ISSN: 2455 – 9938
PubMed- National Library of Medicine - ID: 101731611

EIJO: Journal of Science, Technology and Innovative Research (EIJO–JSTIR)
Einstein International Journal Organization (EIJO)
Available Online at:www.eijo.in
Volume – 11, Issue – 1, January – February - 2026, Page No. : 33 - 40

Novel Anticancer Drugs and Targeted Therapies: Pharmacological Developments and Future Perspectives

[1]Shankar Saini, [2]Lokendra Singh Rathore, [3]Dhirendra Yadav, [4]Indu Sharma

[1-4]Jaipur School of Pharmacy, Maharaj Vinayak Global University, Jaipur, Rajasthan

Corresponding Author: Shankar Saini, Jaipur School of Pharmacy, Maharaj Vinayak Global University, Jaipur, Rajasthan.

Type of Publication: Original Research Article

Conflicts of Interest: Nil

Abstract

Cancer remains one of the leading causes of morbidity and mortality worldwide despite significant advancements in diagnosis and treatment. Conventional chemotherapy, although effective in certain cases, is often associated with systemic toxicity, drug resistance, and limited specificity. Recent pharmacological developments have focused on novel anticancer drugs and targeted therapies that selectively act on molecular pathways involved in tumor growth and progression. These therapies include targeted small-molecule inhibitors, monoclonal antibodies, immunotherapies, antibody–drug conjugates, and gene-based approaches. Advances in molecular biology, genomics, and personalized medicine have enabled the identification of specific biomarkers that guide targeted treatment strategies. While these therapies have improved survival outcomes and reduced adverse effects compared to traditional chemotherapy, challenges such as resistance, cost, and accessibility remain. This review highlights recent pharmacological developments in anticancer drugs, mechanisms of targeted therapies, clinical advancements, and future perspectives in precision oncology.

Keywords: Anticancer drugs, targeted therapy, immunotherapy, monoclonal antibodies, precision medicine, pharmacological advances, cancer treatment.

1. Introduction

Cancer remains one of the most serious global health challenges, representing a leading cause of morbidity and mortality worldwide. It is characterized by uncontrolled cell proliferation, genetic mutations, and the ability of malignant cells to invade surrounding tissues and metastasize to distant organs. According to global health reports, cancer incidence continues to rise due to factors such as aging populations, lifestyle changes, environmental exposures, and improved diagnostic capabilities. Despite considerable advances in detection and treatment, cancer continues to impose significant medical, social, and economic burdens. Traditional therapeutic approaches, including surgery, chemotherapy, and radiotherapy, have played vital roles in cancer management; however, their limitations have driven the search for more targeted and effective pharmacological interventions.

Conventional chemotherapy primarily works by destroying rapidly dividing cells, but this lack of selectivity often results in significant toxicity to normal tissues such as bone marrow, gastrointestinal epithelium, and hair follicles. Common adverse effects include nausea, immunosuppression, alopecia, and organ toxicity, which can negatively impact patient quality of life. Furthermore, tumor heterogeneity and the development of drug resistance frequently reduce the long-term

effectiveness of conventional chemotherapeutic agents. These challenges have highlighted the need for therapies that specifically target molecular mechanisms underlying cancer progression while minimizing damage to healthy cells.

Advances in molecular biology, genomics, and proteomics have greatly enhanced understanding of cancer pathophysiology. Researchers have identified numerous signaling pathways, oncogenes, tumor suppressor genes, and molecular biomarkers involved in tumor initiation and progression. This deeper insight has facilitated the development of novel anticancer drugs designed to act selectively on specific molecular targets. Targeted therapies aim to interfere with cancer cell growth, survival, angiogenesis, and metastasis by modulating defined biological pathways. Such precision approaches offer the potential for improved therapeutic efficacy with reduced systemic toxicity compared to traditional chemotherapy.

Targeted anticancer therapies encompass a wide range of pharmacological strategies, including small-molecule inhibitors, monoclonal antibodies, antibody–drug conjugates, immunotherapies, and gene-based treatments. Small-molecule inhibitors often target intracellular enzymes such as tyrosine kinases that regulate cell proliferation and survival. Monoclonal antibodies, on the other hand, bind specifically to extracellular receptors or antigens expressed on tumor cells, blocking signaling pathways or facilitating immune-mediated destruction. Immunotherapies, particularly immune checkpoint inhibitors, have revolutionized oncology by enhancing the body's immune response against cancer cells. These therapies restore immune surveillance mechanisms that tumors often evade, leading to significant clinical benefits in various cancer types.

The emergence of precision oncology represents a paradigm shift in cancer treatment. Personalized medicine approaches utilize genetic profiling, biomarker identification, and molecular diagnostics to tailor treatment strategies to individual patients. Advances in next-generation sequencing technologies allow clinicians to identify specific mutations and select therapies most likely to be effective for each patient. This individualized approach improves treatment outcomes, reduces unnecessary exposure to ineffective drugs, and enhances overall patient care. Precision medicine also facilitates early detection of resistance mechanisms, enabling timely modification of therapeutic strategies.

In addition to targeted drugs, novel drug delivery systems have contributed significantly to advancements in cancer pharmacotherapy. Nanotechnology-based carriers, liposomal formulations, and antibody–drug conjugates enhance drug stability, improve bioavailability, and enable selective delivery to tumor tissues. These innovations help reduce systemic toxicity while maximizing therapeutic effectiveness. Furthermore, the integration of artificial intelligence and big data analytics into oncology research is accelerating drug discovery, optimizing clinical trial design, and supporting predictive treatment strategies.

Despite remarkable progress, several challenges remain in the development and application of novel anticancer therapies. Drug resistance continues to be a major obstacle, often arising from genetic mutations, alternative signaling pathways, or tumor microenvironment factors. The high cost of advanced targeted therapies and immunotherapies can limit accessibility, particularly in low- and middle-income countries. Additionally, long-term safety data for many newer therapies are still evolving, necessitating ongoing clinical monitoring and research.

Future directions in anticancer pharmacology emphasize combination therapies, innovative immunotherapeutic approaches, gene editing technologies, and personalized treatment strategies. Advances in biotechnology,

pharmacogenomics, and molecular diagnostics are expected to further refine precision oncology. Collaborative efforts among researchers, clinicians, pharmaceutical industries, and regulatory authorities will be essential to translate scientific discoveries into safe, effective, and accessible cancer treatments.

2. Targeted Anticancer Therapies

Targeted anticancer therapies represent a major advancement in modern oncology, focusing on specific molecular mechanisms involved in tumor growth, survival, angiogenesis, and metastasis. Unlike conventional chemotherapy, which affects both cancerous and healthy rapidly dividing cells, targeted therapies are designed to selectively interact with cancer-specific molecules such as receptors, enzymes, and signaling proteins. This selectivity enhances therapeutic efficacy while reducing systemic toxicity and adverse effects. The development of targeted therapies has been driven by advances in molecular biology, genomics, and cancer pathophysiology, enabling identification of biomarkers and therapeutic targets. Among the most important classes of targeted therapies are small-molecule inhibitors, monoclonal antibodies, and antibody–drug conjugates, each offering distinct pharmacological advantages in cancer treatment.

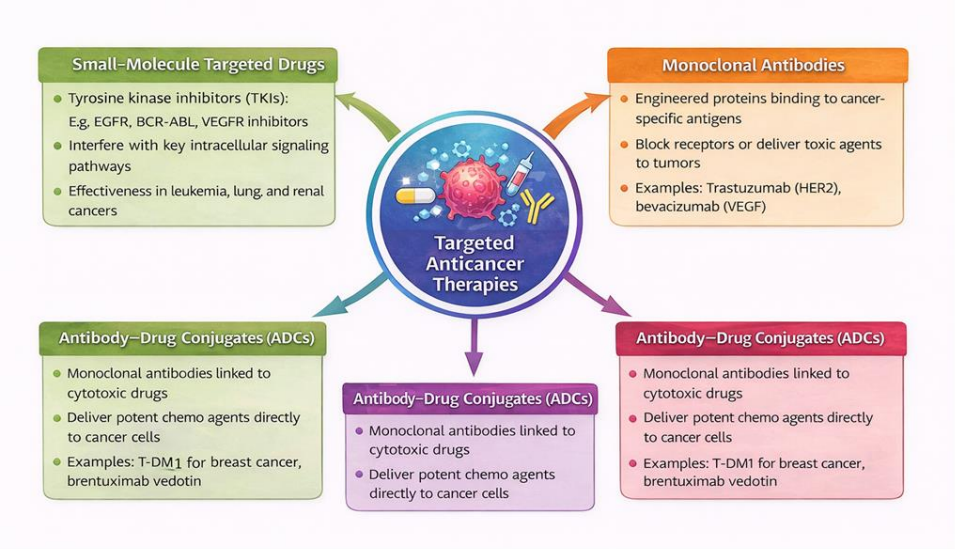

Figure 1: Targeted Anticancer Therapies

2.1 Small-Molecule Targeted Drugs

Small-molecule inhibitors are pharmacological agents designed to penetrate cell membranes and interfere with intracellular signaling pathways essential for cancer cell proliferation, differentiation, survival, and angiogenesis. These molecules typically act by inhibiting specific enzymes, particularly protein kinases, which play crucial roles in signal transduction pathways that regulate cell growth. Tyrosine kinase inhibitors (TKIs) represent one of the most successful classes of small-molecule targeted drugs.

Tyrosine kinases are enzymes responsible for phosphorylation processes that activate signaling cascades involved in cell division and survival. Dysregulation or mutation of these kinases is frequently observed in cancers. For example, the BCR-ABL fusion protein in chronic myeloid leukemia (CML) results from a chromosomal translocation and leads to uncontrolled kinase activity. Imatinib, one of the earliest TKIs, specifically targets this abnormal protein and has significantly improved survival rates in CML patients. Similarly, inhibitors targeting epidermal growth factor receptor

(EGFR), such as gefitinib and erlotinib, are widely used in non-small cell lung cancer, where EGFR mutations drive tumor progression.

Another important target is vascular endothelial growth factor receptor (VEGFR), which regulates tumor angiogenesis. Drugs such as sorafenib and sunitinib inhibit VEGFR signaling, thereby reducing tumor blood supply and limiting cancer growth. Small-molecule inhibitors are also being developed to target additional pathways such as PI3K/AKT/mTOR signaling, which plays a critical role in cell survival and metabolism.

Despite their effectiveness, small-molecule targeted drugs face challenges including acquired drug resistance, off-target effects, and variability in patient response. Resistance may arise from secondary mutations, activation of alternative signaling pathways, or tumor heterogeneity. Continuous research is therefore focused on developing next-generation inhibitors and combination therapies to overcome these limitations.

2.2 Monoclonal Antibodies

Monoclonal antibodies (mAbs) are laboratory-engineered proteins designed to specifically recognize and bind to antigens expressed on cancer cells or within the tumor microenvironment. These antibodies are highly selective and can exert therapeutic effects through multiple mechanisms. They may block receptor signaling, trigger immune-mediated destruction of cancer cells, inhibit angiogenesis, or serve as carriers for cytotoxic drugs or radioactive agents.

One of the most well-known monoclonal antibodies is trastuzumab, which targets the human epidermal growth factor receptor 2 (HER2). Overexpression of HER2 is associated with aggressive breast cancer, and trastuzumab binding inhibits receptor signaling while promoting immune-mediated tumor cell destruction. Another widely used monoclonal antibody is bevacizumab, which targets vascular endothelial growth factor (VEGF) and inhibits tumor angiogenesis. By preventing new blood vessel formation, bevacizumab restricts tumor growth and metastasis.

Monoclonal antibodies offer several advantages over traditional chemotherapy. Their specificity reduces damage to normal tissues, leading to improved tolerability. Additionally, they can be combined with chemotherapy, radiotherapy, or other targeted agents to enhance therapeutic outcomes. Advances in antibody engineering have led to the development of humanized and fully human antibodies, minimizing immunogenic reactions and improving clinical effectiveness.

However, monoclonal antibody therapy also has limitations. High production costs, potential infusion-related reactions, and development of resistance are ongoing challenges. Furthermore, not all patients express the target antigen, necessitating biomarker testing before therapy initiation. Continued research aims to improve antibody design, optimize dosing strategies, and expand therapeutic indications.

2.3 Antibody–Drug Conjugates (ADCs)

Antibody–drug conjugates (ADCs) represent a sophisticated advancement in targeted cancer therapy, combining the specificity of monoclonal antibodies with the potent cytotoxic effects of chemotherapy agents. ADCs consist of three main components: a monoclonal antibody targeting a tumor-specific antigen, a cytotoxic drug payload, and a linker that connects the drug to the antibody. This design allows selective delivery of highly potent chemotherapeutic agents directly to cancer cells, minimizing systemic toxicity.

Upon binding to target antigens on tumor cells, ADCs are internalized into the cell, where the cytotoxic drug is released. The released drug disrupts cellular processes such as DNA replication or microtubule formation, leading to cancer cell

death. This targeted approach enables the use of extremely potent cytotoxic agents that would otherwise be too toxic for systemic administration.

Examples of clinically successful ADCs include trastuzumab emtansine (T-DM1) for HER2-positive breast cancer and brentuximab vedotin for Hodgkin lymphoma. These therapies have demonstrated improved efficacy and safety compared to conventional chemotherapy. ADCs are also being investigated for various other malignancies, including lung cancer, ovarian cancer, and hematological cancers.

Despite their promise, ADC development presents challenges such as optimizing linker stability, avoiding premature drug release, and preventing off-target toxicity. Advances in linker technology, antibody engineering, and payload selection are helping to improve ADC performance and clinical outcomes.

3. Immunotherapy in Cancer Treatment

3.1 Immune Checkpoint Inhibitors

Immunotherapy has emerged as a transformative approach in cancer treatment by harnessing the body's immune system to recognize and eliminate malignant cells. Among immunotherapeutic strategies, immune checkpoint inhibitors have gained particular prominence due to their ability to overcome tumor-induced immune suppression. Normally, immune checkpoints such as programmed death-1 (PD-1), programmed death ligand-1 (PD-L1), and cytotoxic T-lymphocyte-associated antigen-4 (CTLA-4) regulate immune responses to prevent excessive tissue damage. However, cancer cells often exploit these pathways to evade immune detection. Checkpoint inhibitors, including nivolumab, pembrolizumab, atezolizumab, and ipilimumab, block these inhibitory signals, thereby restoring T-cell activity and enhancing anti-tumor immunity. Clinical studies have demonstrated significant improvements in survival outcomes for patients with melanoma, non-small cell lung cancer, renal cell carcinoma, and several other malignancies. Despite their success, immune checkpoint inhibitors may cause immune-related adverse effects such as dermatitis, colitis, and endocrinopathies, which require careful management. Ongoing research focuses on combination therapies, predictive biomarkers, and strategies to overcome resistance, further expanding the clinical applicability of checkpoint blockade therapies.

3.2 Cancer Vaccines and Cellular Therapies

Cancer vaccines and adoptive cellular therapies represent innovative immunotherapeutic modalities aimed at generating highly specific immune responses against tumor cells. Cancer vaccines function by exposing the immune system to tumor-associated or tumor-specific antigens, thereby stimulating immune recognition and destruction of cancer cells. Preventive vaccines such as those against human papillomavirus (HPV) have shown effectiveness in reducing cancer incidence, while therapeutic vaccines are being developed for established cancers including prostate, melanoma, and lung cancers. Cellular therapies, particularly chimeric antigen receptor T-cell (CAR-T) therapy, involve genetic modification of a patient's T lymphocytes to express receptors that specifically target tumor antigens. CAR-T cell therapy has demonstrated remarkable efficacy in hematological malignancies such as acute lymphoblastic leukemia and certain lymphomas. These therapies offer personalized treatment options but are associated with challenges including cytokine release syndrome, neurotoxicity, high costs, and complex manufacturing processes. Continued advancements in gene engineering, tumor antigen identification, and combination immunotherapy approaches are expected to enhance safety,

accessibility, and therapeutic effectiveness, positioning immunotherapy as a cornerstone of future cancer management strategies.

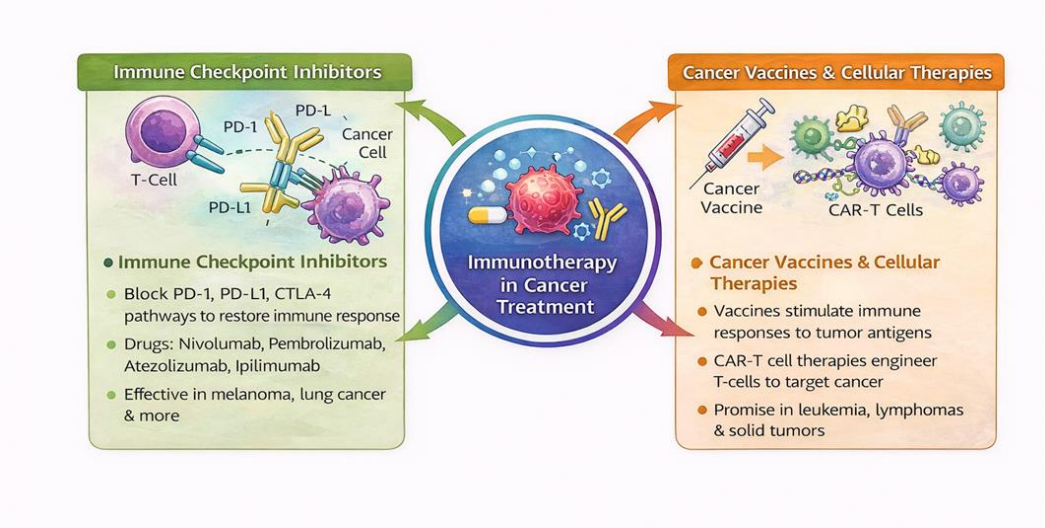

Figure 2: Immunotherapy in Cancer Treatment

4. Advances in Precision Oncology

Precision oncology represents a transformative approach in cancer treatment that focuses on tailoring therapies according to an individual patient's genetic makeup, tumor biology, and molecular characteristics. Advances in next-generation sequencing (NGS), genomic profiling, and molecular diagnostics have enabled clinicians to identify specific mutations, biomarkers, and signaling pathways responsible for cancer progression. This information allows the selection of targeted therapies that are more effective and less toxic compared with conventional treatments.

The identification of predictive biomarkers such as HER2, EGFR mutations, BRCA gene alterations, and PD-L1 expression has significantly improved treatment outcomes by guiding personalized therapeutic decisions. Precision oncology also supports the development of companion diagnostics, which help determine whether a patient is likely to benefit from a specific drug. Furthermore, integration of artificial intelligence, bioinformatics, and big data analytics has accelerated the discovery of novel therapeutic targets.

Overall, precision oncology enhances treatment efficacy, minimizes adverse effects, and promotes individualized patient care. As genomic technologies continue to advance, personalized cancer therapy is expected to become more accessible, improving survival rates and quality of life for cancer patients.

5. Future Perspectives

The future of anticancer drug development is expected to advance significantly through the integration of innovative therapeutic approaches and emerging technologies. Combination therapies involving targeted drugs, immunotherapy, chemotherapy, and radiotherapy are increasingly being explored to enhance treatment efficacy and overcome drug resistance. Novel immunotherapeutic strategies, including next-generation immune checkpoint inhibitors, cancer vaccines, and adoptive cell therapies, hold great promise for improving long-term cancer control. In addition, gene-editing technologies such as CRISPR-Cas systems are being investigated for their potential to correct oncogenic mutations and enhance immune responses against tumors.

Nanotechnology-based drug delivery systems are also gaining attention due to their ability to improve drug solubility, targeted delivery, and reduced systemic toxicity. Furthermore, artificial intelligence and big data analytics are transforming oncology research by enabling rapid identification of therapeutic targets, prediction of treatment responses, and development of personalized treatment strategies. Advances in biotechnology, pharmacogenomics, and molecular diagnostics will continue to support precision medicine, ensuring safer and more effective cancer therapies. Overall, these innovations are expected to enhance survival rates, reduce adverse effects, and improve the quality of life for cancer patients worldwide.

6. Conclusion

Novel anticancer drugs and targeted therapeutic approaches have significantly transformed modern cancer management by improving treatment specificity, minimizing systemic toxicity, and enhancing clinical outcomes. Advances in small-molecule targeted inhibitors, monoclonal antibodies, immunotherapy, and precision oncology have enabled more effective and individualized treatment strategies compared to conventional chemotherapy. These therapies not only improve survival rates but also contribute to better quality of life by reducing adverse effects and improving therapeutic precision. Precision medicine, supported by molecular diagnostics and biomarker identification, has further strengthened personalized cancer treatment approaches.

Despite these remarkable advancements, several challenges remain, including the development of drug resistance, high treatment costs, limited accessibility in developing regions, and variability in patient responses. Addressing these issues requires continued interdisciplinary collaboration among pharmacologists, molecular biologists, clinicians, and healthcare policymakers. Ongoing research focusing on innovative drug delivery systems, combination therapies, and emerging technologies such as artificial intelligence and genomics is expected to further improve cancer therapy. Overall, sustained scientific innovation and equitable healthcare strategies are essential to optimize therapeutic outcomes and advance the future of oncology care.

References

1. Patel, A. A. (2024). Recent advances in immunotherapy in cancer treatment. Cellular and Molecular Biology, 70(5), 89–99.
2. Ghemrawi, R., Abuamer, L., Kremesh, S., Hussien, G., Ahmed, R., Mousa, W., & Khoder, G. (2024). Revolutionizing cancer treatment: Recent advances in immunotherapy. Biomedicines, 12(9), 2158.
3. Ma, S., Hu, R., Xue, X., Qu, M., & Sun, G. (2025). Novel therapeutic strategies for non-small cell lung cancer: Combination therapies with immune checkpoint inhibitors. Oncology Letters, 30(3), 424.
4. Zhang, Y., Li, Y., Fu, Q., Han, Z., Wang, D., Shinge, S. A. U., Muluh, T. A., & Lu, X. (2023). Combined immunotherapy and targeted therapies for cancer treatment: Recent advances and future perspectives. Current Cancer Drug Targets, 23(4), 251–264.
5. Liu, Y., Chen, J., Xu, Y., & Sun, Q. (2022). Novel insight into the role of immunotherapy in gastrointestinal cancer. Molecular and Clinical Oncology, 17(4), 157.
6. Abdeldjouad, F. Z., Brahami, M., & Sabri, M. (2024). Evaluating artificial intelligence in predicting adverse drug reactions among cancer patients: A systematic review and meta-analysis. arXiv Preprint.

7. Ahmad, U., Harun, S., Diagne, M. M., Abdullah, S., Yusoff, K., & Veerakumarasivam, A. (2025). Oncolytic mechanisms and immunotherapeutic potential of Newcastle disease virus in cancer therapy. arXiv Preprint.
8. Kumar, M. (2023). Precision oncology, signaling pathways reprogramming and targeted therapy: A holistic approach to molecular cancer therapeutics. arXiv Preprint.
9. Withrow, A. D. M., Blythe, S. M., Burton, J. T., & Evett, C. G. (2024). Advanced targeted drug delivery for colon cancer using hydroxyapatite nanoparticles. arXiv Preprint.
10. Siegel, R. L., Miller, K. D., Wagle, N. S., & Jemal, A. (2023). Cancer statistics, 2023. CA: A Cancer Journal for Clinicians, 73(1), 17–48.
11. Ferrara, R., Mezquita, L., Auclin, E., & Besse, B. (2023). Immunotherapy resistance in cancer: Mechanisms and strategies. Nature Reviews Clinical Oncology.
12. Doroshow, D. B., Sanmamed, M. F., Hastings, K., Politi, K., Rimm, D. L., Chen, L., Melero, I., Schalper, K. A., & Herbst, R. S. (2023). Immunotherapy in non-small cell lung cancer. Journal of Clinical Oncology.
13. Schmid, P., Adams, S., Rugo, H. S., et al. (2022). Atezolizumab and chemotherapy in advanced triple-negative breast cancer. New England Journal of Medicine.
14. Swanton, C., Govindan, R. (2023). Clinical implications of tumor heterogeneity. Lancet Oncology.
15. Hodi, F. S., Chiarion-Sileni, V., Gonzalez, R., et al. (2022). Long-term survival in advanced melanoma with nivolumab. New England Journal of Medicine.
16. Lu, R. M., Hwang, Y. C., Liu, I. J., et al. (2022). Development of therapeutic antibodies for cancer therapy. Journal of Biomedical Science.
17. Beck, A., Goetsch, L., Dumontet, C., & Corvaïa, N. (2022). Strategies and challenges for antibody–drug conjugates. Nature Reviews Drug Discovery.
18. Tsimberidou, A. M., Fountzilas, E., Nikanjam, M., & Kurzrock, R. (2022). Review of precision cancer medicine. Nature Reviews Clinical Oncology.
19. Haslam, A., & Prasad, V. (2023). Estimation of survival benefit of cancer drugs. JAMA Network Open.
20. Adams, S., Gatti-Mays, M. E., Kalinsky, K., et al. (2023). Current landscape of immunotherapy in breast cancer. JAMA Oncology.
21. Hanna, N. H., Schneider, B. J., Temin, S., et al. (2023). Therapy for stage IV non-small cell lung cancer. Journal of Clinical Oncology.
22. Sharma, P., Siddiqui, B. A., Anandhan, S., Yadav, S. S., Subudhi, S. K., Gao, J., Goswami, S., & Allison, J. P. (2023). The next decade of immune checkpoint therapy. Cancer Discovery.