INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA):IJPS00]
Journal Homepage: https://www.ijpsjournal.com

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**Review Article**

# Cancer Vaccines Delivery Systems: Strategies For Efficient Targeting And Immunization

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ARTICLE INFO

Received: 08 March 2024
Accepted: 12 March 2024
Published: 14 March 2024
Keywords:
Cancer vaccines, immunotherapy, vaccine delivery systems, dendritic cells, gene gun, nanoparticle, Whole cell vaccines, DNA Vaccines, RNA vaccines, peptide vaccines.
DOI:
10.5281/zenodo.10815969

## ABSTRACT

Cancer vaccines indeed hold promise as a potential approach to treating cancer by leveraging the immune system to target cancer cells. There are several types of cancer vaccine platforms currently being explored, including peptide, DNA and RNA, viral vector, whole cell, and dendritic cell vaccines. Clinical trials have demonstrated encouraging results for various types of cancer, indicating the potential to revolutionize cancer treatment through personalized therapies, contrary to popular belief. However, further research is still necessary to determine the safety and effectiveness of these vaccines on a larger scale. Nonetheless, cancer vaccines represent a significant advancement in the ongoing fight against cancer.

## INTRODUCTION

A specific kind of vaccination called a "cancer vaccine" tries to activate the immune system so that it will detect and target cancer cells in the body. Cancer vaccines are created to engage the immune system to recognize and target cancer cells, in contrast to conventional vaccinations that prevent infectious illnesses by teaching the immune system to recognize and eliminate a particular pathogen [1]. A cancer vaccine is a vaccination that either cures or prevents the development of cancer. Vaccinations for cancer therapy are not the same as vaccinations for viruses. These vaccinations attempt to stimulate the immune system to initiate an attack on cells that are cancerous in the body. Instead of avoiding disease, they are intended to stimulate the immune system in order to fight an existing disease. Some

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**Relevant conflicts of interest/financial disclosures**: 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.

cancer therapy vaccines contain cancer cells, fragments of cancer cells, or pure antigens (specific proteins found on cancer cells). To manufacture the vaccine, a patient's own immune cells are sometimes extracted and treated to these compounds in the lab. When the vaccine is complete, it is administered into the body to boost the immune response to cancer cells. Talimogene laherparepvec (T-VEC), for example: This vaccine has been licensed for the treatment of advanced melanoma skin cancer. It is generated from a herpes virus that has been genetically modified in the lab to produce a cytokine, which the body naturally generates. This cytokine stimulates the immune system and can temporarily create flu-like symptoms. Cancer immunotherapy refers to a group of current and prospective treatment techniques aimed at eliminating tumors by stimulating antitumor immunity in the host. Cancer vaccines have not yet had the same clinical impact as other vaccines, but they have preventative and therapeutic promise, either alone or in combination and they may give lifetime immunity against cancer recurrence, possibly forming a key element of future combinatorial immunotherapies [2]. Immunotherapy is one of the finest methods to treat cancer, with a goal to use the energy of the immune system to kill cancer cells. This article discusses different types of immunosuppressive agents currently being inspected for the treatment of cancer. One type of vaccine that has been mentioned is the cancer vaccine. Cancer drugs work by restoring the immune system's action to identify and kill cancer cells. This article includes several clinical trials that tested different cancer drugs against various types of cancer. For example, HER2/neu antibodies have shown to be effective in patients with advanced breast cancer, and DNA antibodies have been tested against breast cancer. Another way to use anti-inflammatory drugs is through the use of cytokines, signaling molecules that help activate the body's immune system. This article discusses the various cytokines studied for the treatment of cancer, including TGF-β. This article also discusses the use of dendritic cells as an anticancer drug. Dendritic cells are unique immune cells that can activate other immune cells to attack cancer cells. This article describes the use of tumor-derived RNA-transfected DCs for the therapy of cancer. Overall, this article provides a general overview of the different types of immunotherapy currently being investigated for the treatment of cancer. It highlights promising clinical trial results for several types of cancer and highlights the potential of immunotherapy to revolutionize cancer treatment.

## MECHANISM OF ACTION OF VACCINES IN NEOPLASM AND THEIR TYPES.

The immune system plays a crucial role in combating various pathogens and diseases, including cancer. Cancer vaccines aim to extend the memory of the immune system against tumor cells by introducing tumor-specific antigens along with adjuvants that activate dendritic cells. This approach stimulates an adaptive immune response that recognizes tumor antigens and impedes their growth, thereby simulating tumor degradation. Ultimately, cancer vaccines seek to enhance the innate immune system's ability to recognize and eliminate cancer-causing agents from the body.[3] Dendritic cells (DCs) play a crucial role in regulating cancer vaccines. They are potent antigen-presenting cells that originate from the bone marrow and are responsible for stimulating an adaptive immune response. DCs provide signals for T cell activation [4], which is essential for mounting an effective immune response against cancer cells. The effect produced by DCs on cancer cells is the stimulation of an adaptive immune response, which recognizes and impedes tumor growth, ultimately leading to tumor degradation. Therefore, DCs are a vital component of cancer vaccines as they play a crucial role in

enhancing the immune system's ability to combat cancer. The immune system plays a crucial role in protecting the body from various pathogens and diseases, including cancer. Cancer vaccines aim to enhance the immune system's memory against malignant cells by introducing tumor-specific antigens and adjuvants that activate dendritic cells. This approach stimulates an adaptive immune response that recognizes tumor antigens and impedes their growth, ultimately leading to tumor degradation. The effectiveness of cancer vaccines is largely dependent on the regulation of dendritic cells, which are potent antigen-presenting cells that originate from the bone marrow and are responsible for stimulating an adaptive immune response [7]. The interaction between immune and non-immune responses during immunogenic cell death of tumor cells leads to the release of DAMPs and tumor antigens, which stimulate the maturation of dendritic cells and induce CD4+ helper cells and cytotoxic T lymphocytes [5]. This inflammatory cascade helps to eliminate tumor-producing factors and provides protection against cancerous or tumor cells. A study conducted on a mice model of melanoma found that transfer of CD4+ cells produced a cytotoxic effect on tumor cells, demonstrating the potential of cancer vaccines to work upon the body's adaptive and innate immune system to combat cancer [6].

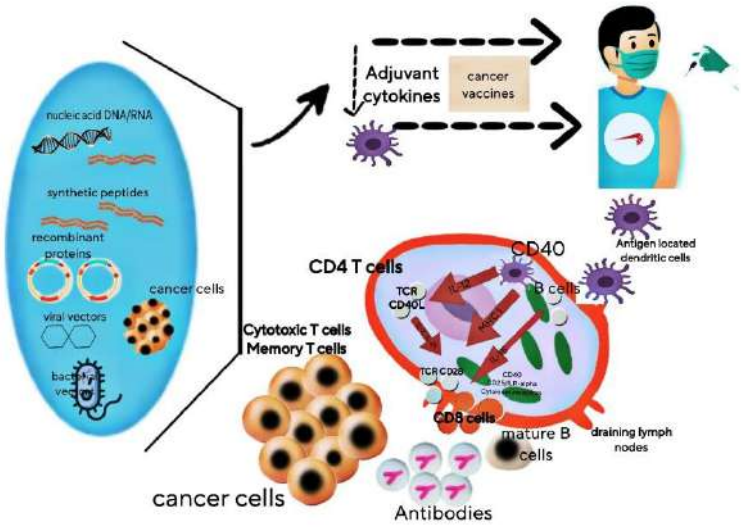


**Fig no.1 Various therapeutic cancer vaccine platforms share a similar mechanism of action[34].**

**VACCINE DELIVERY SYSTEMS**

**ELECTROPORATION:**

Firstly, there essentially is one strategy which improves the uptake of plasmid DNA into antigen presenting cells that is electroporation[8]. It provides electrical impulses of smaller range which leads to formation of transitory interspaces in cell membrane. At the time of membrane destabilization, plasmid DNA present at the outer environment of the target cell gains an entry to the inner cellular compartment of the cell[9]. It enhances DNA consumption by thousand folds and have additional impact due to local tissue damage and consequent stimulation of proinflammatory cytokine in native environs[10,11]. Major demerit when electroporation being used as vaccine delivery system it could produce pain on administration site and also not beneficial for mass vaccination so alternative transport systems can be pursued for that purpose.

**GENE GUN VACCINE DELIVERY:**

Another strategy is using a gene gun to deliver plasmid DNA which coated with heavy metal typically gold particle; antigen presenting cells at the injection site are bombarded with plasmid

coated particles. The gene gun strategy reduces the amount of DNA requirement by 100-1,000 [12]; some promising preclinical data has led to phase 1 and 2 clinical trials in head and neck squamous cell carcinoma and cervical cancer[13].

**NANOPARTICLE VACCINE DELIVERY SYSTEMS:**

Another substitute to deliver drugs which previously suffered from pharmacokinetic restrictions like poor bio-availability, small half-life or substandard solubility in nanoparticle drug delivery systems. Numerous particles have gone under investigation either being vaccine delivery system or being complementary namely liposomes, polymer relating nanoparticles, micelles, gold nanoparticles and virus nanoparticles lone or together with each other[14].

**SELF-ASSEMBLING PEPTIDES:**

To the target cell where antigens has to be conveyed self-assembling peptides is used to deliver vaccines and it works in response to changes in pH solvent, co-assembling molecules, temperature, and ionic strength by spontaneously forming sequence[15,16]. It can have expansive effects can be manufactured to the formation of nano micelles, nanovesicles, nano fibers, nanotubes, nanoribbon & Hydrogels[17]. It has an upper hand over nanoparticles systems to deliver vaccine as involving high drug loading, low drug leakage, biodegradability and being highly permeable to target cell membranes. Considering particle size is a key factor to deliver vaccine and even could impact efficiency of uptake by antigen presenting cells as smaller particles ranging from 20 to 200 nm are more immunogenic and there is no optimal size also needs to be optimized for every vaccine candidate[18-20].

There are several types of cancer vaccines platforms, including:

1. **Peptide vaccines:**

These vaccines use small pieces of protein called peptides that are found on the surface of cancer cells. The immune system is then trained to recognize and attack these peptides[21]. The use of peptide-based therapeutic cancer vaccines offers several advantages, including easy production, cost-effective manufacturing, low risk of causing cancer, immunity to pathogen infections, and high chemical stability. These vaccines need to be taken up by dendritic cells (DCs), where they are broken down into peptides and presented on the surface of HLA molecules for T-cell activation. In the interaction between T cells and DCs, T cells not only recognize specific tumor antigens but also the unique peptide-HLA complex.

2. **DNA vaccines:**

These vaccines use a small piece of DNA that codes for a specific protein found on cancer cells. The DNA is injected into the body, where it is taken up by cells and used to produce the protein. The immune system then recognizes the protein as foreign and attacks it. Nucleic acid vaccines, including DNA and mRNA vaccines, are a newer type of vaccine that have shown promise in cancer treatment. These vaccines work by introducing genetic material into the body that codes for cancer antigens. Once this genetic material is taken up by cells in the body, they produce the cancer antigens, which are then detected by the immune system[22-23]. DNA vaccines are made up of a small piece of DNA that codes for a specific antigen. When this DNA is injected into the body, it is taken up by cells and used to produce the antigen. mRNA vaccines work similarly, but instead of introducing DNA, they introduce a small piece of RNA that codes for the antigen. One advantage of nucleic acid vaccines is that they can be quickly and easily modified to target different types of cancer antigens. This makes them a promising approach for developing personalized cancer vaccines that are tailored to an individual's specific cancer.

Clinical trials of nucleic acid vaccines have shown promising results in treating various types of cancer, including melanoma, breast cancer, and prostate cancer. However, more research is needed to fully understand their effectiveness and safety[24- 26]. Overall, nucleic acid vaccines represent an exciting new approach to cancer treatment and prevention that could potentially improve outcomes for patients with cancer.

3. **RNA vaccines:**

Similar to DNA vaccines, RNA vaccines use a small piece of RNA that codes for a specific protein found on cancer cells. The RNA is injected into the body, where it is taken up by cells and used to produce the protein. The immune system then recognizes the protein as foreign and attacks it.

4. **Viral vector vaccines:**

These vaccines use a modified virus to deliver a specific protein found on cancer cells into the body. The immune system then recognizes the protein as foreign and attacks it. Viral vector vaccines are another type of newer vaccine that have shown promise in cancer treatment. These vaccines use a virus that has been modified to carry genetic material that codes for cancer antigens. When the virus is injected into the body, it infects cells and delivers the genetic material, which is then used to produce the cancer antigens[27]. One advantage of viral vector vaccines is that they can be designed to target specific types of cells, such as cancer cells, while leaving healthy cells unharmed. This makes them a potentially powerful tool for cancer treatment[28]. Clinical trials of viral vector vaccines have shown promising results in treating various types of cancer, including prostate cancer and pancreatic cancer. However, more research is needed to fully understand their effectiveness and safety[29]. Viral vector vaccines represent an exciting new approach to cancer treatment that could potentially improve outcomes for patients with cancer.

5. **Whole cell vaccines:**

These vaccines use whole cancer cells that have been killed or modified to stimulate an immune response. The immune system then recognizes the cancer cells as foreign and attacks them.

6. **Dendritic cell vaccines:**

These vaccines use dendritic cells, which are a type of immune cell that presents antigens to other immune cells. Dendritic cells are taken from the patient's blood, exposed to cancer antigens, and then injected back into the patient to stimulate an immune response against the cancer[30]. These vaccines use dendritic cells, which are a type of immune cell that play a key role in activating the body's immune response. In this type of vaccine, dendritic cells are taken from the patient's own body and modified to produce cancer antigens. The modified dendritic cells are then injected back into the patient, where they activate the immune system to attack the cancer cells[31]. One advantage of dendritic cell-based vaccines is that they can be personalized to each patient's specific type of cancer. This makes them a potentially powerful tool for treating a wide range of cancers. Clinical trials of dendritic cell-based vaccines have shown promising results in treating various types of cancer, including melanoma and prostate cancer. However, more research is needed to fully understand their effectiveness and safety[32]. Overall, dendritic cell-based vaccines represent an exciting new approach to cancer treatment that could potentially improve outcomes for patients with cancer.

## WHY CANCER VACCINES CHOOSE OVER CYTOTOXIC DRUGS?

Cancer vaccines have gained popularity in recent years as a new method of cancer treatment due to their ability to provide long-lasting immunity against cancer. Unlike traditional cytotoxic drugs that kill rapidly dividing cancer cells, cancer vaccines stimulate the immune system to recognize and attack cancer cells[33]. Cytotoxic drugs have been the primary treatment for cancer

for many years. These drugs interfere with cell division, which is crucial for cancer growth. However, they also affect healthy cells that divide rapidly, such as those in the bone marrow, hair follicles, and digestive tract, leading to side effects like hair loss, nausea, and an increased risk of infections. In contrast, cancer vaccines target specific cancer cells and spare healthy cells. They work by presenting antigens specific to cancer cells to the immune system, which recognizes them as foreign and mounts an immune response. There are different types of cancer vaccines, including peptide vaccines, DNA vaccines, and dendritic cell vaccines. Peptide vaccines contain small fragments of proteins specific to cancer cells, while DNA vaccines have genetic material that codes for antigens specific to cancer cells. Dendritic cell vaccines involve exposing harvested dendritic cells to antigens from the patient's cancer cells before injecting them back into the patient. One advantage of cancer vaccines over cytotoxic drugs is their potential for long-lasting immunity. After the immune system recognizes and attacks cancer cells, it can continue to do so even after administering the vaccine, which may lead to a cure for some types of cancer. Another benefit of cancer vaccines is their specificity. Unlike cytotoxic drugs that affect healthy cells along with cancer cells, cancer vaccines only target cancer cells, reducing side effects and improving patients' quality of life.

## RESULT AND DISCUSSION

In conclusion, cancer vaccines are a promising new approach to cancer treatment that offers several advantages over traditional cytotoxic drugs. By stimulating the immune system to recognize and attack cancer cells, cancer vaccines offer the potential for long-lasting immunity and greater specificity than cytotoxic drugs. The development of cancer vaccines represents a significant milestone in the ongoing battle against cancer. These vaccines leverage the body's immune system to specifically target and destroy cancer cells, offering several advantages over traditional cytotoxic drugs. Cancer vaccines stimulate long-lasting immunity against cancer, potentially leading to a cure for certain types of cancer. Moreover, they offer greater specificity, sparing healthy cells and reducing adverse side effects commonly associated with cytotoxic drugs. The development of innovative vaccine delivery systems, such as electroporation, gene gun delivery, nanoparticle systems, and self-assembling peptides, has further enhanced the efficacy and feasibility of cancer vaccines. These delivery systems facilitate the efficient uptake of vaccine components by antigen-presenting cells, thereby enhancing the immune response against cancer cells. Continued investment in research and development is crucial to unlock the full potential of cancer vaccines and realize their promise as a transformative approach to cancer treatment and prevention.

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HOW TO CITE: Parikshit Nagda, Krishna Hingad, Ghisulal Dewasi, Nirmal Sodha, Nihal Singh Rao, Bhaktraj Singh Chauhan, Cancer Vaccines Delivery Systems: Strategies For Efficient Targeting And Immunization, Int. J. of Pharm. Sci., 2024, Vol 2, Issue 3, 445-452. https://doi.org/10.5281/zenodo.10815969