late diagnosis, and limited accessibility in low- and middle-income countries persist. Pharmacists and pharmacy students play an essential role in optimizing cancer therapy through safe medication handling, patient counseling, treatment monitoring, understanding biomarker-driven precision medicine, and contributing to research. Overall, the integrated evidence indicates that while modern technologies are reshaping cancer treatment, achieving meaningful clinical outcomes requires a multimodal strategy combining early detection, conventional and advanced therapies, and coordinated healthcare efforts to overcome existing barriers and enhance quality of life for cancer patients.

III. THE ROLE OF PHARMACY STUDENTS/PHARMACISTS IN CANCER CARE

Pharmacists play a crucial role in **chemotherapy dispensing**, ensuring correct dosing, handling, and safety.
In targeted therapy and immunotherapy, pharmacists must be familiar with **molecular diagnostics** and biomarkers (e.g., PIK3CA mutation for inavolisib) to support precision medicine.
Pharmacists can counsel patients on **side-effect management**, adherence, and monitoring.
In future, pharmacists might contribute to **cell therapy infrastructure** or support **vaccine-based therapies**.
They may also be involved in **research**, such as clinical trials, pharmacovigilance, and development of biosimilars.

NEED OF THE STUDY

- **Rising Global Cancer Burden:** With ~20 million new cases and over 10 million deaths annually, cancer continues to grow as a major public health concern, demanding updated and comprehensive research.
- **Increasing Cancer Incidence in India:** The sharp rise in cancer cases (≈100 per 100,000 population) highlights the need to understand causes, prevention strategies, and improved access to modern treatments.
- **Complexity of Cancer Biology:** Cancer involves uncontrolled cell growth, genetic mutations, and tumor heterogeneity, making it essential to study its mechanisms for better therapeutic approaches.
- **Limitations of Conventional Treatments:** Surgery, chemotherapy, and radiotherapy suffer from toxicity, resistance, and non-specificity, creating a need to explore more advanced and targeted therapies.
- **Advancements in Modern Therapies:** Emerging treatments like immunotherapy, CAR-T cells, targeted therapy, gene therapy, nanotechnology, and precision medicine require detailed analysis for effective clinical integration.
- **Challenges in Current Cancer Care:** Issues such as metastasis, drug resistance, immune evasion, and late diagnosis make further research crucial to improve outcomes.
- **Need for Early Detection:** Innovations such as AI-assisted imaging, liquid biopsies, and biomarker-based diagnostics must be studied for early, accurate, and noninvasive cancer detection.

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- **Healthcare Accessibility Gaps:** High cost and limited availability of advanced therapies in low- and middle-income countries necessitate research into cost-effective and scalable treatment models.
- **Role of Pharmacists in Cancer Management:** As modern treatments become more complex, pharmacists and pharmacy students must expand their roles in medication safety, precision medicine, counseling, and research.
- **Improving Quality of Life for Patients:** There is a strong need to study integrated, patient-centered clinical approaches that address not only survival but also quality of life and supportive care.

IV. FUTURE SCOPE

- **Advancement of Immunotherapy:** Continued development of CAR-T cells, CAR-NK cells, checkpoint inhibitors, and personalized cancer vaccines will enhance treatment precision and long-term survival.
- **Expansion of Precision Medicine:** Wider use of genomic profiling, biomarkers, and AI-driven decision tools will enable highly individualized and more effective cancer therapies.
- **Next-Generation Targeted Therapies:** Development of novel molecular inhibitors and combination regimens may overcome resistance and improve outcomes in solid and hematologic tumors.
- **Growth of Nanotechnology-Based Treatments:**Nanocarriers for targeted drug delivery will help minimize toxicity and improve therapeutic efficacy.
- **Early Detection Innovations:** Liquid biopsies, AI-assisted imaging, and multi-omics diagnostics will allow earlier, noninvasive detection and real-time monitoring of cancer.
- **Improved Access to Advanced Therapies:** Efforts to reduce cost, simplify manufacturing, and strengthen infrastructure may expand the availability of immunotherapies and targeted agents in low- and middle-income countries.
- **Pharmacist Integration in Oncology Care:** Pharmacists will increasingly participate in precision medicine, immunotherapy monitoring, cell therapy support, and cancer research.
- **Multimodal Treatment Approaches:** Integration of surgery, targeted agents, immunotherapy, radiotherapy, and AI-based planning will create more comprehensive and effective cancer management pathways.

V. CONCLUSION

Cancer remains one of the most complex and challenging diseases worldwide, characterized by uncontrolled cell growth, genetic mutations, and the potential to invade or metastasize. Its incidence and mortality continue to rise globally and in countries like India, highlighting the urgent need for effective prevention, early detection, and treatment strategies. Cancer arises from multiple factors, including lifestyle, environmental exposures, infectious agents, and genetic predispositions. Its heterogeneity, both within and between tumors, complicates diagnosis and treatment planning.

Despite these advances, significant challenges remain, including drug resistance, tumor heterogeneity, metastasis, late diagnosis, immune evasion, and limited access to advanced therapies. Overcoming these hurdles requires continued research, integration of multi-modal therapies, and improved healthcare infrastructure. Pharmacists and pharmacy students play a critical role in cancer care by ensuring safe medication management, counseling patients, supporting precision medicine initiatives, and participating in research and clinical trials. Their involvement is pivotal in optimizing patient outcomes and implementing emerging therapies safely.In conclusion, the future of cancer management lies in a multi-faceted approach combining early detection, conventional and advanced treatment modalities, personalized medicine, and collaborative healthcare efforts. Ongoing innovation and research promise to enhance survival rates, reduce adverse effects, and improve quality of life for cancer patients worldwide.

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