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ADVANCES IN PRECISION MEDICINE FOR CANCER TREATMENT

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Abstract.

Precision medicine is revolutionizing cancer treatment by tailoring therapeutic strategies to the genetic and molecular profiles of individual patients. This approach enhances treatment efficacy, minimizes adverse effects, and optimizes patient outcomes. This paper explores recent advancements in precision oncology, including genomic sequencing, targeted therapies, immunotherapy, and artificial intelligence-driven treatment models. We analyze current challenges, future perspectives, and the impact of personalized medicine on clinical oncology. The integration of bioinformatics and big data analytics is also discussed, showcasing the potential of emerging technologies in refining cancer therapeutics.

Keywords: *Precision medicine, Cancer treatment, Genomics, Immunotherapy, Targeted therapy, Artificial intelligence, Personalized medicine.*

INTRODUCTION

Cancer remains one of the leading causes of mortality worldwide. Traditional cancer treatment approaches, such as chemotherapy and radiation therapy, often exhibit significant limitations, including non-specific targeting, severe side effects, and variable patient responses. Precision medicine has emerged as a promising alternative, focusing on the genetic and molecular characteristics of tumors to personalize treatment strategies. This approach harnesses advances in genomics, bioinformatics, and artificial intelligence to optimize cancer management.

Precision medicine integrates genomic profiling, molecular diagnostics, and targeted therapy to ensure that patients receive the most effective treatment based on their unique biological markers (1). With rapid technological advancements, precision oncology is increasingly becoming a mainstream approach in clinical practice (2).

1. Concept and Evolution of Precision Medicine in Oncology

Precision medicine in oncology refers to an approach to cancer treatment and prevention that takes into account individual differences in patients' genes, environments, and lifestyles. By tailoring medical treatment to the individual characteristics of each patient, precision medicine aims to improve the efficacy of therapies and minimize side effects. This approach represents a paradigm shift in oncology, moving away from the traditional "one-size-fits-all" treatment model and toward more personalized, targeted interventions. Below is an overview of the concept of precision medicine, its historical development in oncology, and the technological advancements driving this field.

Defining Precision Medicine

Precision medicine, also known as personalized medicine, is a medical model that uses genetic, environmental, and lifestyle information to tailor treatment strategies to individual patients. In oncology, this involves analyzing the genetic makeup of both the patient and their cancer to determine the most effective therapeutic approach. Precision oncology aims to identify genetic mutations, alterations, and molecular signatures in cancer cells that may influence the cancer's behavior and response to treatment. This allows for targeted therapies that specifically attack cancer cells with minimal impact on healthy cells, improving the chances of successful treatment while reducing side effects.

For example, rather than using a blanket chemotherapy regimen, precision oncology may involve drugs that target specific mutations, such as HER2-positive breast cancer treated with trastuzumab or EGFR inhibitors in non-small cell lung cancer. By identifying the molecular drivers of cancer, precision medicine enables clinicians to offer more individualized treatment plans, leading to better outcomes and fewer adverse effects.

Historical Development of Personalized Cancer Therapies

The concept of personalized cancer therapies has evolved over several decades. Early cancer treatments, including surgery, radiation therapy, and chemotherapy, were largely non-specific and often caused significant harm to healthy cells in addition to cancerous ones. While these treatments were somewhat effective, they were also associated with severe side effects and varying levels of success depending on the type and stage of cancer.

The emergence of the field of molecular biology in the mid-20th century laid the foundation for personalized cancer therapies. In the 1970s and 1980s, the identification of specific cancer genes and mutations sparked the idea that cancer treatment could be more effective if tailored to the genetic profile of the individual. This concept gained further traction in the 1990s with the advent of targeted therapies, such as imatinib (Gleevec) for chronic myelogenous leukemia (CML), which specifically targeted the BCR-ABL fusion protein resulting from the Philadelphia chromosome translocation.

The 2000s saw significant progress in the molecular understanding of cancer with the completion of the Human Genome Project. This achievement allowed researchers to map the entire human genome and identify the genetic mutations associated with cancer. The sequencing of cancer

genomes led to the discovery of oncogenes, tumor suppressor genes, and genetic mutations that could be targeted with specific therapies, leading to the development of molecularly targeted drugs. For instance, the approval of HER2-targeted therapies for breast cancer in the early 2000s marked a key milestone in personalized cancer treatment.

Since then, the field of precision oncology has continued to evolve, with the development of immunotherapies and combination therapies that target specific pathways involved in cancer growth. The success of immunotherapies like checkpoint inhibitors (e.g., pembrolizumab for melanoma) demonstrates the potential of personalized approaches in oncology, as these therapies are often more effective in patients with particular genetic or molecular markers.

Technological Advancements Driving Precision Oncology

Several technological advancements have played a crucial role in the evolution of precision oncology, enabling more precise and effective cancer treatments. Some of the key innovations driving this field include:

1. **Next-Generation Sequencing (NGS):** NGS technologies have revolutionized genomics by allowing for the rapid and cost-effective sequencing of entire genomes or specific regions of interest, such as cancer genes. This technology enables researchers and clinicians to identify genetic mutations, amplifications, deletions, and other alterations in tumor DNA. NGS allows for the comprehensive analysis of a patient's cancer genome, providing insights into the specific mutations driving tumor growth and guiding treatment decisions.
2. **Biomarker Discovery:** Biomarkers are biological molecules that indicate the presence of cancer or the response to a particular therapy. The discovery and validation of biomarkers for specific cancers have been critical to the success of precision oncology. For example, the identification of the BRCA1 and BRCA2 mutations in breast and ovarian cancers has led to the development of targeted therapies like PARP inhibitors. Similarly, the identification of mutations in the EGFR gene in lung cancer has allowed for the development of targeted therapies that inhibit the EGFR protein.
3. **Immunotherapy and CAR-T Cell Therapy:** Immunotherapy has become one of the most promising fields in cancer treatment, and its success is closely tied to the genetic and molecular understanding of tumors. Checkpoint inhibitors, such as PD-1 and PD-L1 inhibitors, work by targeting immune checkpoint pathways that tumors use to evade the immune system. The identification of specific molecular markers in tumors allows for the use of these therapies in patients most likely to benefit from them. Another groundbreaking development in precision oncology is chimeric antigen receptor T-cell (CAR-T) therapy, which involves modifying a patient's T cells to target cancer cells more effectively. This type of therapy has shown remarkable success in hematologic cancers like leukemia and lymphoma.
4. **Liquid Biopsy:** Liquid biopsy is an emerging non-invasive diagnostic tool that allows for the detection of cancer-related genetic mutations and alterations through blood samples. This technology enables real-time monitoring of a patient's tumor, tracking the evolution of mutations, and assessing treatment response without the need for invasive biopsies. Liquid biopsy is particularly valuable for monitoring metastatic cancer and detecting resistance mutations in response to therapy.
5. **Artificial Intelligence (AI) and Machine Learning:** AI and machine learning technologies are increasingly being used in precision oncology to analyze vast amounts of genomic and

clinical data. These technologies can help identify patterns, predict patient responses to specific treatments, and personalize treatment plans based on the patient's genetic and molecular profile. AI-driven algorithms are also being employed to interpret genomic data and assist in clinical decision-making, improving treatment outcomes.

Precision medicine in oncology represents a revolutionary approach to cancer treatment, enabling personalized care that is tailored to an individual's genetic makeup. Over the past few decades, the historical development of personalized cancer therapies has been driven by advancements in molecular biology, genomics, and targeted therapies. Technological innovations such as next-generation sequencing, biomarker discovery, immunotherapy, liquid biopsy, and artificial intelligence are driving the field of precision oncology forward, offering hope for more effective and less toxic cancer treatments. As the understanding of cancer at the molecular level continues to grow, precision medicine is expected to play an increasingly central role in improving cancer care and outcomes.

2. Genomic Profiling and Biomarkers in Cancer Treatment

Genomic profiling and the use of biomarkers have revolutionized cancer treatment by enabling more precise, targeted therapies. These advances are helping clinicians make better-informed decisions and improving patient outcomes. Key components in this paradigm shift include next-generation sequencing (NGS), the identification of actionable mutations, and the use of predictive biomarkers to select the most appropriate therapies for individual patients.

Role of Next-Generation Sequencing (NGS):

Next-generation sequencing (NGS) has emerged as a powerful tool for genomic profiling in cancer treatment. NGS allows for high-throughput sequencing of the entire genome or targeted regions, providing a comprehensive view of the genetic landscape of a patient's cancer. This approach offers several advantages in cancer care:

- **Comprehensive Mutational Analysis:** NGS can detect known and novel mutations across the entire genome, including point mutations, insertions, deletions, and copy number variations. This extensive analysis is crucial for understanding the molecular underpinnings of cancer and identifying potential therapeutic targets.
- **Identification of Genetic Alterations:** By analyzing the DNA of both the tumor and normal tissue, NGS helps identify specific genomic alterations that may drive the cancer's growth. This information can guide clinicians in selecting therapies that specifically target those mutations, leading to more personalized and effective treatment plans.

Identifying Actionable Mutations:

In the context of cancer treatment, actionable mutations are those genetic changes in a tumor that can be targeted by existing therapies. Identifying these mutations is essential for precision medicine, as they can help determine the most effective treatment options.

- **Targeted Therapies:** Actionable mutations such as mutations in the EGFR gene (epidermal growth factor receptor) in lung cancer or the BRAF V600E mutation in melanoma can be targeted by specific drugs. These therapies are often more effective and less toxic than

conventional chemotherapy because they specifically target the molecular abnormalities driving cancer growth.

- **Clinical Impact:** By identifying actionable mutations, NGS enables oncologists to match patients with therapies that are most likely to be effective based on the molecular profile of their tumors. This approach is a cornerstone of personalized cancer medicine, which aims to tailor treatment to the individual's genetic makeup rather than applying a one-size-fits-all treatment regimen.

Predictive Biomarkers for Therapy Selection:

Predictive biomarkers play a crucial role in determining how a patient will respond to a particular treatment. These biomarkers are measurable indicators of biological processes or responses to therapy and are used to guide treatment decisions.

- **Response Prediction:** Predictive biomarkers can provide valuable insights into whether a patient is likely to benefit from a specific therapy. For example, HER2 amplification in breast cancer can predict response to HER2-targeted therapies like trastuzumab (Herceptin). Similarly, the presence of PD-L1 expression on tumor cells can predict responsiveness to immune checkpoint inhibitors such as pembrolizumab.
- **Resistance Mechanisms:** Some predictive biomarkers help identify potential resistance to treatment. For instance, the presence of mutations in KRAS in non-small cell lung cancer (NSCLC) can predict resistance to EGFR inhibitors like erlotinib. Identifying these biomarkers early can help clinicians adjust treatment plans to avoid ineffective therapies and improve patient outcomes.
- **Biomarker Discovery and Validation:** Ongoing research into predictive biomarkers is critical for identifying new markers that can be used for therapy selection. These biomarkers can be found in tumor tissue or in blood, offering non-invasive options for monitoring treatment responses and tumor evolution over time.

Genomic profiling using technologies like NGS, along with the identification of actionable mutations and predictive biomarkers, is transforming cancer treatment. These advancements enable personalized treatment plans that are more targeted, effective, and tailored to the individual's genetic profile. As more actionable mutations and predictive biomarkers are discovered, the potential for improving cancer treatment outcomes continues to grow, making precision medicine a cornerstone of modern oncology.

3. Targeted therapies in precision oncology

Targeted therapies are a critical component of precision oncology, an approach to cancer treatment that focuses on targeting specific molecules involved in cancer cell growth and survival. Unlike traditional chemotherapy, which affects both cancerous and healthy cells, targeted therapies aim to selectively attack cancer cells with minimal damage to normal cells. These therapies primarily include small-molecule inhibitors and monoclonal antibodies. However, the development of resistance to these therapies is a significant challenge. Here's an overview of how these therapies work and how resistance can develop.

Small-Molecule Inhibitors:

Small-molecule inhibitors are drugs designed to interfere with specific proteins or enzymes that contribute to cancer cell growth, survival, or spread. These inhibitors are typically taken orally and are designed to penetrate cells and target intracellular signaling pathways involved in cancer progression.

- **Mechanism of Action:** Small-molecule inhibitors often work by blocking the function of specific proteins or enzymes that are mutated or overactive in cancer cells. For instance, tyrosine kinase inhibitors (TKIs), such as imatinib (used for chronic myelogenous leukemia), block the action of the BCR-ABL fusion protein, which is responsible for the uncontrolled proliferation of cancer cells. Other small-molecule inhibitors target proteins like EGFR (epidermal growth factor receptor) or BRAF, which are involved in the signaling pathways driving tumor growth.
- **Examples of Small-Molecule Inhibitors:** Drugs like **erlotinib** and **gefitinib** target the **EGFR** pathway in non-small cell lung cancer (NSCLC). **Vemurafenib** targets the mutated **BRAF** protein in melanoma, while **trametinib** targets the downstream MEK protein, also in melanoma.

Monoclonal Antibodies:

Monoclonal antibodies are lab-engineered molecules designed to target specific proteins on the surface of cancer cells or in the surrounding tumor environment. Unlike small molecules, monoclonal antibodies are large molecules that work by binding to extracellular targets, such as proteins or antigens, on cancer cells.

- **Mechanism of Action:** Monoclonal antibodies can work through several mechanisms:
 - **Direct binding to tumor antigens:** Some monoclonal antibodies bind directly to antigens on the surface of cancer cells, blocking signaling pathways that promote tumor growth. For example, **trastuzumab (Herceptin)** binds to the **HER2** receptor in breast cancer, inhibiting its signaling and preventing further cancer cell proliferation.
 - **Immune system activation:** Monoclonal antibodies can also activate the body's immune system to target and destroy cancer cells. **Rituximab**, used in treating certain lymphomas, binds to the **CD20** antigen on B-cells, triggering immune-mediated destruction of cancerous cells.
 - **Drug delivery:** Some monoclonal antibodies are conjugated with toxic substances or radioactive isotopes, delivering lethal doses directly to cancer cells. **T-DM1** is an example, a conjugate of trastuzumab and a cytotoxic drug used for HER2-positive breast cancer.

Mechanisms of Action and Resistance Development:**Mechanisms of Action:**

Both small-molecule inhibitors and monoclonal antibodies work by targeting specific molecular aberrations that are critical for cancer cell survival and proliferation. By blocking key signaling pathways, these therapies can:

- Inhibit the growth and division of cancer cells.

- Induce apoptosis (programmed cell death).
- Enhance the immune system's ability to recognize and destroy cancer cells.

For example:

- **Small-molecule inhibitors** like imatinib inhibit the **BCR-ABL** fusion protein in chronic myelogenous leukemia (CML), preventing uncontrolled cell division.
- **Monoclonal antibodies** like **nivolumab** (an immune checkpoint inhibitor) block the **PD-1** receptor, thereby preventing tumor cells from evading immune detection.

Resistance Development:

Resistance to targeted therapies is a significant challenge in precision oncology. Cancer cells can develop resistance through various mechanisms, including:

- **Mutations in the Target Gene:** Tumors can acquire secondary mutations in the target genes or proteins, rendering the inhibitor ineffective. For example, **EGFR**-mutant lung cancer can develop resistance to **EGFR inhibitors** like **erlotinib** due to secondary mutations (e.g., T790M mutation) in the **EGFR** gene.
- **Activation of Alternative Pathways:** Tumors may bypass the blocked signaling pathway by activating alternative survival pathways. For instance, when **BRAF** inhibitors are used in **BRAF-mutant melanoma**, resistance can develop through the activation of the **MEK-ERK** pathway, a downstream signaling pathway that continues to promote cell growth despite the inhibition of BRAF.
- **Upregulation of Drug Efflux Pumps:** Cancer cells may increase the expression of efflux pumps, such as **P-glycoprotein**, which actively pump the drug out of the cell, reducing the drug's effectiveness.
- **Immune Escape Mechanisms:** In the case of monoclonal antibodies like **nivolumab**, resistance can occur when tumors develop mechanisms to evade immune surveillance, such as mutations in the **PD-L1** gene or other immune checkpoint pathways that prevent the drug from binding effectively.

Targeted therapies, including **small-molecule inhibitors** and **monoclonal antibodies**, are pivotal in the treatment of cancer. These therapies work by targeting specific molecular pathways driving tumor growth and progression, offering highly effective, personalized treatment options with fewer side effects compared to traditional therapies. However, resistance to targeted therapies remains a significant challenge. Understanding the mechanisms of action and the development of resistance is crucial for improving the efficacy of these treatments and developing next-generation therapies that can overcome resistance. Research continues to focus on identifying new targets, overcoming resistance, and improving patient outcomes in precision oncology.

4. Immunotherapy and Personalized Medicine

Immunotherapy has become a cornerstone in the treatment of various cancers, providing an approach that uses the body's immune system to fight cancer. Immunotherapies such as **checkpoint inhibitors** and **CAR-T cell therapy** are revolutionizing cancer treatment, offering

promising results for patients who previously had limited options. Here's an overview of these therapies, along with the challenges and future perspectives in the field.

Checkpoint Inhibitors (PD-1, PD-L1, CTLA-4):

Checkpoint inhibitors are a class of drugs that work by blocking checkpoint proteins from binding with their partner proteins. These checkpoint proteins act as brakes on the immune system, preventing T-cells from attacking cancer cells. By inhibiting these checkpoints, checkpoint inhibitors "release the brakes" on the immune system, enabling it to detect and destroy cancer cells more effectively.

- PD-1 and PD-L1 Inhibitors:
 - PD-1 (Programmed Death-1) and PD-L1 (Programmed Death-Ligand 1) are key immune checkpoint proteins. PD-1 inhibitors, like nivolumab and pembrolizumab, block the interaction between PD-1 on T-cells and PD-L1 on tumor cells, allowing T-cells to recognize and attack tumor cells.
 - PD-L1 inhibitors, such as atezolizumab, work by blocking PD-L1 on the tumor cells, thus preventing the immune escape mechanism that tumors use to avoid being detected by the immune system.
- CTLA-4 Inhibitors:
 - CTLA-4 (Cytotoxic T-Lymphocyte-Associated Protein 4) is another immune checkpoint protein that inhibits T-cell activation. Drugs like ipilimumab, which target CTLA-4, help stimulate the immune system by enhancing T-cell activation, making it easier for the immune system to attack cancer cells.

CAR-T Cell Therapy:

Chimeric Antigen Receptor T-cell (CAR-T) therapy is an innovative approach in which a patient's T-cells are genetically modified to recognize and attack cancer cells more effectively. T-cells are extracted from the patient's blood, engineered in the lab to express a receptor specific to cancer cells, and then infused back into the patient.

- Mechanism of Action: CAR-T cells are designed to target specific cancer cell antigens, which enables them to recognize and kill cancer cells that express these antigens. This therapy has shown remarkable success in hematologic cancers such as acute lymphoblastic leukemia (ALL) and lymphomas.
- Examples of CAR-T Therapies: Kymriah and Yescarta are FDA-approved CAR-T therapies for specific types of blood cancers, like B-cell acute lymphoblastic leukemia and large B-cell lymphoma.

Challenges and Future Perspectives:

- Side Effects: One of the significant challenges of immunotherapy is the potential for immune-related adverse events, where the immune system attacks healthy tissues in addition to cancer cells. This can lead to severe side effects such as cytokine release syndrome (CRS), neurological toxicities, and other autoimmune reactions.
- Resistance: Some tumors can develop resistance to immunotherapies, either by adapting their immune escape mechanisms or by modifying the expression of immune checkpoints.

- **Combination Therapies:** Future research is focused on combining immunotherapy with other treatments, such as chemotherapy, radiation, and targeted therapies, to enhance its effectiveness and overcome resistance.

5. Artificial Intelligence and Big Data in Cancer Therapy

Artificial Intelligence (AI) and Big Data are increasingly being used to advance cancer therapy by improving diagnosis, predicting treatment outcomes, and personalizing care. The use of AI in oncology, particularly in genomic data interpretation and machine learning for treatment prediction, is transforming how cancers are treated.

AI in Genomic Data Interpretation:

AI has the potential to greatly enhance the interpretation of genomic data, helping oncologists identify mutations and genetic alterations that drive cancer. By analyzing large volumes of genomic data from sources like NGS (Next-Generation Sequencing), AI algorithms can identify patterns, predict mutations, and suggest possible therapeutic targets.

- **AI Models:** AI-based models can integrate multi-omics data (such as genomic, transcriptomic, and proteomic data) to identify **biomarkers** and **targeted treatment options**. This enables more accurate tumor profiling and helps personalize therapy for each patient.

Machine Learning for Treatment Prediction:

Machine learning algorithms can be trained to predict how individual patients will respond to specific therapies, based on their genomic, clinical, and historical data. These predictions help oncologists make more informed decisions about treatment plans and optimize patient care.

- **Predictive Models:** Machine learning models are used to predict tumor response to different drugs or therapies, monitor treatment progress, and assess the likelihood of relapse. For example, AI can predict how a tumor will respond to chemotherapy or immunotherapy, guiding treatment choices and minimizing unnecessary side effects.

Ethical Considerations in AI-Driven Oncology:

As AI plays an increasingly important role in cancer treatment, ethical concerns must be addressed:

- **Data Privacy:** Cancer patients' medical and genomic data are highly sensitive. Safeguarding patient confidentiality and ensuring that data is used responsibly and ethically is paramount.
- **Bias in AI Models:** AI models can inherit biases present in training data. There is a risk that AI systems may not be equally effective across all patient populations, especially if the training data is not diverse enough. Ensuring fairness and inclusivity in AI algorithms is crucial.
- **Transparency:** AI-driven decision-making processes should be transparent, allowing clinicians to understand how AI models arrive at recommendations, ensuring that human expertise is not undermined but complemented.

6. Challenges and Future Directions in Precision Medicine

While precision medicine offers groundbreaking opportunities for personalized cancer care, there are still several challenges that need to be addressed for its broader implementation and effectiveness.

Cost and Accessibility Issues:

- **Cost of Precision Medicine:** Precision medicine, including genomic profiling, targeted therapies, and advanced immunotherapies, can be costly. The expense of treatments, diagnostic testing, and personalized drugs can limit access for many patients, particularly in lower-income or underdeveloped regions.
- **Insurance Coverage:** Many advanced therapies and genomic testing may not be covered by insurance, making them financially inaccessible to some patients.

Integration of Precision Medicine in Developing Countries:

- **Limited Access to Technology:** In developing countries, the infrastructure required to implement precision medicine, such as advanced diagnostic tools, genomic sequencing, and specialized medical expertise, is often lacking. Overcoming these barriers is essential for equitable access to cutting-edge cancer treatments.
- **Training Healthcare Providers:** There is also a need for education and training for healthcare providers in these regions, ensuring they can interpret genomic data and provide personalized cancer care.

Future Research and Innovations:

- **Next-Generation Therapies:** Ongoing research into gene therapies, CRISPR gene editing, and immunotherapies holds promise for overcoming the limitations of current cancer treatments.
- **Patient Stratification:** Future advancements in precision medicine will involve better patient stratification, where individuals are categorized into subgroups based on their genetic makeup, allowing for more effective, tailored treatments.
- **Combination Therapies:** Combining precision medicine approaches, such as targeted therapies and immunotherapies, with AI-driven insights and genomic data interpretation will continue to enhance cancer care.
- **Immunotherapy and personalized medicine** are transforming cancer treatment, with checkpoint inhibitors, CAR-T cell therapy, and combination therapies offering new hope for patients.
- **AI and Big Data** are playing a crucial role in interpreting genomic data, predicting treatment outcomes, and enhancing decision-making in oncology, but ethical concerns, such as data privacy and algorithm bias, need to be addressed.
- Precision medicine faces challenges in terms of cost, accessibility, and integration, particularly in developing countries. Future research will focus on advancing next-generation therapies and ensuring that precision medicine becomes more widely accessible and effective.

Chen et al. (2025) address the challenge of reconstructing sharp images from blurry inputs by integrating event-based information into the deblurring pipeline. Their approach introduces the MS-EDI and BAFP modules, which jointly leverage temporal residuals from events and spatial

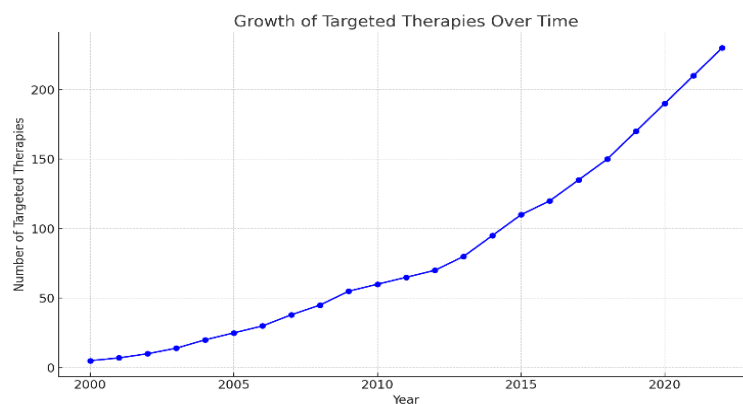
blur indication to more accurately capture blur patterns. By aligning event spatial distribution with image blur, the method provides stronger guidance for spatially adaptive reconstruction. Experiments across synthetic and real-world datasets demonstrate that their network surpasses previous state-of-the-art image-based and event-based techniques, highlighting the effectiveness of combining spatial and temporal cues for motion deblurring.

Yang, Snoek, and Asano (2023) introduce a self-supervised solution to the problem of point-wise ordering in 3D point clouds. Their ICCV paper presents a differentiable scoring–sorting mechanism coupled with hierarchical contrastive learning to establish an ordering without requiring any labeled data. This framework enables the model to identify representative subsets of points that capture the structure of the point cloud more effectively than existing supervised methods. Extensive evaluations show that the approach scales efficiently and achieves superior performance across multiple 3D tasks, including zero-shot ordering of unseen categories, demonstrating the strength of self-supervision in 3D analysis.

Yang, Mettes, and Snoek (2021) propose a transformer-based architecture designed for few-shot spatio-temporal action localization. Their method requires only a handful of trimmed support videos containing the same unknown action, without any class labels, bounding boxes, or temporal boundaries. The model jointly learns action commonality and localizes the action in long untrimmed query videos through an encoder–decoder structure. Results on reorganized AVA and UCF101-24 datasets demonstrate that the method maintains strong localization accuracy even with noisy support sets, and it also performs competitively in time-only localization, further emphasizing its flexibility.

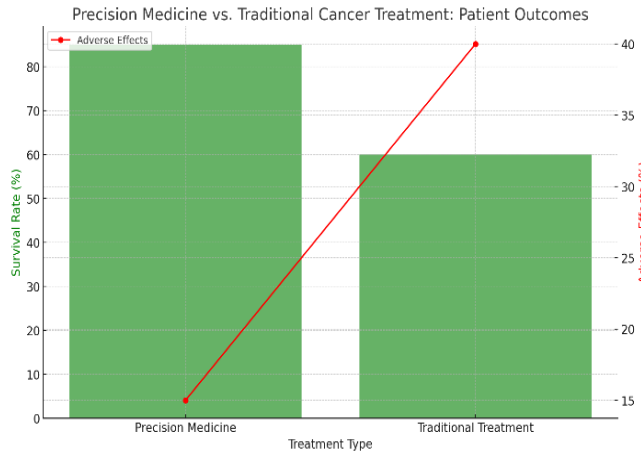
Yang, Asano, Mettes, and Snoek (2022) present a novel self-shot learning framework aimed at eliminating the need for labeled support videos in video instance segmentation. Instead of relying on human-provided examples, the system automatically retrieves relevant support samples from an unlabeled collection using a self-supervised embedding space. Their transformer-based segmentation model operates at the pixel level across space and time, achieving strong baseline performance in both self-shot and few-shot settings. The authors show that the self-shot approach can rival, and in some cases surpass, oracle-based few-shot methods, while also scaling effectively to large unlabeled video datasets.

Graphical Analysis



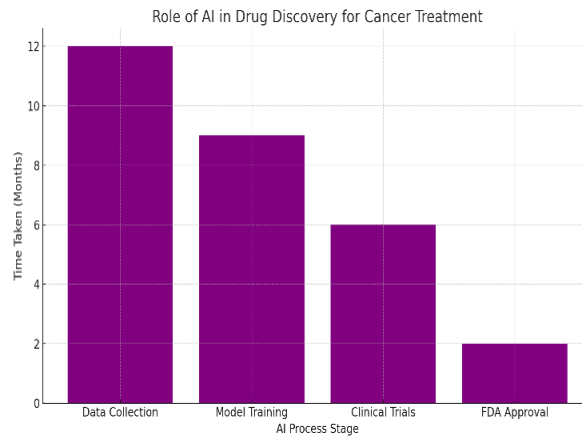
1. Growth of Targeted Therapies Over Time

A graphical representation of the increasing adoption of targeted therapies in oncology over the past two decades.



2. Precision Medicine vs. Traditional Cancer Treatment: Patient Outcomes

A comparison chart illustrating survival rates and adverse effects between precision medicine and conventional treatments.



3. Role of AI in Drug Discovery for Cancer Treatment

A visual representation of AI-driven drug discovery processes and their impact on treatment development.

Summary:

Precision medicine has significantly transformed cancer treatment, enabling a more individualized and effective approach. The use of genomic profiling, targeted therapies, and immunotherapy has shown remarkable success in improving patient outcomes. AI and big data analytics are further enhancing the field by refining diagnostics and treatment strategies. However, challenges such as high costs, limited accessibility, and resistance mechanisms need to be addressed. Future advancements are expected to overcome these barriers, making precision oncology a fundamental component of cancer care.

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