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RESEARCH

# Beyond tumor eradication: how modern cancer research is reshaping survival and quality of life

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Research on cancer has long been interested in the effectiveness of treatments in terms of reducing tumor size and survival of the cancer patient. Although it is still quite important to make cancer tumors disappear, recent developments in cancer science and medicine have broadened the definition of success and shifted it more towards the patient. Nowadays, more emphasis is placed on the length of life of persons after cancer and their functioning and sensations regarding health than ever before. Immunotherapy, targeted therapy, and improved supportive care as new treatment approaches have enabled many individuals to live longer with controlled cancer but also raised new clinical and social problems. The long lives have resulted in new issues such as the persistent side effects, mental health challenges, financial issues, and inequality in the access to these new and improved treatments. The paper examines recent discoveries in cancer research and the way alterations in the treatment are transforming the meaning of having a longer life and how it is transforming the quality of life for people. It talks of the key breakthroughs in the field of immunetherapy and molecular science, how patients rate their health, what is known about living longer with cancer, and what is right and fair as changes to cancer treatment continue to occur.

**Keywords:** cancer research, ongoing study, quality of life, immunotherapy, precision oncology, patient-reported outcomes

## Introduction

Cancer continues to be among the leading causes of morbidity and mortality in the world. It is a huge issue even after many years of struggle and development of new methods of treating the disease. Previously, the objective of treating cancer was solely to ensure that the condition disappears permanently. The success was largely determined by the extent to which the tumors were reduced or the duration of time during which the patients remained cancer-free and alive. These are still very important, but they do not give the entire picture of what patients experience (1–3). Our thinking on cancer has evolved in recent years due to various new discoveries in biology, immunology, genetic research, and the way we test new treatments. These changes have been able to save a number of lives and, in some cases, have transformed some of the cancers into conditions that people can live with over a longer period of time. Due to this, the impact of cancer and its cure has become increasingly evident, and a good number of them are reconsidering what true success in curing ought to be like. Nowadays the cancer world understands that to live longer and not to think about whether the patient is well or not in terms of physical, mental, and social levels is not the whole story. Cancer studies have become a major concern now because of the quality of life (QoL) and the success of a patient following

cancer treatment. This review examines the ways in which the new science is transforming the duration of life, as well as the QoL, of people. It demonstrates that the objectives of cancer research are evolving in the era of more targeted and customized therapy (4–7).

## Evolution of treatment goals in oncology

The initial stage of cancer management was concerned with cytotoxic chemo treatment and big surgeries. Such techniques, though helpful in certain instances, tended to be highly toxic and have long-term health problems. The success was largely determined by scans and rates of survival, and not often by the account of the patient. Combination chemo, adjuvant therapy, and multi-modal treatment began, which increased the rate of cure in certain cancers such as breast cancer, Hodgkin lymphoma, and testicular cancer. However, these benefits were accompanied by some long-term consequences such as cardiovascular damage, secondary cancers, infertility, and brain problems. Consciousness of these effects resulted in a slow increase in the scope of cancer research beyond tumor outcomes. Treatment objectives have become broader in the present day. In addition to controlling tumors, physicians and researchers now consider the feelings of the sick individuals, how many of them work or are able to do their everyday activities, the extent to which they can bear the treatment, and their desires. Regulators and funders have contributed towards this change and now emphasize more on results that are important to patients in clinical trials (8–11).

## Advances in immunotherapy and their impact on survival and quality of life

One of the most viable discoveries of the new cancer fight is immunotherapy. Programmed cell death protein 1 (PD-1), programmed cell death ligand 1 (PD-L1), and cytotoxic T lymphocyte antigen 4 immune checkpoint inhibitors have provided long-term outcomes in numerous cancer forms, including melanoma, non-small cell lung cancer, kidney cancer, and head and neck cancer. In contrast to chemo, immunotherapy is able to provide long-term control of the disease in some individuals even after taking medicine. This has brought fresh hope to cancers that had a very bad prognosis. Immunotherapy is typically not as difficult to administer as chemo drugs, in terms of good living, but there are also dangers of immune-related side effects (12–16). Examples of immune-based therapies that can provide more people with an opportunity to live include chimeric antigen receptor (CAR) T-cell therapy (its challenges were shown in **Figure 1**), bispecific antibodies, and cancer vaccines. However, they may also introduce new issues, including cytokine release syndrome, brain effects, and extremely high costs, potentially disadvantaging patients as well as causing other people to have a difficult time accessing such treatments. Some of the ongoing clinical trials are discussed in **Table 1**.

This scheme shows the key biological impediments to the effectiveness of CAR T-cell therapy in solid malignancies. (1) Tumor heterogeneity and antigen escape: Solid tumors are made up of different cell types with different or low expression of tumor-associated antigens (TAAs), and

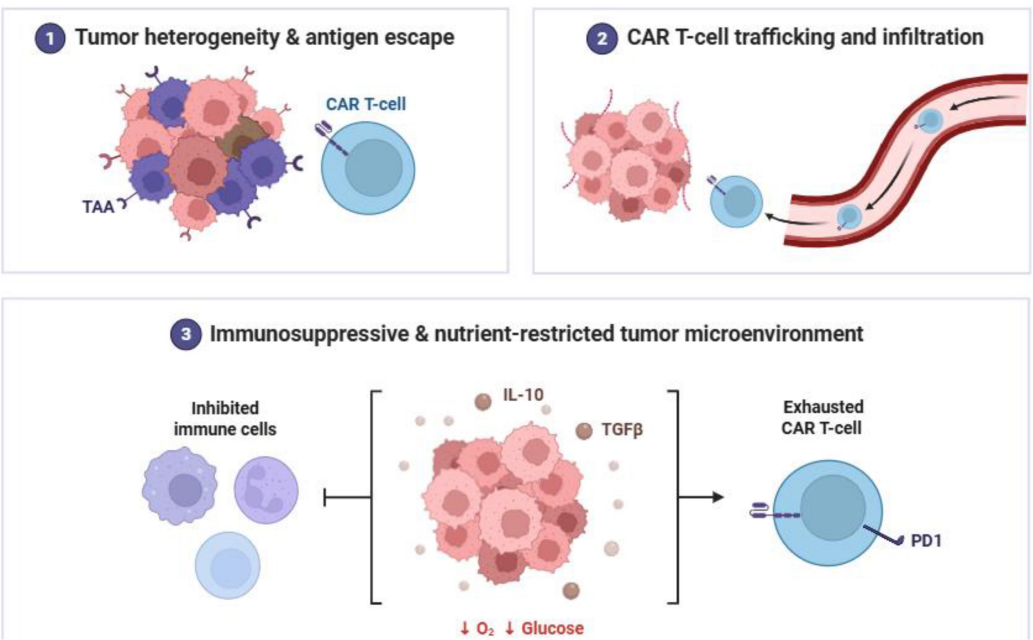


**FIGURE 1 |** Challenges involved in chimeric antigen receptor (CAR) T cell therapy.

**TABLE 1 |** Selected ongoing and recent clinical trials in modern cancer research.

| Sl. no. | Therapy/approach | Cancer type | Trial ID | Phase | Key focus | Sponsor |
|---|---|---|---|---|---|---|
| 1 | Personalized mRNA cancer vaccine + anti-programmed cell death protein 1 (PD-1) | Melanoma | NCT03897881 | Phase II | Recurrence-free survival and immune response | Moderna/ BioNTech |
| 2 | CAR-T cells targeting CLDN18.2 | Gastric cancer | NCT04404595 | Phase I/II | Overall survival and safety | CARsgen |
| 3 | KRAS G12C inhibitor (Adagrasib) | Non-small cell lung cancer (NSCLC) | NCT03785249 | Phase II | Progression-free survival | Mirati Therapeutics |
| 4 | Bispecific T-cell engager (CD3 × BCMA) | Multiple myeloma | NCT04649359 | Phase I | Response durability and tolerability | Amgen |
| 5 | Circulating tumor DNA (ctDNA)-guided adjuvant therapy | Colorectal cancer | NCT04050345 | Phase III | Minimal residual disease monitoring | NCI |
| 6 | AI-assisted radiotherapy planning | Head and neck cancer | NCT05013099 | Phase II | Toxicity reduction and QoL | MD Anderson |

this allows cancer cells to avoid CAR T-cell recognition. (2) Damaged CAR T-cell trafficking and infiltration: Tumor vasculature and stromal architecture: Abnormal vascular structure and thick stroma impede effective homing and infiltration of CAR T cells into the tumor mass. (3) Immunosuppressive and metabolically adverse tumor microenvironment: The CAR T-cell dysfunction and exhaustion (inhibitory receptor expression, e.g., PD-1) are caused by inhibitory cytokines (e.g., IL-10, TGF-$\beta$) and immunesuppressive cells, hypoxia, and nutrient deprivation (reduced oxygen and glucose). All of these together make CAR T-cell therapy less persistent, active, and antitumor in solid tumors.

## Precision oncology and targeted therapies

Precision oncology has revolutionized the process of cancer treatment and concentrated on the molecular fabric of every tumor. Recent technologies such as DNA sequencing and markers have enabled us to identify drugs that are specific to certain cancer-causing genes such as epidermal growth factor receptor (EGFR), human epidermal growth factor receptor 2 (HER2), BRAF, and Kirsten rat sarcoma viral oncogene homolog (KRAS). Therapies targeting these genes have provided improved outcomes and extended lifespans to individuals with numerous types of cancer, and the therapy has a lesser number of side effects than typical chemo (17). This has contributed to improved lives of most patients. Nevertheless, the issue of cancer resistance is massive in scale, and drugs are frequently administered in combinations and observed at the molecular level in patients. Precision oncology has also been aided by liquid biopsy tech to enable us to observe the changes and responses of tumors in real time. Such noninvasive tests imply that patients do not need to receive tissue samples so frequently, and they can detect resistance in the initial stages, which helps patients to treat it much faster and more conveniently (18–24).

## Cancer as a chronic disease: implications for survivorship

The number of people who beat cancer is high, and this is a big win for today's cancer work. But it also brings new issues for the health systems. Survivorship covers the physical, mental, and social effects seen by patients from the time they find out they have cancer until they are out of active treatment for a long time. The long-term survivors may have ongoing symptoms like tiredness, pain, nerve issues, and thinking problems. Also, mental stress, fear of the cancer coming back, and issues fitting back into society are often seen. As survivorship grew, research on it increased, working on ways to help through recovery programs, mental health care, and changes in how people live. Survivorship studies also focus on how important it is to have well-planned follow-up care, which can include watching for delayed effects, other cancers, and other health problems. This full care system shows the new thought that cancer treatment does not end with active care (25–28).

## Patient-reported outcomes and quality-of-life assessment

Cancer studies and care now use patient-reported outcome measures (PROMs), which are patient-reported outcome measures. They demonstrate patient attitudes towards symptoms, functioning, and QoL. This provides valuable information that will supplement regular health examinations. The inclusion of PROMs in the studies

**TABLE 2** | Recent patents related to emerging cancer therapies and quality-of-life–focused innovations.

| Sl. no. | Patent/application title (representative) | Patent/publication no. | Year | Technology area | Relevance to modern cancer research |
|---|---|---|---|---|---|
| 1 | Compositions and methods for mRNA cancer vaccines encoding tumor neoepitopes | WO2021155149 A1 | 2021 | Personalized mRNA cancer vaccines | Foundational intellectual property covering mRNA vaccines encoding multiple tumor-specific neoantigens for individualized cancer immunotherapy |
| 2 | Methods for personalized mRNA cancer vaccination | WO2024151811 A1 | 2024 | Precision oncology/mRNA vaccines | Describes next-generation individualized mRNA vaccine design, manufacturing, and administration strategies |
| 3 | Chimeric antigen receptor T cells with enhanced tumor infiltration | WO2020190902 A1 | 2020 | CAR-T cell therapy (solid tumors) | Claims CAR-T constructs co-expressing chemokine receptors to improve trafficking and infiltration into solid tumors |
| 4 | RNA formulations for targeted delivery to antigen-presenting cells (APCs) | US10485884 B2 | 2019 | RNA delivery/ immunotherapy | Covers lipid nanoparticle and RNA formulations optimized for immune activation with reduced systemic toxicity |
| 5 | Selective inhibitors targeting mutant Kirsten rat sarcoma viral oncogene homolog (KRAS) proteins | Representative KRAS inhibitor patent families (e.g., Mirati/Amgen) | 2020–2024 | Targeted molecular therapy | Patent families supporting KRAS G12C and emerging KRAS-variant inhibitors used in precision oncology |
| 6 | Sustained-release compositions for immunotherapeutic agents | WO2023178456 A1 | 2023 | Drug delivery systems | Describes controlled-release platforms designed to prolong immunotherapy exposure while reducing dosing frequency and adverse effects |

demonstrates that although treatments may enable patients to live longer, the impacts of the treatment on patient feelings may be quite variable. This has altered the manner in which doctors make decisions in regard to treatments, approval of medicines, and the collaboration of patients and doctors. Evidence on health apps and electronic records also provides further evidence on the QoL among most patient groups. These realities assist in making the treatment of cancer more equal and individualized (29, 30).

## Ethical and societal considerations in modern cancer research

Ethical concerns have been compounded with the increase in treatment options. Decisions regarding the intensity of the treatment, whether to continue the treatment in the advanced stage of the disease, and the methods of distributing the limited resources all require careful decisions regarding what is in the best interest of a patient, their QoL, and their preferences. The cost factor has been central in the form of financial strain, particularly expensive targeted medications and immunotherapy. Money trouble may lead to abandonment or worse mental states in patients; hence, the necessity to modify policies and conduct research on the topic of cost and value is high. It is a challenging process to ensure the provision of the best cancer treatments to every corner of the world. The disparities in terms of location, wealth, and health systems continue to influence the outcomes; hence, it is essential to incorporate different studies and collaborate internationally. Some of the recent patents in cancer technologies were discussed in **Table 2** (31).

## Future directions in cancer research

It is probable that in the future the studies of cancer will combine biological breakthroughs with a patient-oriented perspective. Better detection, better treatment plans, and better survivorship may be achieved by AI, systems biology, and digital health tools. The less strong, yet effective, de-escalation strategies are gaining popularity, particularly in the case of early and low-risk cancers. This is capable of assisting the patients to maintain their life as good without a loss in the length of their life. Finally, it will be the capacity of the modern cancer work to be integrated into new science in the way people live, to ensure that the purpose of life is not only to live longer but also to live better (32–38).

## Conclusion

Nowadays research of cancer has passed miles behind attempting to kill tumors. The emergence of new treatments such as immunetherapy, targeted drugs, and new ways of providing care is providing many with a better chance at living, yet it is also highlighting the importance of how people live. With the beginning to treat cancer as a long-term disease, the research should be changed in its direction to survivorship, QoL, and ethics. The human touch is adding to the science of cancer care and is not only

prolonging the longevity of people but also their well-being by improving the QoL.

## List of abbreviation

CAR: chimeric antigen receptor; CAR-T: chimeric antigen receptor T-cell; TAA: tumor-associated antigen; PD-1: programmed cell death protein 1; PD-L1: programmed cell death ligand 1; CTLA-4: cytotoxic T-lymphocyte–associated protein 4; IL-10: interleukin-10; TGF-β: transforming growth factor-β; ctDNA: circulating tumor DNA, PROMs: patient-reported outcome measures; QoL: quality of life; EGFR: epidermal growth factor receptor; HER2: human epidermal growth factor receptor 2; KRAS: Kirsten rat sarcoma viral oncogene homolog; NSCLC: non-small cell lung cancer; ADC: antibody–drug conjugate; AI: artificial intelligence; APC: antigen-presenting cell; BCMA: B-cell maturation antigen; CDK4/6: cyclin-dependent kinases 4 and 6.

## Author contributions

Conceptualization, literature search, manuscript drafting, validation, grammar corrections and final approval were performed by the author.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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