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CHAPTER 11

The role of the immune system in cancer immunotherapy

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ABSTRACT

Cancer is a globally distributed disease that has a high mortality rate and is associated with various risk factors such as smoking, pollution, excessive sun exposure, as well as genetic factors and hereditary genetic alterations. Its development is associated with alterations at a molecular level, generating cell mutations. Traditional treatments such as chemotherapy and radiotherapy aim to destroy cancer cells or prevent them from multiplying, but they have unfavorable side effects. Thus, the most widely studied therapeutic technique today is immunotherapy, which interferes with the patient's immune system, amplifying its response through the mechanisms of influence of specific cell receptors.

Immunotherapy is a more specific and less reactive way of treating cancer, divided into active and passive. Active immunotherapy is a strategy to restore the patient's immune system, either through the administration of non-specific immunological agents and cytokines, or through vaccines. Passive immunotherapy, on the other hand, is an approach that directly supplies the body with cells and antibodies that are ready for the immune response.

In line with the above, there are various models of immunotherapy, including CAR-T cells, monoclonal antibodies, checkpoint inhibitors and vaccines.

This revolutionary cancer treatment is proving to be a hopeful way of fighting cancer in a precise and effective way, with low rates of side effects.

Keywords: Cancer, Immunotherapy, Cancer treatments, Oncogenesis.

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INTRODUCTION

CANCER

It is of great relevance to address that cancer is not a pathological alteration that is simple to understand, much less of recent onset.

Since the 1930s, it has been observed that chicken sarcoma viruses can cause similar modifications in organ explants and in the chorioallantoic membrane of eggs. This transformation of the cells *in vitro* of tissues affected by the viruses could be compared to the process by which they would cause tumors in the animals. This finding proved to be of great importance with regard to the study of tumors in humans, as it provides a basis for the conception of the probable viral etiology related to some human cancers and for the discovery of activated proto-oncogenes in tumors not associated with viruses (INCA, 2020).

According to the above, in the 1950s, it was possible to observe that some viruses, when in contact with cells *in vitro*, did not cause classic and expected cytopathic effects, but rather the emergence of regions with morphologically altered cell clusters, bringing even more consistent foundations to the previous findings (CHAMMAS and VILLA, 1993).

When addressing the subject of cancer, it is necessary to understand that it refers to cell expansion in an abnormal and disorganized way, leading to aggressive and rapid growth. This modification results from the interaction between the genetics of the individual exposed to the environment and its agents, such as: physical factors, including ultraviolet and ionizing radiation; carcinogenic chemical risk factors, such as substances derived from tobacco, arsenic (a contaminant in drinking water), asbestos, and aflatoxin (a food contaminant); and biological factors, such as viruses, bacteria, or parasites (INCA, 2021).

The process of senility is also shown to be an agent of great relevance in the development of cancer, since long-term exposure to the previously mentioned factors results in an accumulation of damage, responsible for increasing the risks related to carcinogenesis. This fact is combined with the tendency of the effectiveness of repair mechanisms to decrease as the person ages (SILVA and SILVA, 2005)

CANCER EPIDEMIOLOGY: GLOBAL AND BRAZILIAN OVERVIEW

Cancer is a disease with global distribution, so it is relevant to discuss its epidemiology, which is the study of the distribution and determinants of the disease in populations, revealing important data for the development of prophylactic and therapeutic measures (BENEDETTI, FERREIRA, LIMA-REIS, et.al, 2020).

INCIDENCE

According to the World Health Organization (WHO), it is estimated that, in 2020, there were about 19.3 million new cases of cancer in the world. In addition, in relation to Brazil, the National Cancer Institute (INCA) estimates that for the 2023-2025 triennium there will be about 704 thousand new cases of cancer per year. However, excluding non-melanoma skin cancer, that number drops to 483,000 new cases.

Worldwide, the most common types of cancer vary according to sex and geographic region, but the most reported are neoplasms of the lung, breast, colon and rectum, prostate and stomach. In this sense, in Brazil, non-melanoma skin cancer leads the statistics, followed by female breast, prostate, colon and rectum, lung and stomach. (IARC, 2020)

MORTALITY

From the systemic involvement that this pathology can achieve and the severe effects on the individual's immune system that are engendered from the treatment choices of such, it is noted that cancer is a significant cause of death in the world and in Brazil. In this vein, the WHO estimates that, in 2020, about 10 million deaths were caused by cancer. In addition, it should be noted that in Brazil, according to INCA statistics (2020), cancer ranks second among the causes of death by disease.

RISK FACTORS

The risk factors associated with carcinogenesis can be divided into behavioral factors, such as smoking, alcoholism, inadequate diet, sedentary lifestyle, and excessive sun exposure; environmental factors, such as air pollution, radiation, and exposure to carcinogens; and genetic factors, among which family history of cancer and hereditary genetic alterations stand out. (WHO, 2020)

PREVENTION

Thus, many types of cancer can be prevented by adopting healthy habits, such as maintaining a balanced diet, practicing physical activity regularly, avoiding smoking and excessive alcohol consumption, and protecting yourself from the sun. Thus, it reverberates that, both globally and in Brazil, investment in cancer prevention, early diagnosis and appropriate treatment campaigns is essential to reduce the incidence, mortality and improve the quality of life of cancer patients. (INCA, 2020)

MOLECULAR BASIS AND IMMUNOLOGY OF CANCER

Cancer is a complex disease that begins and progresses through a gradual accumulation of mutations in the DNA of cells. These mutations can manifest in several ways, including changes in

the sequence of bases, loss or gain of genetic material, and simple or complex chromosomal rearrangements (BLANK et al., 2016).

The first evidence of the role of mutations in cancer arose from the observation of recurrent and specific genetic changes in certain types of tumors. These alterations, initially observed at the chromosomal level, revealed an intriguing pattern: the mutations affected different stages of the pathways that control cell proliferation, differentiation and survival (GUEMBAROVSKI and CÓLUS, 2008).

As research advances, we understand that cancer is the result of the uncontrolled growth of cell populations that have accumulated mutations over time, in a process known as monoclonal expansion. This process culminates in the formation of tumors, composed of cells with different patterns of genetic alterations, demonstrating great heterogeneity both within the tumor itself and among different patients, even those with histologically similar tumors.

In summary, cancer is a multigenic disease that originates from a single normal cell that accumulates mutations over successive cell divisions, initiating a process of clonal evolution (CAVENE and WHITE, 1995).

Some factors are associated with the oncogenic process, as occurs in the cases of:

SELF-SUFFICIENCY IN SIGNS OF GROWTH

Cancer cells acquire the ability to manufacture their own growth factors, ensuring their uncontrolled growth. Oncogenes and mutated genes act as the mentors behind this self-sufficiency (ONUCHIC and CHAMMAS, 2010).

INSENSITIVITY TO GROWTH INHIBITORY SIGNALS

Cancer cells evade inhibitory signals and continue their proliferation. The retinoblastoma gene, when mutated, contributes to this insensitivity by disrupting the orderly regulation of cell division. (GUEMBAROVSKI and CÓLUS, 2008).

EVASION OF CELL DEATH

Cancer cells are able to escape programmed death, allowing them to accumulate and persist. The p53 gene, a tumor suppressor, plays a crucial role in orchestrating apoptosis. Loss of p53 function enables cancer cells to evade cell death, granting them an unfair advantage (Martinez et al., 2006).

UNLIMITED REPLICATION POTENTIAL

Cancer cells defy natural limitation by acquiring the ability to replicate indefinitely. This immortality results from mutations in specific genes, turning them into perpetual growth machines (CASALICCHIO, SEDA, and SOUZA, 2022)

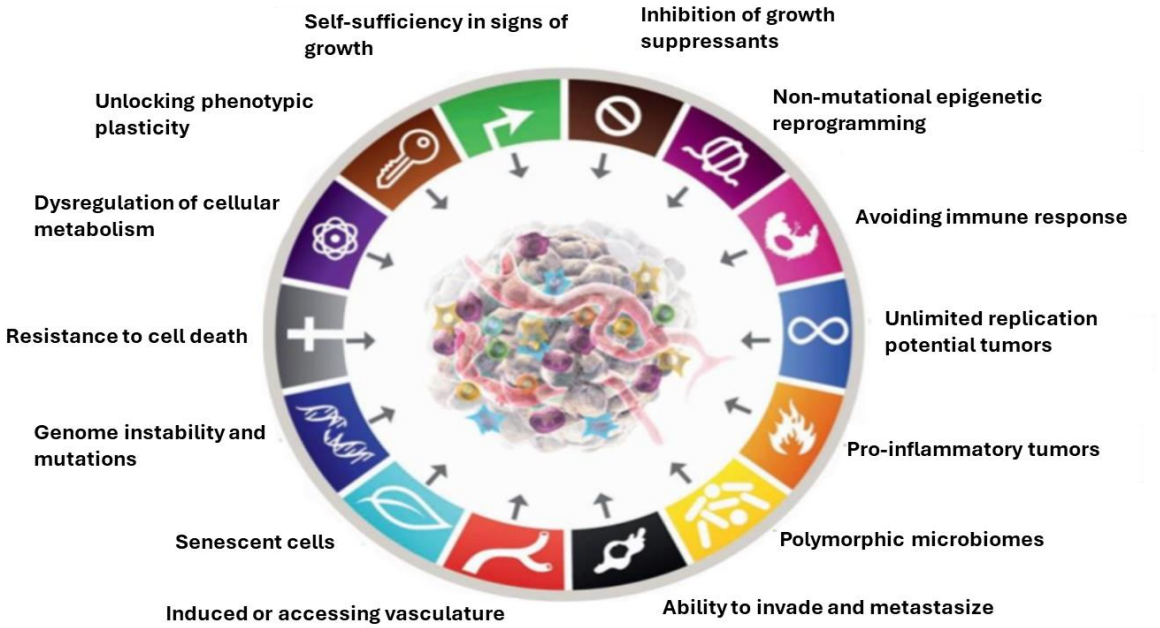
DEVELOPMENT OF SUSTAINED ANGIOGENESIS

Tumors require a constant supply of oxygen and nutrients, which are supplied by a network of blood vessels. Cancer cells induce the formation of new blood vessels, a process called angiogenesis, ensuring their nutrition and growth. Disruption of the p53 gene may contribute to uncontrolled angiogenesis, providing an uninterrupted lifeline for the tumor (FETT-CONTE, SALLES, 2002).

ABILITY TO INVADE AND METASTASIZE

The most lethal aspect of cancer is its ability to invade surrounding tissues and establish distant metastases. The mechanisms underlying this invasive behavior are not yet fully understood. However, research suggests that interactions between cancer cells and their microenvironment play a crucial role, allowing them to break free from their primary location and colonize new territories (OLIVEIRA and GOMIDE, 2020) (TEIXEIRA, 2007).

Figure 1. Hallmarks of Cancer- new additions. HANAHAN, 2022.



IMMUNOTHERAPY

At first, surgery was used to treat cancer, a procedure that has been recorded since 3000 B.C. and consists of tumor excision. Over the years, with science and technology, other possibilities have been structured for oncological propaedeutics, such as radiotherapy, which aims to destroy cancer cells or prevent them from multiplying by means of ionizing radiation; chemotherapy, which, through the advent of drugs with cytotoxic action, has the same purpose as radiotherapy, but uses a systemic reaction (PEREIRA, 2023). Nevertheless, these therapeutic techniques often bring serious side effects to the body, including: emesis, inappetence, weakness, hair loss and skin reactions from the toxic effect of radiation; thus interfering with patients' quality of life (NANI, et al, 2021).

In this context, from the nineteenth century onwards, a new modality for the treatment of cancer began to be studied: immunotherapy, with the intention of being a less aggressive and more specific process compared to conventional ones. Thus, the need for a less reactive treatment culminated in studies on the mechanisms of influence of specific cell receptors on the stimuli of the body's own defense response in tumor cells, thus achieving a therapy that stimulates the patient's immune system to counteract the disease. Immunotherapy, because it has this action of amplifying the individual's own immune response to fight tumor cells, has been of great importance for some types of cancer and for immunotherapy research (FONTOURA et al., 2021).

In immunotherapy, different ways of action in the body are explored. Some treatments have the most generalized mechanism, that is, it induces a general immune response throughout the body, while others have a more restricted and targeted action, by causing the immune system to attack cancer cells in particular (FACUNDO and SILVA, 2019).

ACTIVE IMMUNOTHERAPY

Active immunotherapy stands out as an approach in the fight against cancer because it is a strategy that awakens, trains, and equips the patient's own immune system to recognize and eliminate cancer cells accurately and efficiently. Substances that restore and stimulate the immune response are used. Examples of this method include cell therapies such as CAR-T cells and vaccines, which involve stimulating the immune system itself to recognize and eliminate tumor cells. Active immunotherapy is divided into two modalities: specific and nonspecific (SANCHES, MOURA, RODRIGUES et al, 2023).

SPECIFIC

This division of immunotherapy relies on substances, such as prophylactic and therapeutic vaccines, that enable the immune system to recognize and eliminate tumor cells accurately (PENATTI, 2019). According to Oliveira and Gomide, it can be autologous, being produced from the

patient's own cell culture, or heterologous, when they are produced with the cells of another patient with a similar neoplasm.

For better understanding, imagine an army that is highly trained and equipped to fight a specific enemy. Specific active immunotherapy creates exactly this army of defense cells, which specialize in identifying and attacking tumor cells. Prophylactic vaccines prepare the immune system to recognize the tumor antigens and molecules present on the surface of cancer cells. This works as pre-training, equipping the body to identify and fight the tumor before it even develops. Therapeutic vaccines, on the other hand, are composed of inactivated tumor cells or fragments of them. When injected into the body, they serve as targets for the immune system trained by prophylactic vaccines, triggering a precise and targeted attack against the tumor, and a long-lasting specific immune response, capable of promoting tumor regression, that is, the reduction or even the disappearance of cancer (GIACOMINI and MENEZES, 2012).

Despite the previously mentioned factors, specific active immunotherapy goes beyond fighting cancer. It can also be used to prevent the recurrence of the disease and even to treat other diseases, such as infectious diseases and autoimmune diseases (FREIRE, 2019).

NONSPECIFIC

Nonspecific active immunotherapy consists of the administration of stimulating and restorative substances of the immune system in general, involving nonspecific immunological agents and cytokines (nonspecific immunomodulatory agents) that will stimulate or potentiate the immune response. In this way, this strategy strengthens our body's defenses against unwanted invaders, through the introduction of microorganisms, meticulously grown in the laboratory, into the body, aiming to awaken and amplify the power of the immune system. These microorganisms are endowed with immunogenicity, that is, they have the ability to stimulate the immune system, triggering a series of beneficial events (SONG, ZHANG and WU, 2018).

Cytokines, which are introduced along with the microorganisms, play a key role in the treatment. These messenger molecules, secreted by microorganisms, serve as a communication bridge between cells, amplifying the immune response and directing it to fight invaders**.** Cytotoxic cells, also known as killer cells, are strengthened by nonspecific immunotherapy. This leads to an intensification of the action of these cells, which culminates in the elimination of cancer cells and other pathogens (BILIERI and GALVINHO, 2019).

Accordingly, nonspecific immunotherapy demonstrates great versatility in its field of action. It can be used to fight cancer autonomously, that is, as the main treatment. In other situations, it assumes a complementary role, acting as an adjuvant to potentiate the response of other types of

immunotherapy, such as cancer vaccines. This synergy between the methods contributes to a more robust attack against cancer cells (OLIVEIRA and GOMIDE, 2020).

PASSIVE IMUNOTHERAPY

Passive immunotherapy plays a crucial role in the fight against cancer. It works as a direct reinforcement of the patient's immune system, because, instead of stimulating the body's own immune cells to recognize and attack the tumor, this approach directly provides the body with cells and antibodies ready for the immune response (CAMPOS, et al, 2020).

One of the main types of Passive Immunotherapy involves the infusion of T cells and NK cells, known as effector cells. These cells, grown in the laboratory from healthy donors or the patient himself, are trained to recognize and eliminate tumor cells accurately and efficiently (TEIXEIRA, et al, 2019).

Another Passive Immunotherapy strategy uses monoclonal antibodies, artificial molecules that bind to specific proteins on the surface of tumor cells. These antibodies can act in several ways, such as: (GUIMARÃES, SILVA and RANGEL, 2008)

1. Target Marking: Directing effector cells of the immune system to tumor cells, facilitating their identification and elimination.
2. Blocking Growth Signals: Disrupting the signals that stimulate the growth and proliferation of tumor cells.
3. Induction of Cell Death: Activating mechanisms that lead to the death of tumor cells.

Adoptive Cell Therapy, a specific type of Passive Immunotherapy, stands out for using the patient's own immune cells to fight cancer. Through a painstaking process in the laboratory, T cells or NK cells are collected from the patient, multiplied, and trained to recognize and attack tumor cells. As for their types, they include: (BILIERI and GAVINHO, 2019).

1. Lymphocin-Activated Killer Cell (LAK) Therapy: The patient's T cells are cultured with cytokines, substances that stimulate them to become efficient killer cells.
2. Tumor-Infiltrating Lymphocyte (LIT) Therapy: T cells that have already infiltrated the tumor are collected, expanded, and reinfused into the patient

In summary, the advantages of Passive Immunotherapy are: precision, observed, for example, in the action of mAbs, which can bind to specific targets in tumor cells, minimizing the impact on healthy cells; efficacy, since it can be effective in the treatment of several types of cancer, including those that do not respond to other therapies; and safety, as it usually has fewer serious side effects than other cancer therapies, such as chemotherapy and radiotherapy (JESUS, 2002).

MODELS OF IMMUNE THERAPY

VACCINE

In the field of immunization, DNA vaccines represent a groundbreaking milestone, the result of biotechnological advances in recombinant DNA. These vaccines contain fragments of DNA that encode specific antigens of a pathogen, and when administered to the patient, these DNA molecules are internalized by the cells of the immune system, which recognize them as foreign genetic material. For vaccines to work, the antigen needs to be recognized by the cell that presents the antigen (APC) and then induce specific cytotoxic T lymphocytes against the antigen, that is, trigger the immune response (DINIZ and FERREIRA, 2010).

In a more lucid way, vaccines work as messengers, presenting the immune system with tumor antigens, unique molecules present on the surface of cancer cells. After this exposure, white blood cells, especially dendritic cells, are activated and become experts in identifying and fighting cancer. To enhance this immune response, pro-inflammatory molecules, such as IL-2 (interleukin 2), are released. These cytokines act as adjuvants, amplifying the number of activated dendritic cells at the vaccination site (SANMAMED, CHEN, 2018).

A crucial step in this method, encompassed as active immunotherapy, is the purification of dendritic cells, starting from the patient himself. They are incubated in the laboratory with the tumor antigens extracted from the individual's cancer cells. This incubation process ensures that the dendritic cells are trained and ready to recognize and specifically attack cancer. Finally, the "trained" dendritic cells are injected back into the patient, where they infiltrate the tumors and release substances that attract and activate other immune system cells, such as cytotoxic T lymphocytes, which act by inducing cell death (FRANCELINO et al, 2022).

Recombinant DNA technology allows the production of antigens with high precision and purity, ensuring a specific and effective immune response, as they can induce long-lasting immune responses, both humoral and cellular, protecting the individual for long periods. DNA vaccines are still in clinical development, but preliminary results are extremely promising (DINIZ and FERREIRA, 2010).

CAR-T CELL IMMUNOTHERAPY

CAR-T cell therapy is an active immunotherapy, that is, it uses the patient's own immune system to fight cancer. This revolutionary approach offers hope for patients with hematologic malignancies and solid tumors that do not respond to traditional treatments (SOARES et al, 2022).

CAR-T cells (Chimeric Antigen Receptor T-cells) are T cells, a type of white blood cell crucial for the body's defense, that are genetically modified in the laboratory. Through genetic engineering, an artificial receptor called CAR (Chimeric Antigen Receptor) is inserted into T cells,

which makes them able to recognize and attack cancer cells with precision. This CAR receptor works like a radar, allowing CAR-T cells to identify and bind to specific proteins present on the surface of tumor cells, triggering their destruction (CERRANO et al., 2020).

It is a complex and customized process that requires a specialized laboratory infrastructure. Key steps include:

1. T-cell collection: A blood sample from the patient is collected for extraction of the T-lymphocytes.
2. Genetic modification: Incorporation of the patient's cancer-specific CAR receptor into the T cells.
3. Cell expansion: The modified CAR-T cells are multiplied in large numbers in the laboratory to ensure a sufficient amount for treatment.
4. Quality Control: CAR-T cells are rigorously tested to ensure their safety and functionality prior to infusion into the patient.

CAR-T cell therapy has shown promising results in the treatment of several types of cancer, especially in hematological malignancies: acute B-cell lymphoma (ALL), non-Hodgkin's lymphoma (NHL), acute myeloid leukemia (AML) and multiple myeloma (MM). Likewise, it has demonstrated potential in the treatment of solid tumors: lung tumors, sarcoma, melanoma, and head and neck tumors (in ongoing clinical studies) (ROEX et al., 2020).

CAR-T cell immunotherapy is particularly effective in patients who have not responded to treatments, such as chemotherapy or targeted therapy. The mechanism of action of CAR-T cells allows for a targeted, individualized, and persistent attack on cancer cells while minimizing damage to healthy tissues, which results in fewer serious side effects compared to traditional treatments (VOORDECKERS et al, 2024).

CHECKPOINT INHIBITORS

In a study, researchers at the University of Texas at Austin unraveled the crucial role of cytotoxic T-lymphocyte antigen-4 (CTLA-4) in tumor growth. CTLA-4, also known as CD152, acts as a brake on the immune system by suppressing the activation of cytotoxic T cells (CTLs), which are responsible for fighting cancer cells directly. By blocking the activity of CTLA-4 with the use of specific antibodies (anti-CTLA-4), the researchers observed a surprising reversal: the CTLs regained their ability to attack tumors (ALLISON et al., 1996).

CTLA-4 is a protein present on the surface of activated T cells, having the function of maintaining self-tolerance and modulating the immune response against pathogens and cancer cells. After activation of T cells, through their T antigen receptor (TCR), they express CTLA-4 on their surface. This protein binds with high affinity to the B7-1 (CD80) and B7-2 (CD86) molecules present

in antigen-presenting cells (APCs). This interaction generates a series of signals within the T cell that inhibit its activation and proliferation, thus preventing autoimmune reactions and exaggerated responses to pathogens (SEIDEL, OTSUKA, and KENJI, 2018).

Acting then as an immune "checkpoint", this suppression is crucial to prevent autoimmunity, but in the context of cancer, it becomes an obstacle to an effective immune response (FRANCELINO et al., 2022).

By blocking CTLA-4, anti-CTLA-4 releases CTLs from their inactive state, allowing them to return to their cytotoxicity role. This immunotherapeutic approach has shown promising results in several types of cancer, including melanoma, lung, and kidney. (TEIXEIRA et al., 2019).

Recent evidence suggests that the antitumor effect of anti-CTLA-4 goes beyond simple CTLA-4 inhibition. One of the most important mechanisms appears to be regulatory T cell (Treg) depletion. Treg acts as immune system suppressors, preventing T cells from attacking other cells, including cancer cells. By eliminating Treg, anti-CTLA-4 releases effector T cells to attack tumors more vigorously.

Another aspect of anti-CTLA-4 is its ability to unblock the activity of APCs, leading to increased production of pro-inflammatory cytokines and the activation of other immune cells, such as dendritic cells and natural killer (NK) cells. This general amplification of the immune response, coming from synergistic actions of anti-CTLA-4, leads to the credibility of the treatment (BARRY et al., 2018).

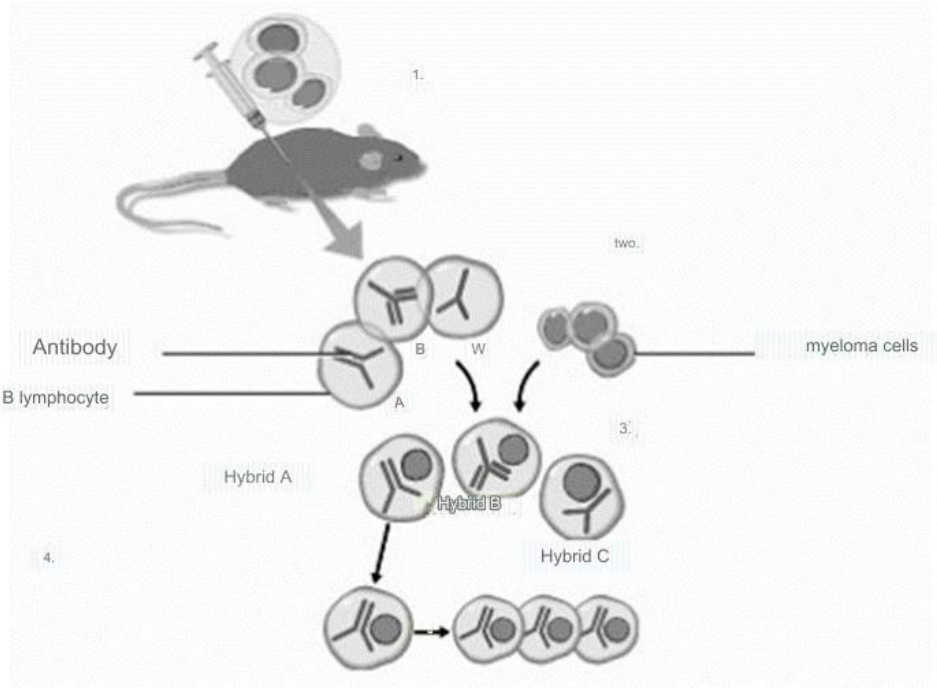
MONOCLONAL ANTIBODIES

The use of monoclonal antibodies (mAb) is a type of passive immunotherapy. mAb are nothing more than antigen-recognizing proteins with a high degree of affinity and in a specific way, developed from the cell fusion technique, described by Kohler and Milstein in 2005.

This method allows the creation of hybridomas, hybrid cells that combine the characteristics of a B lymphocyte (immunized against a specific antigen) with those of a myeloma cell (immortal). This fusion results in cells capable of producing monoclonal antibodies (ACM) on a large scale, as illustrated in Figure 2 (FIGUEIREDO, 2020).

This technique is widely used in the treatment of B-cell lymphoma, in which the monoclonal antibody (mAb) binds to the CD20 protein, present on the surface of malignant B cells. By binding to CD20, anti-CD20 mAb activates a series of mechanisms that lead to the destruction of tumor cells, such as the activation of the patient's own immune cells and the direct death of malignant B cells (AFONSO, 2017).

Figure 2. Somatic cell hybridization technique. SANTOS, 2006.



CHEMOTHERAPY *VERSUS* IMUNOTHERAPY

Chemotherapy and immunotherapy stand out as therapeutic approaches to combat malignant neoplasms. Each with its strengths and weaknesses, they represent distinct approaches in the fight against this disease. (BARROS, 2001)

Chemotherapy acts as a general bombardment, releasing its chemical compounds to destroy cancer cells throughout the body. This strategy, however, is not always precise, also affecting healthy cells and causing undesirable side effects, such as nausea, fatigue and hair loss.

On the other hand, immunotherapy emerges as a promising alternative, training the patient's own immune system to recognize and eliminate cancer cells. This more specific approach minimizes damage to healthy cells, potentially offering a longer-lasting and less toxic response (WOLCHOK, BOLAND, AND HUNG, 2023).

MECHANISMS OF ACTION

Chemotherapy drugs disrupt the cycle of cell division, preventing cancer cells from proliferating. This tactic is effective against several types of cancer, but it can be unforgiving to healthy cells, causing systemic side effects. (BILIERI and GAVINHO, 2019)

Meanwhile, immunotherapy stimulates the patient's immune system so that it recognizes and specifically attacks cancer cells. This approach uses a variety of techniques, such as monoclonal antibodies and immune checkpoint inhibitors, to awaken the body's natural power against disease. (SILVA, 2024)

EFFICACY AND APPLICATIONS

Chemotherapy is a therapeutic approach with a broad spectrum of action. It is effective in the treatment of several types of cancer, both in early and advanced stages, and can be used as a single therapy or in combination with other treatments, such as radiation therapy or surgery.

In the case of immunotherapy, great potential has been observed in the treatment of some specific types of cancer, such as melanoma, lung and kidney, thanks to the high specificity involved in this method. Its effectiveness varies according to the type of tumor and the characteristics of the patient. (JUNIOR, 2023)

SIDE EFFECTS AND QUALITY OF LIFE

Chemotherapy can cause several side effects, such as nausea, fatigue, hair loss, changes in the oral mucosa and taste, in addition to increasing the risk of infections. These effects can significantly impact the patient's quality of life.

On the contrary, immunotherapy is shown to be a milder approach with fewer side effects. It usually has less severe and more tolerable side effects than chemotherapy. The most common side effects include fatigue, skin reactions, digestive issues, and autoimmune changes (WOLCHOK, OLAND, AND HUNG, 2023).

IMMUNOTHERAPY: A TURNING POINT IN THE FIGHT AGAINST CANCER

In summary, when analyzing the information clarified throughout this chapter, it becomes clear that immunotherapy represents a milestone in oncological studies, as it offers a new perspective for the treatment of various types of cancer. This innovative approach shows itself as a hope in the fight against this disease, responsible for reducing the quality of life of countless people, even leading to death. Thus, with the objective of activating the patient's own immune system to attack cancer cells in a precise and effective way, and with low rates of side effects, this method is revolutionary and promising for cancer treatment.

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