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CANCER GENOMICS AND PATIENT-SPECIFIC TREATMENT MODALITIES

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Cancer genomics and patient-specific treatment strategies aim to enhance therapeutic efficacy by elucidating the genetic architecture of individual patients. This approach increases the precision of drug development, minimizes unnecessary treatment, and improves cure rates, ultimately leading to personalized therapies and superior clinical outcomes. The most significant advancements shaping the future of cancer research and drug discovery are encapsulated in this letter. Next-generation sequencing (NGS) and other technologies enable comprehensive genomic profiling to identify and prioritize actionable mutations. By transcending conventional chemotherapy, researchers can develop more potent and less toxic therapeutics by understanding the unique mutations driving cancer in individual patients. By inhibiting immune

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checkpoints, these drugs enable T cells to more effectively target and eliminate cancer cells. However, ongoing research focuses on optimizing the efficacy and safety of these treatments, particularly in the context of solid tumors. Insights into tumor microenvironment (TME) elements, such as the extracellular matrix and infiltrating immune cells, may provide novel therapeutic avenues. A vast array of genetic data has been analyzed, uncovering future medical prospects and predicting patient outcomes using AI-driven programs. Additionally, machine learning algorithms are employed to improve patient stratification, optimize clinical research, and evaluate treatment regimens using real-world data.

INTRODUCTION

The discovery of cancer genomics and personalized medicine has revolutionized the world of medicine. This research has unlocked the genetic secrets of cancer, making it possible to develop treatments tailored to each patient. This discovery has improved the chances of accurate diagnosis, effective treatment, and recovery. Scientists are continuously researching cancer genomics and patient-specific treatment approaches. They are using advanced genetic technology and bioinformatics to understand the details of each patient's DNA. This allows for the development of specific drugs and therapies that are more effective and safer, thus opening up new hopes for scientists. Cancer genomics and personalized treatment strategies are developed based on the genetic makeup of the human body. In this way, specific drugs are prescribed based on the mutations found in each individual's DNA. This causes less damage to the body and makes the treatment more effective. Our knowledge of cancer biology has grown dramatically over the past decade, but many new potential disease targets have emerged, but our ability to translate these findings into effective treatments was limited by around 90% failure rates. The "valley of death" by pharmaceutical companies in the development of cancer therapy becomes an incredibly complicated phenomenon when pharmaceutical companies' F&E costs are lowered and new molecular units are increasing.. Precision medicine applies artificial inteligence and brain machine learning for create and use database necessary for next generationsequencing (NGS)(Dlamini et al. 2022) . This mini-check provides insight into improving the accuracy and efficiency of cancer moral development, while also explaining curiosity-based research and rigorous preclinical and clinical drug elimination procedures practiced in the industry. DNA is the most important molecule in cell reproduction, and tumor cells grow faster than normal cells, so searching for anticancer drugs has been running for over 50 years.

As a result, DNA is often the target of anticancer drugs, and the overwhelming majority of drug therapies used today damage DNA, preventing cell growth and ultimately killing cells. However, over the past decade or three decades, a new era

of cancer therapy has been created, with chronic oral therapy with molecular targeted medicinal drugs replacing intravenous administration of cytotoxic and non-specific chemotherapy. New and modern therapies for cancer have been made possible by assessing many genetic and functional biological properties to define tumor cells from normal cells. These properties are called cancer properties. (Compton et al., 2020). Diet also plays an important role in cancer genomics and patient-specific treatment strategies. Based on each patient's genetic makeup and the nature of the disease, an appropriate diet is prescribed, which strengthens the immune system and increases the effectiveness of treatment. Dietary restrictions and a healthy diet are helpful in the fight against cancer. The majority of anticancer drugs are specifically designed for specific molecular targets with these properties. Ten features of cancer cells, including sustained proliferation signals, growth-detachment, and restricted cell death, cause tumor growth and metastasis. A series of biopharmaceuticals containing small molecules, monoclonal antibodies, and non-antibody proteins have been discovered and used to treat various forms of cancer based on these license plates for target identification. Over 200 biopharmaceuticals for cancer have already been approved, and many other clinical studies have invaded II and II studies or other stages of phase I and II preclinical development. Used as individual active ingredients or combination programs, these agents revolutionize cancer treatment by converting previous deadly cancers into chronic diseases instead of fatal conversion. This is a classic example of all the new fields of personalized medicine. Nevertheless, the long-term ability to stabilize or cure malignant disease due to primary or secondary drug resistance, the efforts of residual cancer stem cells, and side effects of drug products remain limited. . (Dragu et al., 2015) Oral routes for these drugs ensure a higher quality of life, but post-treatment recurrence is virtually inevitable, and treatment failure and intolerance are rare. Furthermore, the transition to target agents brings a new paradigm for cancer treatment.

In this paradigm, an increase in oral chemotherapy is an increasing challenge. (Foulon et al., 2011) The mechanism of pharmaceutical resistance in targeted therapy for cancer is narrow and detailed along with tumor heterogeneity, and can be a component of treatment under drug stress and selective pressure in melanoma cells in human lung capacitor cells. Another figure was a patient with metastatic breast cancer treated with the inhibitor Byl719, and the patient showed a long-term clinical response. Nevertheless, the patient became resistant to the drug and died a few days later. (Little et al., 2002). The ability of targeted drug translation research to generate more clinically relevant data is important as it can be used to investigate the combination of resistance and rational medication and lead the "go-go" or "no-go" untechnology. (Neville et al., 2020) Two different approaches are often central to efforts to understand resistance. Genetic molecular profiling with radiation index increase probability of early cancer diagnosis and provide proper radiotherapy treatment of breast or liver tumours(Zeidane et al. 2025). Radiotherapy and chemiotherapy assisted with machine learning are efficient for treatment of locally advanced esophageal and rectal cancers (Boniface et al. 2021).

Genomic-Driven Therapeutic Interventions

Using this strategy, physicians and researchers will better predict which programs to prevent illness, and treatment in different population groups will be effective. This is the opposite of "one-size-fits-all" strategies in which prevention and treatment programs for the general population are created without taking into account individual characteristics. The term "Precision Medicine" has long been in healthcare, but the term itself was recently created. For example, randomly selected donor blood is given to patients who require a transfusion. To minimize the risk of problems, the recipient's blood type is compared to the donor's blood type. Although the majority of clinical specialties have cases, precision medicine plays a relatively low role in everyday healthcare. Researchers are investigating the future and looking at strategies in many areas of health and healthcare. One of the treatment choice options as a possible number of patients with many different cancers is often molecular testing, allowing physicians to choose treatment to maximize survival, while simultaneously avoiding the risk of side effects. In order for patients and health service providers to achieve accurate and clinically relevant results, the FDA seeks to ensure the accuracy of the NGS test.

The FDA also poses other regulatory challenges due to the vast amount of data generated by the NGS. Current regulatory approaches are suitable for traditional diagnosis of diseases and conditions (such as blood glucose and cholesterol), but a single test with these new sequencing methods covers millions of tests. To develop an agile regulatory strategy for this rapidly developing technology, the FDA has worked with key interest groups in the industry, laboratories, academic centers, associations of patients and professionals. The FDA also used advanced open-source computing technology and consensus to support the creation of NGS tests. This approach increases testing and research innovation and accelerates the availability of more accurate and reliable genetic testing. A better understanding of the molecular pathogenesis of a disease is the basis of precision medicine, allowing patients to better identify who respond to a particular course of treatment. This explains the general observation that patients who appear to have obviously the same clinical diagnosis or symptoms usually respond differently to the same treatment scheme. Patient characteristics known as biomarkers are markers of disease process or medical ability aims to become a drug.

(2021), (Mirnezami et al., 2021), and patients' characteristics are markers of disease process.

Germline-Inherited and Somatically Acquired Mutations

This is a specific technique that allows researchers to remove and insert DNA into specific locations. The controversy over the social and ethical aspects of human genetic change was supported by major advances in gene editing technology. The double helix structure of DNA was discovered in the 1950s, and since then there has been an idea that genetic processing can be used to treat diseases and alter their properties. Identifying the latter has the inevitable assumption that genetic

diseases could be avoided or even reversed by discovering "molecular errors" that are responsible for them.
The technology was suitable for some contexts, but its limited applicability makes it difficult to promote. Scientists build gene therapy, a drug therapy with DNA modifications as an ingredient, to heal and avoid human disease. Device enzymes can be used to treat diseases that have developed, such as diabetes and cystic fibrosis. Two different types are somatic cells and germline therapies with genetic therapy. Kaneburn treatment processes DNA from germ cells such as sperm and eggs. Germ cells' DNA changes migrate to subsequent generations. However, somatic cell methods deal with non-germ cells. These non-germ cell changes affect only patients who have received gene therapy. In 2015, a one-year-old girl, Leila, was treated with genetic processing so that she could fight cancer known as leukemia, and doctors began somatic gene therapy, but instead of applying CRISPR to heal Layla, she used the story. Genome processing is just one of the techniques scientists use to investigate many human diseases. They have many genes along with people, so they change the genome of animals such as zebrafish and mice. For example, people and mice have over 85% of the same genes! Scientists can examine the effects of altering one or more mouse genes on animal health and speculate about possible consequences of the same changes in the human genome
. (Gaj et al., 2016)

Biotechnology-Driven Cancer Therapies
Active immunotherapy utilizes the immune system to specifically target tumor cells. As a cancer vaccine for CAR-T cells, antibody-directed therapy, and treatment, or as a therapeutic vaccine. These vaccines work by strengthening the body's immune system and attacking cancer. Passive immunotherapy, on the other hand, enhances the performance of the immune system in attacking tumor cells rather than specifically targeting tumor cells. Cytokines and checkpoint inhibitors are just a few examples. By identifying specific markers called antigens, activated cell therapy attempts to destroy cancer cells. New immunotherapeutics are being developed by medical professionals to treat other forms of cancer. T-lymphocytes are taught by checkpoint proteins and other proteins to determine when to turn on/off. (Consider traffic monitors that regulate traffic by switching and maintaining stems.) T lymphocytes are recommended to destroy cancer cells to kill cancer cells. To avoid healthy cells, they are closed. Protein cells cannot lower T cells if the connection is isolated. In this way, T cells continue to kill cancer cells.. (Farkona et al., 2016). Biology-based engineered cells combined with machine learning allow for formulating alternative treatmetn for drug therapies. (Yi et al. 2025).

Treatment Resistance
Similar to microbial infections, a serious obstruction to cancer treatment is drug resistance, which leads to 90% of cancer-affected patients' deaths(Ingham et al., 2025) . The major obstacle to effective cancer treatment is the emergence of drug resistance. When patients take old or specific drugs, sometimes cancer cells can defeat the effects of these drugs. This weakens the treatment and can lead to relapse. Most cancer patients develop resistance to chemotherapy, radiation,

targeted therapy molecules, and immunotherapy. This resistance reduces the effectiveness of the treatment and hinders the long-term survival of the patient. Therefore, it is necessary to re-evaluate the treatment. Drug resistance and treatment failure can occur for a number of reasons. These include genetic changes, cancer cell mutations, drug malabsorption, and the patient's immune system and late detection of cancer. These factors affect the treatment process and allow the disease to relapse. Resistance to treatment occurs when some cells become resistant to drugs. This resistance is often due to genetic changes that are already present in the tumor. These changed cells make the drugs less effective and make it harder to control the disease. However, malignant tumors use both epigenetic and non-genetic mechanisms to develop resistance to drugs. Epigenetic changes alter the expression of genes in cells, while non-genetic factors affect the cell's environment and signaling. Both of these mechanisms reduce the effectiveness of treatment and perpetuate the disease. It is important to understand that cancer cells in the same patient may be resistant to some drugs and sensitive to others. The same situation can be seen in breast cancer or metastatic breast cancer. This complex resistance strategy of cells makes treatment more difficult and increases the need for research.

Drug resistance in breast cancer is a complex clinical problem that arises due to multiple molecular changes. These changes include genetic mutations, alterations in signaling pathways, and alterations in the cellular environment. These factors make drugs less effective and make it difficult to control the disease. While receptor-targeted drug therapy over the past decade has been an impressive hope for the struggle for hormone-positive breast cancer, several studies have shown that selective pressures in treatment affect tumor growth. To enhance complexity, resistance induced by targeted therapy is a factor and vice versa. This is because it is often used in targeted therapies of the clinical ER+ or HER-2+ subtypes. Each resistance mechanism is paired with a variety of treatment plans and drugs suitable for the individual clinical context. Active substances that specifically inhibit any method have been targeted in preliminary clinical studies. For example, the active ingredient influx pump is inhibited by verapamil, whereas hormonal therapy resistance is targeted for rapamycin. Acquired treatment resistance is one of the main roadblocks for effective cancer treatment. In the early stages of tumorigenesis, when genetic mutations cause abnormalities of conventional caspase-mediated apoptosis, relative resistance of transformed cells is usually provided by inducing a wide range of stimuli, including the host immune system and apoptosis, including the transformed cells. Apoptosis-inducing therapy is increasingly being selected for its defects in apoptosis. A multidrug-resistant process occurs when cancer cells with efficient excretion of therapeutic agents are resistant.

. (Marine et al., 2020)

Liver metastasis

This situation makes metastasis more apparent. When cancer cells develop resistance to drugs, they easily spread to other parts of the body. Due to this spread, the disease becomes more dangerous and complicated. Therefore, prevention of metastasis and better treatment strategies are of utmost

importance. When they are excised, they are considered as black spots of solid peritoneum. These cells or tissues remain as remnants of the original cancer. Their presence increases the risk of recurrence of the disease and makes complete cure difficult. Therefore, complete drainage is essential. Imaging is part of the standard follow-up examination of cancer patients, but is usually performed using computed tomography (CT) using PVP (portal vein phase). This method can detect cancer cells hidden in the internal parts of the body or re-forming tumors in a timely manner, which is helpful in treatment. CT scans are so common and readily available that they can be accessed quickly by most patients, especially for this type of surgery. It helps doctors pinpoint the exact location and condition of the affected area, which improves surgical planning and treatment outcomes. Lumps or masses found in these surveillance patients are beyond the capabilities of the CEUS center. CEUS (contrast-enhanced ultrasound) can identify small or obvious masses, but it is not possible to fully diagnose complex or large lumps. Therefore, advanced imaging techniques are required. However, CT and MRI can provide inconclusive results within this group. One of the main features of the CEU is to effectively rule out these results. All the processes of the mechanism are different, but they all affect each other. Clinical symptoms and imaging are the main ways in which liver metastasis in breast cancer is identified. Surgical resection is the main treatment for this type of metastasis and can also involve chemotherapy and interventional therapy. Although further research needs to be conducted to establish this in the end, immunotherapy will be developed in relation to the development of liver breast cancer metastasis. Quantitative multiparametric magnetic resonance imaging (MRI) biomarker MRI (mpMRI) scan allows for early diagnosis of operable cases(Welsh et al, 2025).

Prevention and Management of Liver Metastasis in Cancer Patients

Two strategies are required to prevent liver metastasis. First, major cancer lesions must be suppressed through surgical intervention, chemotherapy, and radiation therapy. Second, immunotherapy and high-frequency expansion can prevent liver metastasis in triple-negative breast cancer (TNBC) patients and slow down its progression. The future of TNBC therapy is ensured by the development of new targeted drugs and a deeper understanding of the tumor microenvironment. Most primary neoplasms can metastasize in the liver, including melanoma, colorectal, breast, kidney, and pancreatic cancer. A correct diagnosis of liver metastasis is critical before these patients receive appropriate treatment. Patients with liver and metastasis may require systemic chemotherapy or segmental and frequent dilation, whereas liver and metastasis-free patients may receive terminal surgical therapy. Therefore, a correct diagnosis of liver metastasis in individuals with primary malignant disease is of utmost importance. The liver is one of the most common sites for metastasis from solid malignancy. Imaging is performed when the normal liver shows several liver masses. In only 20% of cases, liver metastasis is seen as a solitary lesion and occurs in both liver lobes. The most common cause of liver metastasis is pancreatic, stomach, and intestinal cancers (most often the stomach and large intestine).(Horn et al., 2020). Activation of Major facilitator superfamily domain containing protein-2a (Mfsd2a)is crucial in the prevention on cancer cell progression from liver to colorectalcancer cell line (Sun et al. 2025).

Metabolic Reprogramming of Cancer Cells

A hallmark of cancer cell growth is metabolic reprogramming, which enables these cells to adapt their survival to environmental challenges and meet their escalating nutritional and energy demands. Cancer cells efficiently utilize nutrients to synthesize proteins, lipids, and nucleotides, thereby sustaining continued growth. These cells sequester nutrients from their microenvironment to support their proliferation and survival. To accommodate evolving microenvironments and therapeutic interventions, cancer cells can alter their metabolic pathways. These changes enable them to acquire more nutrients, store energy, and produce new biomolecules, thereby developing resistance to treatment and ensuring their survival. Our mission is to enhance patient outcomes by elucidating the dynamics of metabolic variables and developing personalized treatment strategies tailored to each patient's unique circumstances (Khanile et al. 2025). This not only facilitates effective disease management but also improves the patient's overall health and quality of life. Additionally, lipid and amino acid metabolism can be modified, and cellular antioxidant systems can be restored in cancer cells through glutamine metabolism. Cancer cells often arise due to high growth rates and high metabolic requirements. Glutathione, an essential antioxidant that mitigates oxidative damage, is produced by glutamine.

Glutamine Metabolism and Lipid Biosynthesis in Cancer Progression

Cancer cells exhibit a high demand for glutamine, utilizing it to hydrolyze large molecules and produce nutrient-rich glutamine. Glutamine catabolism targeting has emerged as a promising potential therapeutic strategy. Research has revealed that glutamine inhibition triggers alternative metabolic pathways to counteract immunological escape. High-energy molecules such as glutamine can rapidly provide energy and precursors for the biosynthesis of various biological polymers. Additionally, instead of entering the TCA cycle, aerobic processes also convert a significant proportion of glutamine to lactic acid, thereby reducing reactive oxygen species (ROS) levels, which is advantageous for tumor growth. To sustain activity during invasion, trailing cells also engage in other metabolic processes beyond energy production. To maintain cell structure and function, essential biomolecules such as proteins, lipids, and nucleotides must be synthesized. For instance, lipids are a critical component of the cell membrane, and cancer cells, which are constantly proliferating and increasing, require the synthesis of new membranes. These metabolic connections can be obtained from follower cells through the active collection and utilization of nutrients in microenvironments. Furthermore, follower cells exhibit highly dynamic metabolic activity in response to environmental changes, which is strengthened and deregulated, leading to increased lipid and fatty acid synthesis. (Martinez-Outschoorn et al., 2017). Some cancer cells ‘hacks’ glutamine mechanism of host and instead of overcoming them, support them. (Nan et al. 2025).

Indication of treatment resistanceAntibiotics are ineffective against bacterial infections caused by resistant strains. Antibiotics should only be prescribed and advised by healthcare professionals. Bacteria proliferate whenever possible, and their genetic codes (DNA) can sometimes change or alter themselves as antibiotic defense mechanisms, as observed in *Campylobacter jejuni* (Zhou et al, 2013).. , These newly modified bacteria are unknown to antibiotics, rendering them ineffective. Alternatively, the genetic modifications enable bacteria to withstand the effects of the drug, leading to the spread of drug-resistant, infectious bacterial diseases. In such cases, antibiotics cannot cure the illness, and alternative treatments may become increasingly challenging to implement. Some bacteria, such as *Mycobacterium tuberculosis*, exhibit inherent resistance to antibiotics. The widespread use of antibiotics to treat bacterial infections has contributed to the development of antibiotic-resistant strains. As antibiotic usage continues to rise, the problems associated with antibiotic resistance may worsen. Antibiotics are ineffective against viral infections, although symptoms of viral and bacterial diseases may overlap. Most microorganisms causing antibiotic-resistant infections lack vaccines, with pneumococcal vaccines being an exception. Pneumococcal vaccines protect against pneumonia caused by *Streptococcus pneumoniae* and are recommended for various population segments, particularly for individuals over 65 years and infants under 2 years of age. Other vaccines, such as influenza vaccines, are also crucial for preventing viral diseases.

Liquid Biopsy and Circulating Biomarkers in Cancer Diagnosis and Treatment

The most accurate method for cancer diagnosis remains biopsy, which is also the most effective detection tool. However, when liquid biopsies identify cancer, they provide valuable information about tumor cells that can aid physicians in developing targeted therapeutic agents. Advanced cancer is termed metastatic cancer, characterized by the spread of primary tumors to other parts of the body. Grasso et al. (2025) found choline decrease as sign of metastasis progression. Tumor fragments break down and circulate through the bloodstream. The accuracy of prediction improves when the number of tumor cells is higher. A type of cancer treatment known as targeted therapy aims to eliminate specific subtypes of cancer cells. For instance, targeted therapies can be designed to target DNA errors in cancer cells, which can be detected via liquid biopsies. In contrast to liquid biopsies, traditional biopsies are significantly more invasive. Numerous liquid biomarker diagnostic tests have been developed, and further advancements are being pursued in various research stages.Liquid biopsies for analysis of circulating tumour DNA are efficient method of detection of early-stage cancers (Vavoulis et al. 2025).**Liquid Biopsies: A Faster, Safer Alternative for Cancer Monitoring**

The Food Drug Agency(FDA) has clarified the use of circulating tumor cells (CTCs), which are recognized by diagnostic tests. CTCs are employed to predict outcomes in patients with metastatic colon, prostate, and breast cancer. Physicians at the University of Chicago School of Medicine are increasingly utilizing fluid biopsies, a novel technique that employs rapid blood tests instead of invasive needle biopsies to detect tumor-derived markers. While cancer specialists at the University of Chicago School of Medicine anticipate the benefits of this faster, safer, and more

convenient testing method, needle biopsies remain the gold standard for assessing patients' genetic profiles and cancer diagnosis, particularly for metastatic cancer patients requiring multiple biopsies before and after treatment. Dr. Ali Rosenberg, an oncologist at the University of Chicago School of Medicine, specializing in head, neck, and thyroid cancers, highlighted that liquid biopsies can monitor patients' treatment responses and provide real-time updates. As cancer progresses, tumor DNA is shed into the bloodstream, making blood tests more convenient and cost-effective in certain cases compared to needle biopsies, which often require ultrasound or CT scans. A significant advantage of liquid biopsies is their rapid turnaround time, achieving results within a week, approximately 2-3 times faster than tissue-based PSIA for obtaining genetic information. However, liquid biopsies are not universally suitable. Certain individuals with unique genetic profiles may experience distorted test results and false positives. Additionally, repeated fluid biopsies may be necessary if a malignant tumor is identified(Ignatiadis et al., 2021). Kurzeder et al. 2025 recommended digoxin for reducing CTCT..

The Role of Thiamine and Riboflavin in Cancer Genomics and Personalized Medicine The importance of thiamine in cancer genomics and patient-specific treatment strategies has been emphasized. Thiamine is crucial for energy production and cellular metabolism within the body. Thiamine deficiency has been observed in certain cancer patients, and its replenishment can enhance treatment efficacy and mitigate weakness. A strong association exists between riboflavin and cancer. Riboflavin (vitamin B2) aids in cellular energy production and strengthens antioxidant defenses. Sufficient levels of riboflavin help reduce the detrimental effects of cancer cells. Several studies have linked riboflavin deficiency to cancer development, suggesting its therapeutic potential.. B vitamins administration reduces Warburg effect (Frost et al. 2025)Conclusion

The development of individualized therapies tailored to each patient's genetic profile holds promise for significantly enhancing treatment efficacy while reducing adverse effects. Immunotherapies, such as CAR-T cell therapy and immune checkpoint inhibitors, have demonstrated unprecedented success in treating various cancer types, with efforts underway to expand their use across diverse tumor entities. Additionally, the progression of early detection through liquid biopsies, combined with the exciting prospects of genetic processing, cancer vaccination, and nanomedicine, may revolutionize disease diagnosis and treatment paradigms. These advancements hold great promise, yet they must address critical challenges: (1) Drug resistance, (2) Increasing access to novel therapies, and (3) Personalized cancer treatments. Concurrently, advances in clinical research, medicine, and tailored treatment protocols are accelerated by convergent cancer therapies, as science continues to push boundaries and ultimately paves the way for a future of controllable or curable diseases.

References

Abou Zeidane, R., Lichtman-Mikol, S., & Speers, C. (2025). Genomic Molecular Profiling in Breast Cancer: Transforming Radiation Decision-Making Through Precision Medicine. *Current Breast Cancer Reports*, *17*(1), 1-15.

Boniface, C.; Deig, C.; Halsey, C.; Kelley, T.; Heskett, M.B.; Thomas, C.R., Jr.; Spellman, P.T.; Nabavizadeh, N. The Feasibility of Patient-Specific Circulating Tumor DNA Monitoring throughout Multi-Modality Therapy for Locally Advanced Esophageal and RectalCancer: A Potential Biomarker for Early Detection of Subclinical Disease. *Diagnostics* **2021**, *11*, 73. https://doi.org/10.3390/diagnostics11010073

Dlamini, Z., Skepu, A., Kim, N., Mkhabele, M., Khanyile, R., Molefi, T., ... & Hull, R. (2022). AI and precision oncology in clinical cancer genomics: From prevention to targeted cancer therapies-an outcomes based patient care. *Informatics in Medicine Unlocked*, *31*, 100965.

Foulon V, Schöffski P, Wolter P. Patient adherence to oral anticancer drugs: an emerging issue in modern oncology. Acta Clinica Belgica. 2011 Apr 1;66(2):85-96.

Frost, Z., Bakhit, S., Amaefuna, C. N., Powers, R. V., & Ramana, K. V. (2025). Recent Advances on the Role of B Vitamins in Cancer Prevention and Progression. *International Journal of Molecular Sciences*, *26*(5), 1967. https://doi.org/10.3390/ijms2605196

Gaj T, Sirk SJ, Shui SL, Liu J. Genome-editing technologies: principles and applications. Cold Spring Harbor perspectives in biology. 2016 Dec 1;8(12):a023754.

Grasso, D., Marzocchi, B., Scoccianti, G., Palchetti, I., Campanacci, D. A., Antonuzzo, L., Scolari, F., Pillozzi, S., & Bernini, A. (2025). Untargeted Metabolomics and Liquid Biopsy Investigation of Circulating Biomarkers in Soft Tissue Sarcoma. *Cancers*, *17*(3), 553. https://doi.org/10.3390/cancers17030553

Ignatiadis M, Sledge GW, Jeffrey SS. Liquid biopsy enters the clinic—implementation issues and future challenges. Nature reviews Clinical oncology. 2021 May;18(5):297-312.

Ingham, J., Ruan, J. L., & Coelho, M. A. (2025). Breaking barriers: we need a multidisciplinary approach to tackle cancer drug resistance. *BJC reports*, *3*(1), 11.

Khanyile, R., Chipiti, T., Hull, R., & Dlamini, Z. (2025). Radiogenomic Landscape of Metastatic Endocrine-Positive Breast Cancer Resistant to Aromatase Inhibitors. *Cancers*, *17*(5), 808. https://doi.org/10.3390/cancers17050808

Kurzeder, C., Nguyen-Sträuli, B. D., Krol, I., Ring, A., Castro-Giner, F., Nüesch, M., ... & Aceto, N. (2025). Digoxin for reduction of circulating tumor cell cluster size in metastatic breast cancer: a proof-of-concept trial. *Nature Medicine*, 1-5.

Lee, J., & Hahn, S. (2018). Precision oncology: New developments and challenges. *Clinical Cancer Research*, 24(23), 5377–5383.

Longley DB, Johnston PG. Molecular mechanisms of drug resistance. The Journal of Pathology: A Journal of the Pathological Society of Great Britain and Ireland. 2005 Jan;205(2):275-92.

Little SJ, Holte S, Routy JP, Daar ES, Markowitz M, Collier AC, Koup RA, Mellors JW, Connick E, Conway B, Kilby M. Antiretroviral-drug resistance among patients recently infected with HIV. New England Journal of Medicine. 2002 Aug 8;347(6):385-94.

Nan, D., Yao, W., Huang, L., Liu, R., Chen, X., Xia, W., ... & Lu, Y. (2025). Glutamine and cancer: metabolism, immune microenvironment, and therapeutic targets. *Cell Communication and Signaling*, *23*(1), 45.

Sun, L., Li, X., Xiao, Y., Yu, W., Chen, X., Wang, Z., ... & Pu, L. (2025). Mfsd2a suppresses colorectal cancer progression and liver metastasis via the S100A14/STAT3 axis. *Journal of Translational Medicine*, *23*(1), 59.

Welsh, F., Sundaravadanan, S., Sethi, P., Kazeroun, M., Fichera, A., Nadziruddin, I., ... & Rees, M. (2025). Quantitative liver function imaging and whole genome sequencing–Effective modalities for a new era in personalised decision-making for operable colorectal liver metastases?. *HPB*.

Yi, W., Hu, S., Qian, X., Yan, W. and Li, Y. (2025), Synthetic Biology-Based Engineering Cells for Drug Delivery. Exploration, 5: 20240095. https://doi.org/10.1002/EXP.20240095

Vavoulis, D.V., Cutts, A., Thota, N. *et al.* Multimodal cell-free DNA whole-genome TAPS is sensitive and reveals specific cancer signals. *Nat Commun* **16**, 430 (2025). https://doi.org/10.1038/s41467-024-55428-y

Zhou, Y., Bu, L., Guo, M., Zhou, C., Wang, Y., Chen, L., & Liu, J. (2013). Comprehensive genomic characterization of Campylobacter genus reveals some underlying mechanisms for its genomic diversification. *PloS one*, *8*(8), e70241.