

Review

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A Mannose-Modified Lipid Calcium Phosphate Nanoparticle Vaccine Increased the Anti-Tumor Immune Response by Modulating the Tumor Microenvironment

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Review

A Mannose-Modified Lipid Calcium Phosphate Nanoparticle Vaccine Increased the Anti-Tumor Immune Response by Modulating the Tumor Microenvironment

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Abstract: With the rapid development of tumor immunotherapy, nanoparticle vaccines have attracted much attention as a potential therapeutic strategy. The potential role of the mannose-modified lipid calcium phosphate nanoparticle vaccine in enhancing the anti-tumor immune response was investigated. The aim of this study was to investigate the effect of mannose modification on the immune response of nanoparticles in regulating the tumor microenvironment through systematic review and analysis and to explore its potential clinical application in tumor therapy. Currently, despite the potential advantages of nanoparticle vaccines in immunotherapy, achieving an effective immune response in the tumor microenvironment remains a challenge. Tumor immune escape and overexpression of immunosuppressive factors limit its clinical application. Therefore, this study will explore how to intervene in the immunosuppressive mechanism in the tumor microenvironment through mannose-modified lipid calcium phosphate nanoparticle vaccines so as to improve the immunotherapy effect of tumor patients and provide new ideas and strategies for the field of tumor therapy.

Keywords: nanoparticle vaccine; anti-tumor immune response; calcium phosphate (CaP); tumor microenvironment; review

1. Introduction

In the current medical field, tumor immunotherapy, as a revolutionary treatment, has brought new hope for tumor patients[1–3]. However, despite some success, tumor immunotherapy still faces a number of challenges and limitations[4].

The core idea of tumor immunotherapy is to activate the body's own immune system to attack and eliminate tumor cells[5]. However, the presence of the tumor microenvironment seriously affects the activity and function of immune cells, thus weakening the effectiveness of immunotherapy[6–10]. The tumor microenvironment includes tumor cells, immune cells, blood vessels, interstitial cells, and other components, which interact with each other in a complex way, forming a situation of immunosuppression[11]. The overexpression of immunosuppressive factors, the existence of immune escape mechanisms, and the immunosuppressive effect of tumor cells are some of the main challenges facing tumor immunotherapy[12]. To overcome these challenges, in recent years, scientists have focused on finding new strategies and methods to improve the effectiveness of tumor immunotherapy[13–16]. As a new therapeutic strategy, nanoparticle vaccines have attracted much

attention[17]. Compared with traditional vaccines, nanoparticle vaccines have better biological stability, higher drug loading capacity, and stronger targeting, which can effectively improve the effect of immunotherapy[18–20].

As a new nanoparticle carrier, the mannose-modified lipid calcium phosphate nanoparticle vaccine has unique advantages and potential application prospects[21–25]. Mannose modification can make it easier for nanoparticles and tumor cells to be recognized and taken up[26]. This can increase the amount of vaccine that is enriched in tumor tissues, which improves the effectiveness of tumor immunotherapy[27–30]. In addition, mannose modification can also regulate the expression of immunosuppressive factors in the tumor microenvironment, destroy the interaction between tumor cells and immune cells, and further enhance the effect of immunotherapy[31–33].

In conclusion, the mannose-modified lipid calcium phosphate nanoparticle vaccine has great potential and broad application prospects as a new type of tumor immunotherapy. In this paper, we will systematically review and analyze the research progress of this vaccine in enhancing the anti-tumor immune response and regulating the tumor microenvironment, so as to provide a theoretical basis and practical guidance for further research in this field.

2. Regulation and Influence of Tumor Microenvironment

2.1. Characteristics of Tumor Microenvironment and Immunosuppressive Mechanism

The tumor microenvironment is an important part of tumor growth and development, and its characteristics are closely related to the immunosuppressive mechanism[34–36]. There are a lot of immunosuppressive factors, like transforming growth factor β (TGF- β) and interleukin-10 (IL-10), in the area around the tumor[35]. These can stop immune cells from doing their job and make it harder for them to find and kill tumor cells. A lot of immunosuppressant molecules are made by tumor cells and the cells that surround them, like programmed death ligand-1 (PD-L1), acidic extracellular matrix protein (TSP), and others[36–40]. These molecules work with ligands on the surface of immune cells to make the immune system tolerate and escape. In addition, the highly acidified and hypoxic environment in the tumor microenvironment is also an important factor in immunosuppression, which not only affects the activity and function of immune cells but also induces apoptosis and functional abnormalities in immune cells[41–44]. The inflammatory response and immune cell infiltration in the tumor microenvironment are also closely related to immunosuppression[45–48]. The inflammatory response can promote the activation and infiltration of immune cells, but it can also lead to the functional polarization and immune escape of immune cells[49]. The tumor microenvironment provides favorable conditions for tumor escape by regulating the activity, function, and quantity of immune cells and changing the local physiological environment, thereby inhibiting the immune response[50].

The combined application of bio-3D printing technology and bio-nanocarrier technology has constructed a new tumor treatment platform[51–54]. 3D bioprinting can accurately manufacture complex three-dimensional structures, while bionanocarrier technology can effectively deliver drugs or genes[55]. This combined application platform can enable customized tumor treatment programs, targeting drugs or gene carriers to the tumor site to improve treatment effectiveness[56]. In addition, the combination of these two technologies can improve the tumor immune microenvironment[57–60]. The tumor immunosuppressive microenvironment can be controlled by releasing nanocarriers carrying specific immunomodulators. It can also boost the activity of immune cells, help tumor cells die and immune cells invade, and improve the immune response of patients[61]. This combined application platform provides a new way for personalized and precise tumor therapy and has important clinical application prospects(Figure 1).

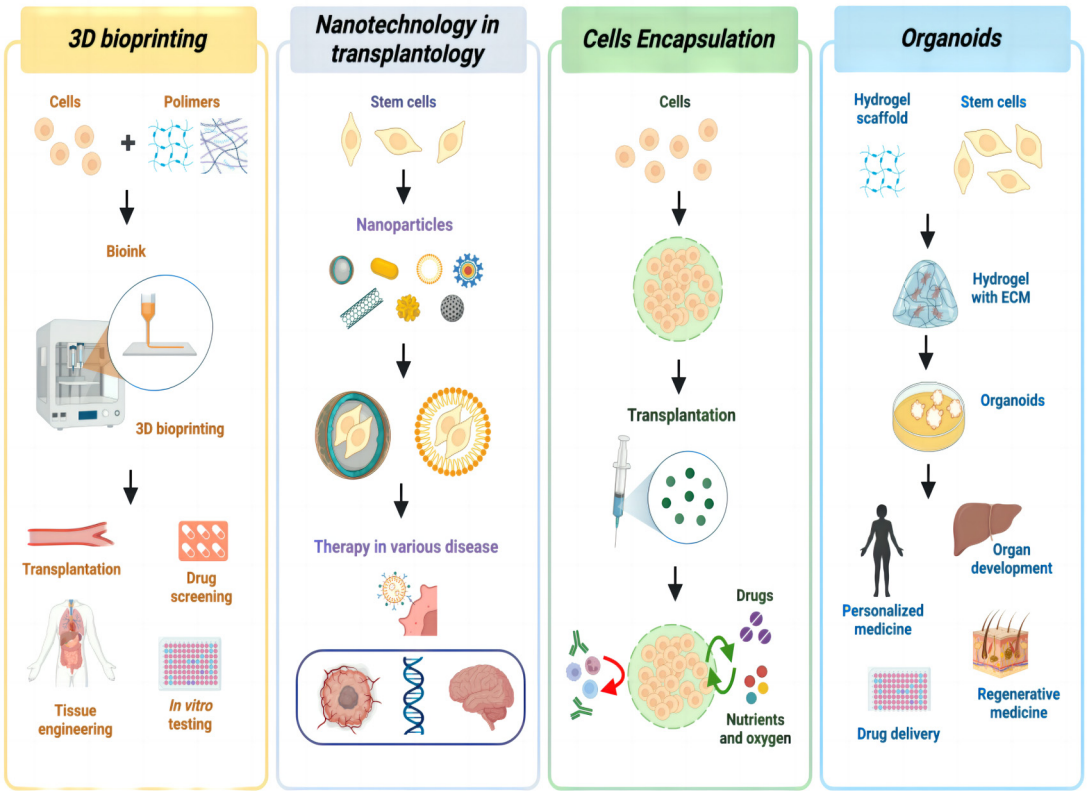


Figure 1. Bio-3D printing technology and nanocarriers combined application platform.

2.1.1. Cell Interaction with Tumor Stroma

Cell interactions in the tumor microenvironment are closely related to tumor mesenchyma and have important effects on the immune response[62–64]. The tumor stroma is composed of tumor cells, stromal cells, and stroma, and its complex cellular interactions affect the characteristics of the tumor microenvironment and the mechanism of immunosuppression[65]. Tumor cells influence the behavior of surrounding cells by secreting cytokines and chemokines, such as vascular endothelial growth factor (VEGF) and tumor necrosis factor (TNF), and regulating tumor stromal formation and function[66]. Mesenchymal cells, including tumor-associated macrophages (TAMs) and tumor-associated fibrocytes (CAFs), interact with tumor cells by secreting cytokines and molecules, such as TGF- β and IL-6, to promote tumor growth, invasion, and metastasis and inhibit the activity of immune cells[67–70].

The pharmacokinetic study of carrying antitumor drugs with nanoparticles as carriers has shown remarkable effects[71]. In a mouse tumor-forming model, the nanocarrier can effectively improve the bioavailability and stability of the drug in vivo, thereby prolonging the plasma half-life of the drug and enhancing the sustained release effect of the drug in vivo[72]. At the same time, in terms of brain metastases, this nanoparticle shows excellent ability to penetrate meninges and target tumors, so that anti-tumor drugs can effectively cross the blood-brain barrier to reach brain tumor foci and then exert anti-tumor effects(Figure 2).

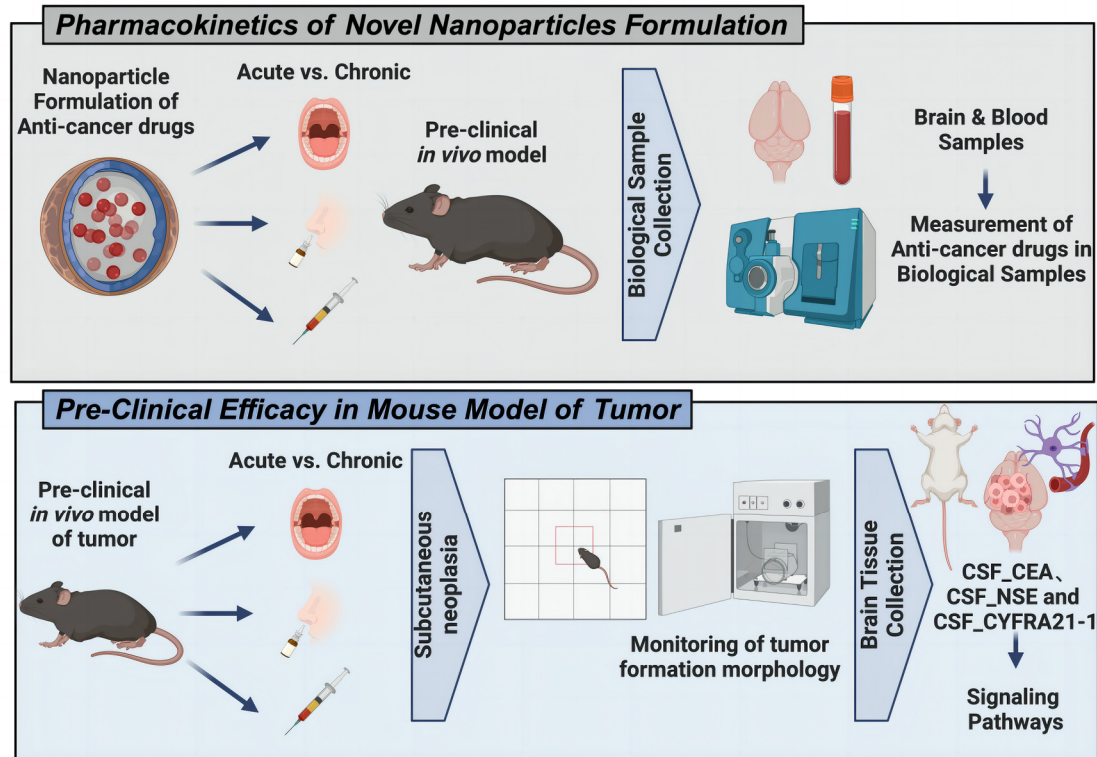


Figure 2. Nanoparticle carrier penetrates meninges to target and kill tumors in mouse brain metastatic tumor model.

2.1.2. Immune Escape and Tumor Suppressor Cells

Immune escape and tumor suppressor cells in the tumor microenvironment are important reasons for the hindered immune response[73–75]. Tumor cells and their surrounding cells and molecules work together in the tumor microenvironment to form a pattern of immune escape[76]. Tumor cells make too many immunosuppressive molecules, like PD-L1 and PD-L2, and immunosuppressive factors, like TGF- β and IL-10. These stop immune cells from working and make it harder for them to find and kill tumor cells[77]. To add to this, tumor suppressor cells in the area around the tumor, like TAMs and Tregs, control the immune response and help the tumor grow and spread by releasing immunosuppressive substances like IL-10 and TGF- β [78–80].

The photoacoustic imaging process of the mannose-modified lipid calcium phosphate nanoparticle vaccine in tumor mouse models(Such as Hepatocellular carcinoma, HCC) consists of the following steps: Related study establish the mouse tumor model by selecting suitable cancer cell lines. The mannose-modified lipid calcium phosphate nanoparticle vaccine was injected into mice to evaluate its effect on regulating the tumor microenvironment. Next, the study used ultrasound imaging technology to image the tumors in the mice, observing the vaccine's distribution and the state of tumor growth[81]. In imaging data processing, photoacoustic signals need to be unmixed and oxygen saturation (StO₂) calculated to assess the oxygenation level of tumor tissue. Additionally, we must stain the tumor tissue to identify angiogenesis, hypoxia, and molecular markers linked to tumor immune escape[82]. Through this process, the anti-tumor immune effect of the mannose-modified lipid calcium phosphate nanoparticle vaccine in mice can be comprehensively evaluated, which provides an important reference for further clinical research(Figure 3).

In vivo photoacoustic imaging of mannose modified lipid calcium phosphate nanoparticle vaccine in Mouse model (PAI)

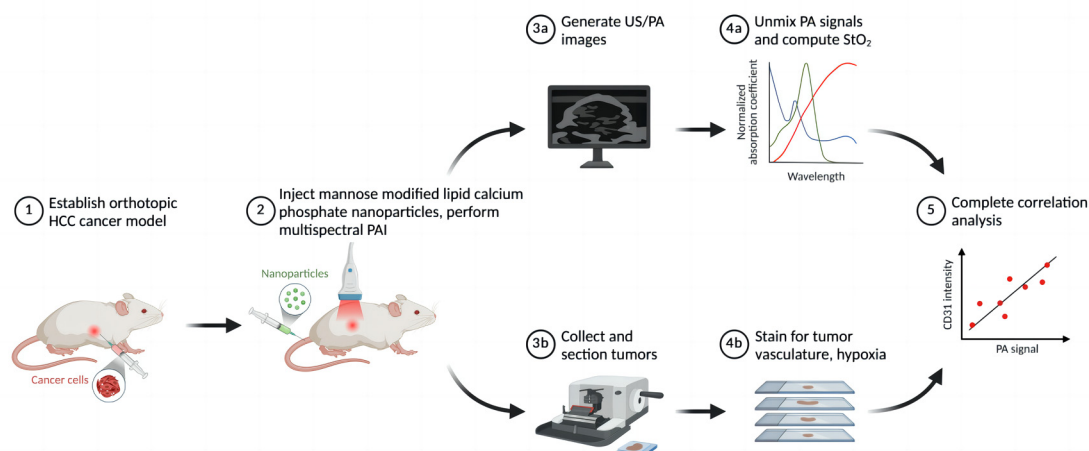


Figure 3. Photoacoustic imaging (PAI) process of mannose modified lipid calcium phosphate nanoparticle vaccine in mouse model.

2.2. Role of Nanoparticles in the Immune System

2.2.1. Structure and Function of Lipid Calcium Phosphate Nanoparticles

Lipid calcium phosphate nanoparticles are important nanocarriers that have the potential to modulate anti-tumor immune responses in the immune system[83]. These nanoparticles are structurally designed to improve vaccine stability, biocompatibility, and immunogenicity. The core of the lipid calcium phosphate nanoparticles is a kernel composed of calcium phosphate that can stably coat vaccine antigens[84]. Its surface is often modified with molecules such as mannose, which are used to enhance the specific recognition of antigens and promote antigen presentation and uptake by immune cells[85]. Moreover, the lipid envelope of nanoparticles can improve the stability of the vaccine, prolong its circulation time in the body, and enhance the targeted delivery of immune cells[86]. These lipid calcium phosphate nanoparticles can interact with antigen-presenting cells in the immune system to help process and present antigens more effectively. This makes T cells and B cells respond more strongly. The nanoparticles can also mimic the structure and appearance of the virus. This makes the immune system react strongly, which improves the body's ability to find and destroy tumor cells[87]. In general, as an effective vaccine carrier, lipid calcium phosphate nanoparticles play an important role in the immune system, enhancing the anti-tumor immune response by promoting antigen presentation and immune cell activation, and providing new strategies and hopes for tumor treatment.

Our study can use photoacoustic imaging (PA) to measure oxidative stress in lipid calcium phosphate nanoparticles. Lipid calcium phosphate nanoparticles were injected into the tumor site to locate the targeted organs and tumor sites in vivo, and the distribution and signal intensity of lipid calcium phosphate nanoparticles were monitored in real time by photoacoustic imaging technology, and the intensity of the PA signal reflected the degree of oxidative stress[88]. During the observation process, we can infer the degree of oxidative stress in the tumor microenvironment from the changes in signal intensity, and further evaluate the role of lipid calcium phosphate nanoparticles in modulating the tumor immune response[89]. This process effectively combines lipid calcium phosphate, nanoparticle technology, and photoacoustic imaging technology to provide a feasible, non-invasive measurement method for the study of oxidative stress in the tumor microenvironment and provides an important reference for the optimal design of anti-tumor immunotherapy(Figure 4).

Lipid Calcium Phosphate Nanoparticles to Measure Oxidative Stress By Photo-Acoustic Imaging (PA)

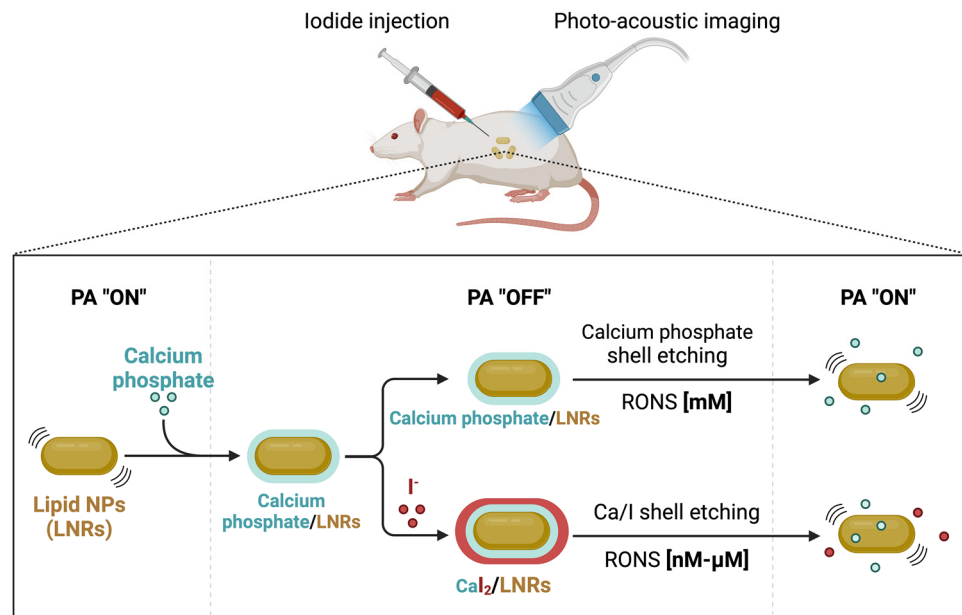


Figure 4. Schematic illustration of lipid calcium phosphate nanoparticles measuring oxidative stress using photoacoustic imaging (PA).

2.2.2. Immune System Interaction with Nanoparticles

The role of nanoparticles in the immune system is an important research area, and their interaction with the immune system has an important impact on the anti-tumor immune response[90–94]. Nanoparticles can act as effective carriers for vaccines, delivering antigens stably to the immune system. By changing their surface in the right way, nanoparticles can better recognize antigens and deliver them to immune cells more precisely, which helps activate immune cells and present antigens[95]. The size, shape, and surface properties of nanoparticles can regulate their absorption, distribution, and metabolism in the immune system, affecting their recognition and response to immune cells[96]. In particular, the specific structural design of nanoparticles can mimic the characteristics of pathogens, inducing the immune system to produce a specific and persistent immune response[97]. Nanoparticles can also regulate the immunomodulatory role of the immune system by stimulating the activity of immune cells and secreting immunomodulatory factors, enhancing the immune response[98]. The tumor mRNA-LNPS vaccine uses nucleic acid nanocarrier technology to deliver mRNA encoding tumor-associated antigens to body cells, prompting the synthesis of corresponding antigen proteins in cells, thus triggering specific immune responses[99]. The interaction mechanism between the vaccine and the immune system mainly includes two aspects: one is to promote antigen expression through the imported mRNA, activate antigen-presenting cells, and initiate the autoimmune response; the second is to stimulate the body's natural immune response by simulating virus infection[100]. These mechanisms are similar to the action principle of the COVID-19 nucleic acid vaccine, which stimulates the immune system to produce targeted antibodies and cellular immune responses through the antigen encoded by nucleic acid. In addition, the association between the tumor mRNA-LNPs vaccine and tumor immunity lies in the fact that by inducing immune cells to recognize and attack tumor cells, the tumor microenvironment is changed, thus enhancing the anti-tumor immune response[101–104]. The mechanism of this vaccine is similar to that of the COVID-19 vaccine, but it targets tumor antigens, which is expected to bring new breakthroughs in tumor immunotherapy(Figure 5).

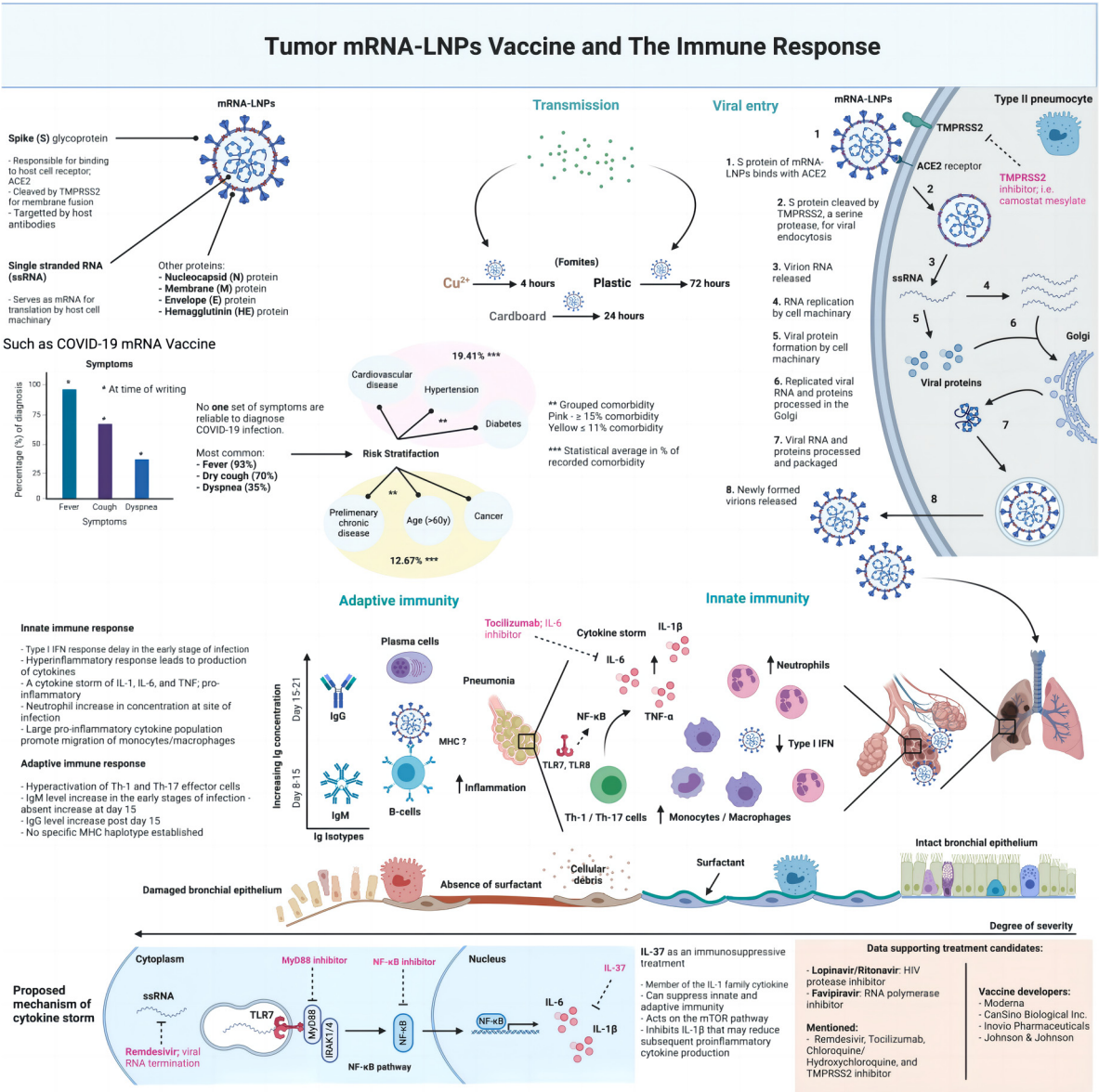


Figure 5. Schematic diagram of interaction mechanism between Tumor mRNA-LNPs Vaccine and immune system.

3. Design and Preparation of Mannose Modified Lipid Calcium Phosphate Nanoparticle Vaccine

3.1. Techniques and Principles of Mannose Modification

The design and preparation of mannose-modified lipid calcium phosphate nanoparticle vaccine is a critical and complex process, and its successful realization depends on various techniques and principles[105]. Mannose modification technology is to chemically covalently bind mannose to the surface of lipid calcium phosphate nanoparticles to endow vaccine with good biocompatibility and stability[106]. The core of this step is to control the modification reaction conditions to ensure adequate modification of mannose and avoid the occurrence of side reactions[107–109]. The preparation of lipid calcium phosphate nanoparticles is based on the principle of nanotechnology, and the raw materials such as lipid calcium phosphate are prepared into nanoparticles with a certain size and shape by a suitable method. The key to this step is the selection of appropriate materials and process parameters, as well as characterization and optimization of the properties of the nanoparticles[110]. A comprehensive consideration of mannose modification technology and nanoparticle preparation principle can achieve accurate design and effective preparation of lipid

calcium phosphate nanoparticle vaccine, providing a reliable experimental basis for subsequent anti-tumor immune response research.

3.1.1. Mannose Modification and Immune Response

The design and preparation of a mannose-modified lipid calcium phosphate nanoparticle vaccine is a key research task. Using mannose modification technology, mannose can be added to the surface of nanoparticles to make them more biocompatible and stable in living cells. They may also be able to change the immune system[111–114]. This modification can change the surface charge and structure of the nanoparticles, thus affecting the recognition and response of immune cells. Furthermore, mannose-modified nanoparticles can regulate the tumor microenvironment through immune induction against tumor-associated antigens and promote the occurrence and enhancement of anti-tumor immune responses[115]. Therefore, this design and preparation process not only considers the stability and biocompatibility of the vaccine but also integrates the strategy of immune regulation, providing a new idea and method for enhancing the anti-tumor immune response[116–118]. Mannose is a kind of natural polysaccharide. In the process of purification, acid hydrolysis, alkali precipitation, and gel filtration are often used to obtain high-purity mannose[119]. In terms of biotransformation, microbial fermentation techniques, such as *Escherichia coli* or yeast, are usually used to introduce target genes into the host through genetic engineering methods to synthesize mannose[120]. Mannose modification technology is used to covalently connect mannose to the surface of lipid calcium phosphate nanoparticles, which is often achieved by chemical crosslinking or enzyme catalysis. The development of these technologies has provided researchers with effective means to improve the biological activity and drug delivery performance of nanoparticles, thus playing an important role in tumor immunity vaccine research(Figure 6).

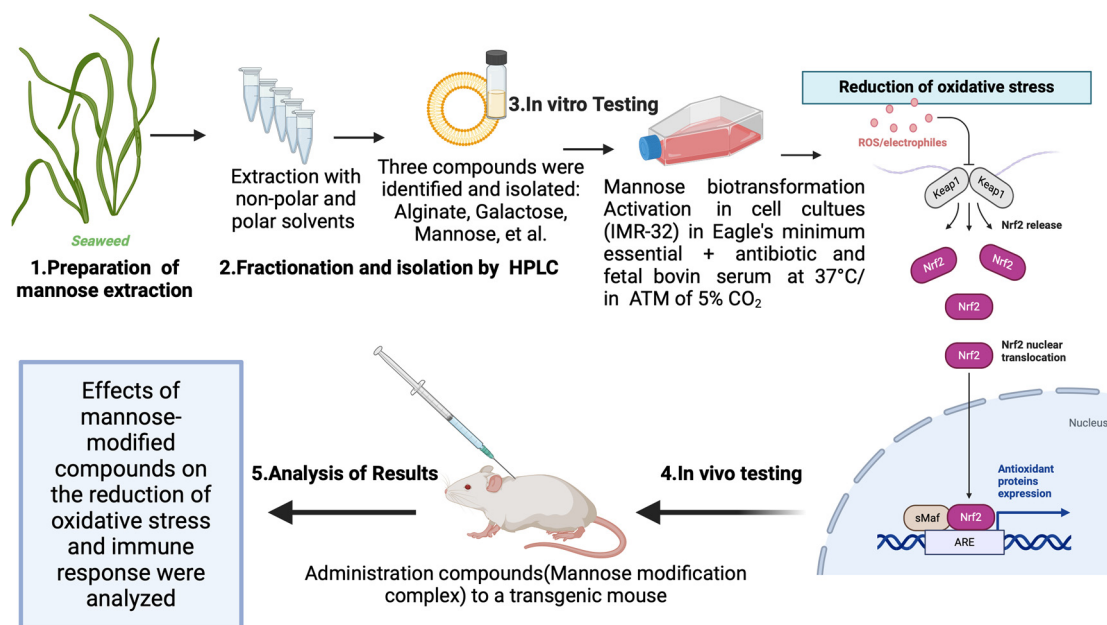


Figure 6. Schematic diagram of mannose purification, biotransformation and covalent modification techniques.

3.1.2. Effect of Mannose Modification on Vaccines

Mannose modification can confer good biocompatibility and immunological activity on nanoparticle vaccines[121]. Mannose modification can improve the stability of the vaccine and increase its circulation time in the body. In addition, mannose-modified nanoparticles can bind specifically to immune cells to improve the cellular uptake rate and antigen delivery efficiency of the vaccine[122–124]. Mannose modification can also turn on certain immune signaling pathways and improve the ability of antigen-presenting cells to show antigens, which makes the immune response

of antigen-specific T cells stronger[125–128]. In the design and preparation of the mannose-modified lipid calcium phosphate nanoparticle vaccine, the influence of mannose modification on the vaccine is reflected in the aspects of improving stability, enhancing immune activity, and promoting antigen presentation, which provides strong technical support for tumor immunotherapy[129].

Mannose-modified lipid calcium phosphate nanoparticles have demonstrated a potentially revolutionary role in cancer therapy, and their ability to target cancer-causing long non-coding RNAs has brought new hope for cancer therapy[130]. By regulating the tumor microenvironment, the nanoparticles can not only inhibit the growth and spread of tumor cells but also enhance the body's anti-tumor immune response[131]. At the same time, combined with the research progress on tumor immunity, mannose-modified lipid calcium phosphate nanoparticles are not only a means of direct attack against tumor cells but also an innovative strategy to promote the body's immune system to participate in the anti-tumor process(Figure 7).

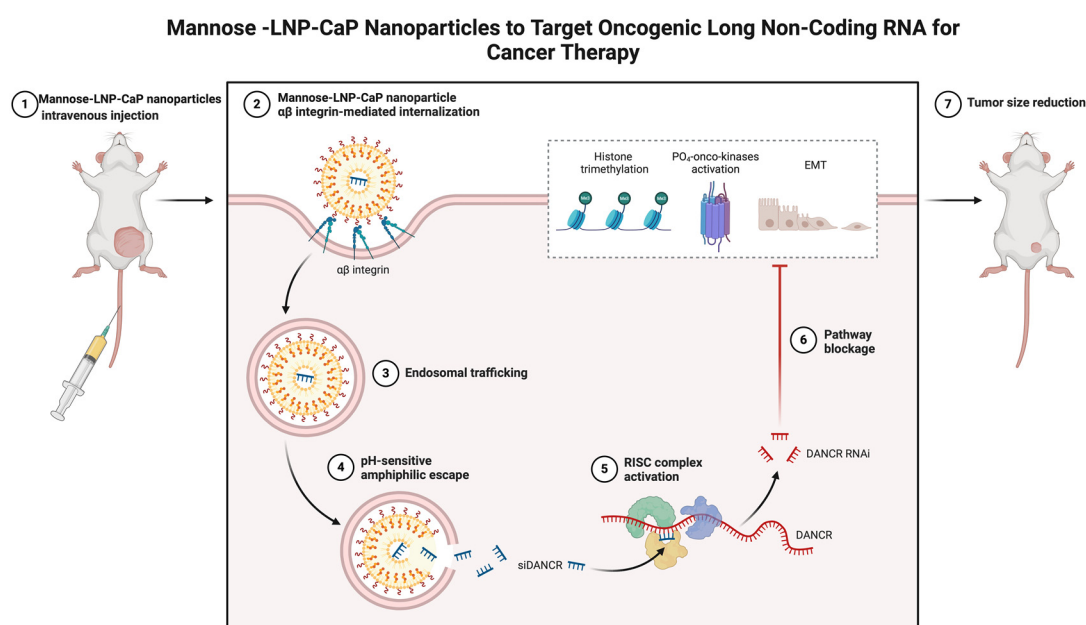


Figure 7. Mannose-LNP-CaP nanoparticles target carcinogenic long non-coding RNA for cancer therapy.

3.2. Design and Preparation of Lipid Calcium Phosphate Nanoparticles

3.2.1. Preparation Method and Structural Advantages

Lipid calcium phosphate (CaP) nanoparticles have attracted much attention due to their unique advantages in vaccine delivery systems. Its design and preparation are essential for improving the bioavailability and immunological efficacy of vaccines[132–135]. Usually, the preparation process includes the solvent precipitation method and the co-precipitation method[136]. In solvent precipitation, the addition of phosphate and calcium ions causes the formation of calcium phosphate nanoparticles in solution. The co-precipitation of the drug and calcium phosphate is typically how the co-precipitation method produces the drug's carrier[137–140]. In addition, mannose-modified lipid calcium phosphate nanoparticles have attracted much attention in recent years[141]. The preparation methods include pre-modification synthesis and post-modification synthesis. In pre-modification synthesis, the mannose group reacts with calcium phosphate nanoparticles at the same time to form mannose-modified nanoparticles[142–145]. In post-modification synthesis, calcium phosphate nanoparticles are first synthesized and then chemically or physically bound to mannose groups[146]. The mannose modification makes the nanoparticles more biocompatible and helps them target better, which makes the vaccine more effective at delivering antigens in living organisms[147–

150]. The design and preparation of lipid calcium phosphate nanoparticles is the key link in the research. Their structural advantages provide a good platform for vaccine delivery and lay the foundation for regulating the tumor microenvironment and enhancing the anti-tumor immune response.

3.2.2. Stability and Biocompatibility of Nanoparticles

Lipid calcium phosphate (CaP) nanoparticles are an important vaccine delivery system and have potential applications in anti-tumor immunotherapy[151]. Their design and preparation need to take into account the stability and biocompatibility of nanoparticles, which are essential to improving vaccine effectiveness and safety[152–154]. The stability of nanoparticles can be achieved by adjusting preparation methods and adding surface modifiers. In the preparation process, the size, morphology, and dispersion of nanoparticles can be controlled by solvent precipitation or the co-precipitation method to ensure their stability[155]. Also, using the right surface modifiers, like polyvinylpyrrolidone (PVP), can make nanoparticles more stable and stop them from being cleared out of the bloodstream and breaking down in living things[156].

Biocompatibility is one of the important indicators to evaluate the application of nanoparticles[157]. Mannose-modified lipid calcium phosphate nanoparticles have received much attention due to their good biocompatibility[158]. Mannose, as a kind of natural sugar in the human body, has good biocompatibility and biodegradability, which can reduce the immune response and toxic side effects on the body[159]. Mannose-modified nanoparticles can effectively avoid the clearance and decomposition of nanoparticles caused by immune responses, thus extending their circulation time in the body and increasing their accumulation in tumor tissues[160]. Additionally, changing the mannose can improve the specific binding between nanoparticles and tumor cells, allowing for more precise targeted delivery and a better immune response against the tumor in the vaccine[161–165].

In general, the stability and biocompatibility of lipid calcium phosphate nanoparticles are the problems that need to be paid attention to and solved in the research. Through rational design and preparation methods and the introduction of biocompatible modifications such as mannose, the application effect of nanoparticles in anti-tumor immunotherapy can be effectively improved, providing strong support for regulating the tumor microenvironment and enhancing the anti-tumor immune response.

4. Immunomodulatory Mechanism of Mannose Modified Lipid Calcium Phosphate Nanoparticle Vaccine

4.1. Tumor Antigen Presentation and T Cell Activation

4.1.1.

The mannose-modified lipid calcium phosphate nanoparticle vaccine plays an important role in enhancing the anti-tumor immune response, and its immune regulation mechanism involves several links[166]. As a carrier, this nanoparticle can effectively load tumor antigens and their related immune stimulators (such as proteins, nucleic acids, etc.) stably on its surface or inside. Mannose-modified nanoparticles can achieve precise, targeted delivery through specific binding to tumor cell surfaces[167–170]. This targeted loading allows the nanoparticles to be more efficiently sought out in tumor tissue and swallowed by tumor cells[171]. Nanoparticles release tumor antigens that are loaded on them. This makes it easier for antigen-presenting cells, like dendritic cells, to take in and process these antigens, which then causes immune cells to recognize and respond to the tumor antigens. In addition, mannose modification is able to interact with specific receptors on the surface of tumor cells to promote intracellular phagocytosis and the internal presentation of nanoparticles[172–180]. Finally, the release of these immune stimulators and the presentation of tumor antigens will activate the body's immune system, especially promoting the activation and

proliferation of antigen-specific T cells and B cells, thus strengthening the immune response to tumors[181–184].

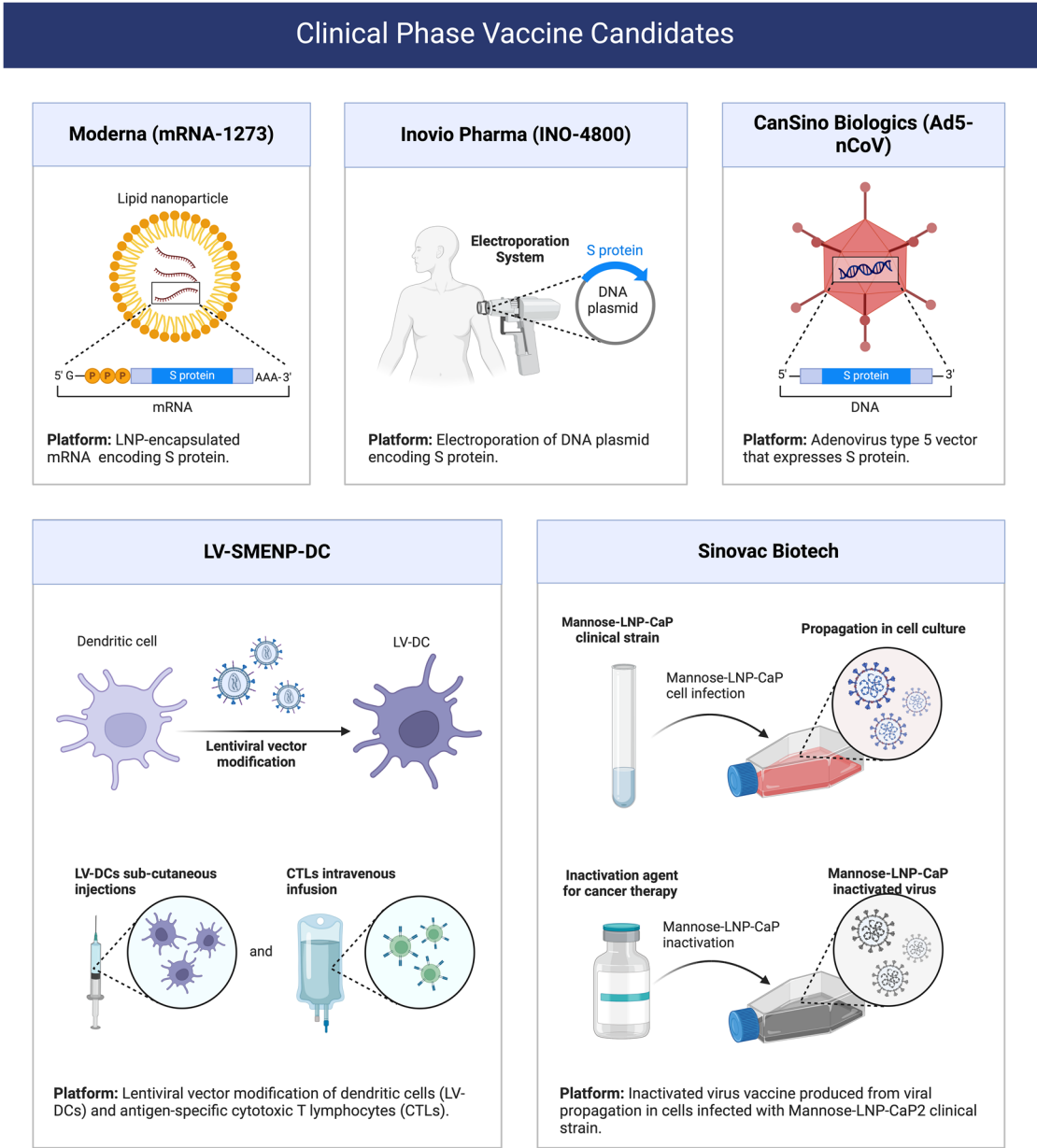
The mannose-modified lipid calcium phosphate nanoparticle vaccine regulates the tumor microenvironment and enhances the anti-tumor immune response by targeting tumor antigen delivery, promoting antigen presentation, activating immune cells, and providing new ideas and methods for tumor therapy.

4.1.2. Activation of T Cells by Mannose Modified Lipid Calcium Phosphate Nanoparticle Vaccine

The mannose-modified lipid calcium phosphate nanoparticle vaccine changes the microenvironment of the tumor, which boosts the immune response against it[185]. One way it does this is by activating T cells, T cells are an important part of the immune system and play a key role in recognizing and eliminating tumor cells[186–188]. Mannose-modified nanoparticles can enhance the immune response by promoting the activation and proliferation of T cells in a variety of ways[189].

Mannose-modified nanoparticles can effectively improve the delivery efficiency of tumor antigen. These nanoparticles act as carriers that can stably load tumor antigens and release them into the tumor microenvironment[190]. Antigen-presenting cells (such as dendritic cells) take up and process these tumor antigens before presenting them to T cells and inducing an immune response to the tumor antigen. Mannose-modified nanoparticles modulate immunosuppressive factors in the tumor microenvironment, thereby reducing T cell suppression[191–195]. In the tumor microenvironment, the presence of immunosuppressive factors (such as PD-L1, TGF- β , etc.) can inhibit the activation and function of T cells[196]. Nanoparticles modified with mannose can control the production and release of these immune-suppressing substances by interacting with specific receptors on the surface of tumor cells. This makes T cells less inhibited and more active, leading to more cell growth and activation[197]. Mannose-modified nanoparticles were also able to activate T-cell co-stimulatory signaling pathways. Co-stimulatory signaling is a key factor in T cell activation and proliferation, among which the CD28/B7 and CD40/CD40L signaling pathways play an important role in T cell activation and function[198–200]. Nanoparticles modified with mannose can turn on these co-stimulatory signaling pathways by attaching to the right receptors on the surface of T cells. This makes T cells' immune response stronger.

Mannose-modified lipid calcium phosphate nanoparticle vaccine, as an innovative immunotherapy method, has received extensive attention and research in recent years[201]. By modulating the tumor microenvironment, this vaccine can significantly enhance the anti-tumor immune response, providing new possibilities for tumor treatment. Several studies[202–205] have explored the treatment of this nanoparticle nucleic acid vaccine through clinical trials. These clinical trials typically involve the treatment of tumor patients in groups, with one group receiving the mannose-modified lipid calcium phosphate nanoparticle vaccine and the other group acting as a control group receiving either standard treatment or a placebo. The main purpose of the trial was to assess the effect of the vaccine on tumor growth in patients and the extent to which it activated the immune system[206]. By comparing the effects of treatment on different groups of patients, researchers can assess the effectiveness and safety of the vaccine. In clinical trials[207–212], researchers typically look at data on several aspects, including changes in tumor size, longer patient survival, and increased immune cell activity. These data can not only help judge the therapeutic effect of the vaccine but also provide an important basis for further optimization of the vaccine design and treatment plan(Figure 8).



enabling the body to produce a more durable and powerful response to further treatment with tumor vaccines or other immunomodulators[227–230].

As a new way to treat tumors with immunotherapy, mannose-modified lipid calcium phosphate nanoparticle vaccine has shown great promise in improving the immune response to tumors and building immune memory[231–235]. This provides new ideas and strategies for the future treatment of cancer and is expected to play an important role in clinical practice, bringing more effective treatment effects and a better quality of life for patients[236–240]. The main determinants of drug resistance include heterogeneity of the tumor microenvironment, immunosuppressive mechanisms, and inefficiency of drug delivery[241]. A mannose-modified lipid calcium phosphate nanoparticle vaccine can improve the immunogenicity of tumor cells, regulate the tumor microenvironment, and promote an anti-tumor immune response by simulating natural antigen presentation(Figure 9).

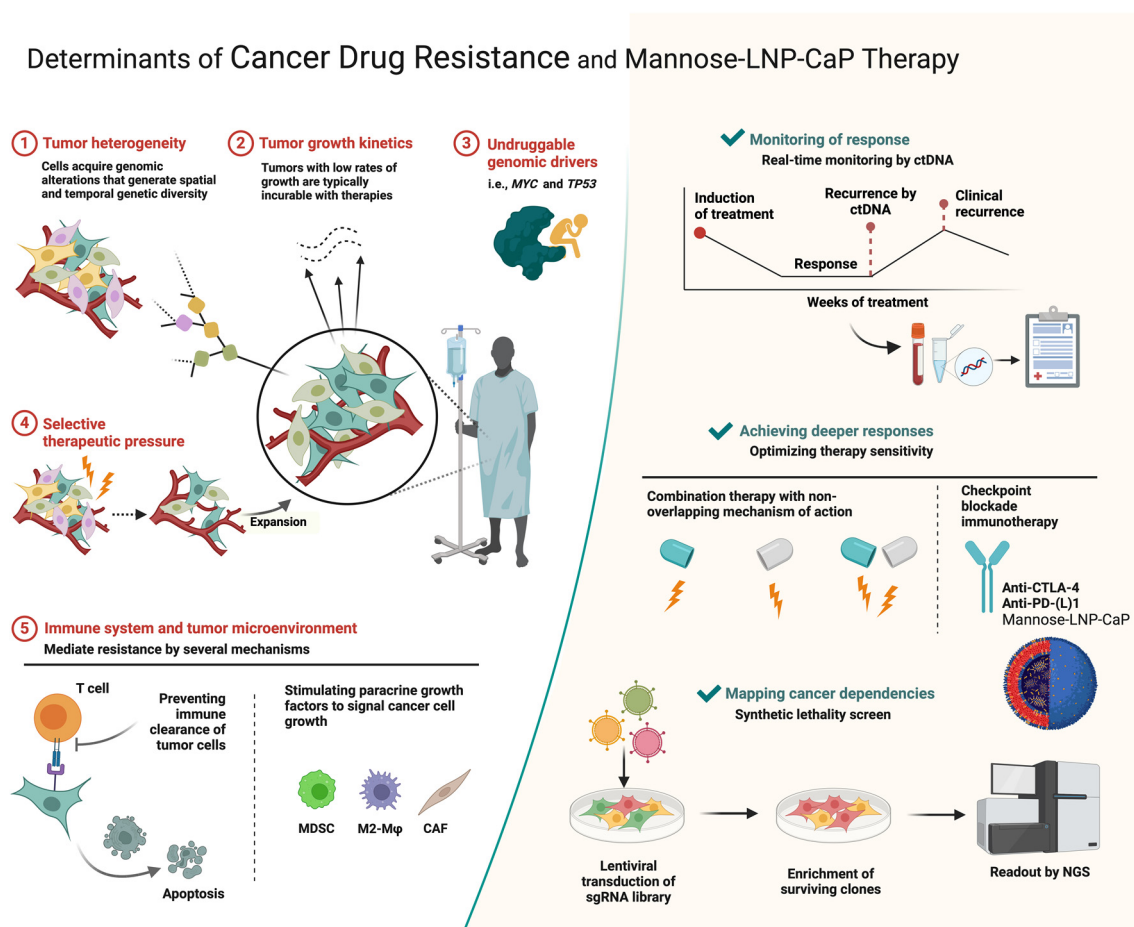


Figure 9. Schematic diagram of determinants of Cancer Drug Resistance and Mannose-LNP-CaP Therapy.

4.3. Analysis of Immune Cell Infiltration in Tumor Tissue

Tumor tissue immune cell infiltration analysis is one of the important indicators to evaluate the effect of the mannose-modified lipid calcium phosphate nanoparticle vaccine on enhancing the anti-tumor immune response in the regulation of the tumor microenvironment[242]. Through immunohistochemical staining, flow cytometry, and other techniques, different types of immune cell infiltration in tumor tissues can be quantitatively analyzed, such as CD8+ T cells, CD4+ T cells, natural killer cells, and so on. It was found that the mannose-modified lipid calcium phosphate nanoparticle vaccine can significantly increase the amount of CD8+ T cell infiltration in tumor tissues, improve the ratio of CD8+/CD4+ T cells, and promote the transformation of the tumor immune microenvironment[243–245]. In addition, the vaccine can also effectively increase the degree of invasion of natural killer cells, thereby enhancing the clearance of tumor cells[246]. The analysis of

tumor immune cell infiltration showed that a mannose-modified lipid calcium phosphate nanoparticle vaccine could regulate the tumor microenvironment and enhance the anti-tumor immune response significantly.

5. Enlightenment and Research Prospect of Preclinical Research

As a novel tumor immunotherapy strategy, mannose modified lipid calcium phosphate nanoparticle vaccine has shown great potential in preclinical studies[247–250]. Through in-depth investigation of its mechanism of action, we found that the vaccine can effectively regulate the tumor microenvironment and enhance the anti-tumor immune response of the body. Studies[251–253] have shown that mannose-modified nanoparticles can promote uptake and endocytosis of tumor cells through specific targeting, thereby improving the efficiency of antigen delivery and activating the activity of tumor-associated antigen-specific T cells. In addition, the vaccine can also induce immune cells in the tumor microenvironment, such as plasma cells and dendritic cells, to release pro-inflammatory factors, and inhibit the function of immunosuppressive cells, thereby promoting the activation and expansion of T cells, enhancing the killing ability of cytotoxic T lymphocytes, and finally realizing the effective elimination of tumors.

6. Research Future Prospects

In future studies, we can further optimize the formulation and preparation process of mannose-modified lipid calcium phosphate nanoparticle vaccine to improve its stability and bioavailability in vivo, thereby enhancing its anti-tumor immunotherapy effect[254]. In addition, the vaccine could be explored in combination with other tumor therapies, such as chemotherapy, radiotherapy and immune checkpoint inhibitors, to achieve better therapeutic outcomes. In addition, it is possible to design personalized treatment regimens for different types and stages of tumors and verify their safety and efficacy through preclinical and clinical studies. In general, mannose modified lipid calcium phosphate nanoparticles vaccine has broad application prospects in the field of tumor immunotherapy, and is expected to become one of the important strategies for tumor therapy in the future.

7. Conclusions

Mannose-modified nanoparticles can effectively regulate the tumor microenvironment, inhibit tumor growth, and enhance the infiltration of immune cells. This vaccine not only induces a strong and long-lasting antigen-specific T cell response but also activates anti-tumor effector cells such as natural killer cells and macrophages. In addition, after reviewing the literature, we found that the vaccine could induce antibody production and thus enhance humoral immune response; namely, the mannose-modified lipid calcium phosphate nanoparticle vaccine showed good potential in regulating tumor microenvironment, promoting immune cell infiltration, and inducing antibody and T cell responses, providing a new idea and strategy for tumor immunotherapy.

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References

- Huang, J. L., Chen, H. Z., & Gao, X. L. (2018). Lipid-coated calcium phosphate nanoparticle and beyond: a versatile platform for drug delivery. *Journal of drug targeting*, 26(5-6), 398–406. <https://doi.org/10.1080/1061186X.2017.1419360>
- Haynes, M. T., & Huang, L. (2014). Lipid-coated calcium phosphate nanoparticles for nonviral gene therapy. *Advances in genetics*, 88, 205–229. <https://doi.org/10.1016/B978-0-12-800148-6.00007-9>
- Shen, Y., & Ma, H. (2022). Oridonin-loaded lipid-coated calcium phosphate nanoparticles: preparation, characterization, and application in A549 lung cancer. *Pharmaceutical development and technology*, 27(5), 598–605. <https://doi.org/10.1080/10837450.2022.2090958>
- Favarin, B. Z., Bolean, M., Ramos, A. P., Magrini, A., Rosato, N., Millán, J. L., Bottini, M., Costa-Filho, A. J., & Ciancaglini, P. (2020). Lipid composition modulates ATP hydrolysis and calcium phosphate mineral propagation by TNAP-harboring proteoliposomes. *Archives of biochemistry and biophysics*, 691, 108482. <https://doi.org/10.1016/j.abb.2020.108482>
- Satterlee, A. B., & Huang, L. (2016). Current and Future Theranostic Applications of the Lipid-Calcium-Phosphate Nanoparticle Platform. *Theranostics*, 6(7), 918–929. <https://doi.org/10.7150/thno.14689>
- Zhou, C., Yu, B., Yang, X., Huo, T., Lee, L. J., Barth, R. F., & Lee, R. J. (2010). Lipid-coated nano-calcium-phosphate (LNCP) for gene delivery. *International journal of pharmaceutics*, 392(1-2), 201–208. <https://doi.org/10.1016/j.ijpharm.2010.03.012>
- Dong, K., Zhang, Y., Ji, H. R., Guan, Z. L., Wang, D. Y., Guo, Z. Y., Deng, S. J., He, B. Y., Xing, J. F., & You, C. Y. (2024). Dexamethasone-Loaded Lipid Calcium Phosphate Nanoparticles Treat Experimental Colitis by Regulating Macrophage Polarization in Inflammatory Sites. *International journal of nanomedicine*, 19, 993–1016. <https://doi.org/10.2147/IJN.S442369>
- Cruz, M. A. E., Ferreira, C. R., Tovani, C. B., de Oliveira, F. A., Bolean, M., Caseli, L., Mebarek, S., Millán, J. L., Buchet, R., Bottini, M., Ciancaglini, P., & Paula Ramos, A. (2020). Phosphatidylserine controls calcium phosphate nucleation and growth on lipid monolayers: A physicochemical understanding of matrix vesicle-driven biomineralization. *Journal of structural biology*, 212(2), 107607. <https://doi.org/10.1016/j.jsb.2020.107607>
- Tang, J., Li, B., Howard, C. B., Mahler, S. M., Thurecht, K. J., Wu, Y., Huang, L., & Xu, Z. P. (2019). Multifunctional lipid-coated calcium phosphate nanoplatfroms for complete inhibition of large triple negative breast cancer via targeted combined therapy. *Biomaterials*, 216, 119232. <https://doi.org/10.1016/j.biomaterials.2019.119232>
- Li, J., Chen, Y. C., Tseng, Y. C., Mozumdar, S., & Huang, L. (2010). Biodegradable calcium phosphate nanoparticle with lipid coating for systemic siRNA delivery. *Journal of controlled release : official journal of the Controlled Release Society*, 142(3), 416–421. <https://doi.org/10.1016/j.jconrel.2009.11.008>
- Zhang, J., Zhang, H., Jiang, J., Cui, N., Xue, X., Wang, T., Wang, X., He, Y., & Wang, D. (2020). Doxorubicin-Loaded Carbon Dots Lipid-Coated Calcium Phosphate Nanoparticles for Visual Targeted Delivery and Therapy of Tumor. *International journal of nanomedicine*, 15, 433–444. <https://doi.org/10.2147/IJN.S229154>
- Wu, C., Xu, J., Hao, Y., Zhao, Y., Qiu, Y., Jiang, J., Yu, T., Ji, P., & Liu, Y. (2017). Application of a lipid-coated hollow calcium phosphate nanoparticle in synergistic co-delivery of doxorubicin and paclitaxel for the treatment of human lung cancer A549 cells. *International journal of nanomedicine*, 12, 7979–7992. <https://doi.org/10.2147/IJN.S140957>
- Oyane, A., Wang, X., Sogo, Y., Ito, A., & Tsurushima, H. (2012). Calcium phosphate composite layers for surface-mediated gene transfer. *Acta biomaterialia*, 8(6), 2034–2046. <https://doi.org/10.1016/j.actbio.2012.02.003>
- Liu, H., , Zhang, H., , Yin, N., , Zhang, Y., , Gou, J., , Yin, T., , He, H., , Ding, H., , Zhang, Y., , & Tang, X., (2020). Sialic acid-modified dexamethasone lipid calcium phosphate gel core nanoparticles for target treatment of kidney injury. *Biomaterials science*, 8(14), 3871–3884. <https://doi.org/10.1039/d0bm00581a>
- Li, J., Yang, Y., & Huang, L. (2012). Calcium phosphate nanoparticles with an asymmetric lipid bilayer coating for siRNA delivery to the tumor. *Journal of controlled release : official journal of the Controlled Release Society*, 158(1), 108–114. <https://doi.org/10.1016/j.jconrel.2011.10.020>
- Tseng, Y. C., Xu, Z., Guley, K., Yuan, H., & Huang, L. (2014). Lipid-calcium phosphate nanoparticles for delivery to the lymphatic system and SPECT/CT imaging of lymph node metastases. *Biomaterials*, 35(16), 4688–4698. <https://doi.org/10.1016/j.biomaterials.2014.02.030>
- Sethuraman, V., Janakiraman, K., Krishnaswami, V., Natesan, S., & Kandasamy, R. (2021). In vivo

- synergistic anti-tumor effect of lumefantrine combined with pH responsive behavior of nano calcium phosphate based lipid nanoparticles on lung cancer. *European journal of pharmaceutical sciences : official journal of the European Federation for Pharmaceutical Sciences*, 158, 105657. <https://doi.org/10.1016/j.ejps.2020.105657>
18. Dolci, L. S., Panzavolta, S., Albertini, B., Campisi, B., Gandolfi, M., Bigi, A., & Passerini, N. (2018). Spray-congealed solid lipid microparticles as a new tool for the controlled release of bisphosphonates from a calcium phosphate bone cement. *European journal of pharmaceuticals and biopharmaceutics : official journal of Arbeitsgemeinschaft fur Pharmazeutische Verfahrenstechnik e.V*, 122, 6–16. <https://doi.org/10.1016/j.ejpb.2017.10.002>
 19. Tanaka, Y., & Schroit, A. J. (1986). Calcium/phosphate-induced immobilization of fluorescent phosphatidylserine in synthetic bilayer membranes: inhibition of lipid transfer between vesicles. *Biochemistry*, 25(8), 2141–2148. <https://doi.org/10.1021/bi00356a044>
 20. Wang, X., Zhang, M., Zhang, L., Li, L., Li, S., Wang, C., Su, Z., Yuan, Y., & Pan, W. (2017). Designed Synthesis of Lipid-Coated Polyacrylic Acid/Calcium Phosphate Nanoparticles as Dual pH-Responsive Drug-Delivery Vehicles for Cancer Chemotherapy. *Chemistry (Weinheim an der Bergstrasse, Germany)*, 23(27), 6586–6595. <https://doi.org/10.1002/chem.201700060>
 21. Genge, B. R., Wu, L. N., & Wuthier, R. E. (2008). Mineralization of annexin-5-containing lipid-calcium-phosphate complexes: modulation by varying lipid composition and incubation with cartilage collagens. *The Journal of biological chemistry*, 283(15), 9737–9748. <https://doi.org/10.1074/jbc.M706523200>
 22. Guo, W., Morrisett, J. D., Lawrie, G. M., DeBakey, M. E., & Hamilton, J. A. (1998). Identification of different lipid phases and calcium phosphate deposits in human carotid artery plaques by MAS NMR spectroscopy. *Magnetic resonance in medicine*, 39(2), 184–189. <https://doi.org/10.1002/mrm.1910390204>
 23. Liu, Y., Hu, Y., & Huang, L. (2014). Influence of polyethylene glycol density and surface lipid on pharmacokinetics and biodistribution of lipid-calcium-phosphate nanoparticles. *Biomaterials*, 35(9), 3027–3034. <https://doi.org/10.1016/j.biomaterials.2013.12.022>
 24. Tang, J., Howard, C. B., Mahler, S. M., Thurecht, K. J., Huang, L., & Xu, Z. P., (2018). Enhanced delivery of siRNA to triple negative breast cancer cells in vitro and in vivo through functionalizing lipid-coated calcium phosphate nanoparticles with dual target ligands. *Nanoscale*, 10(9), 4258–4266. <https://doi.org/10.1039/c7nr08644j>
 25. Skrtic, D., & Eanes, E. D. (1992). Membrane-mediated precipitation of calcium phosphate in model liposomes with matrix vesicle-like lipid composition. *Bone and mineral*, 16(2), 109–119. [https://doi.org/10.1016/0169-6009\(92\)90881-d](https://doi.org/10.1016/0169-6009(92)90881-d)
 26. Claudio T. (1992). Stable expression of heterologous multisubunit protein complexes established by calcium phosphate- or lipid-mediated cotransfection. *Methods in enzymology*, 207, 391–408. [https://doi.org/10.1016/0076-6879\(92\)07028-m](https://doi.org/10.1016/0076-6879(92)07028-m)
 27. Dolci, L. S., Panzavolta, S., Torricelli, P., Albertini, B., Sicuro, L., Fini, M., Bigi, A., & Passerini, N. (2019). Modulation of Alendronate release from a calcium phosphate bone cement: An in vitro osteoblast-osteoclast co-culture study. *International journal of pharmaceuticals*, 554, 245–255. <https://doi.org/10.1016/j.ijpharm.2018.11.023>
 28. Chen, J., Gao, P., Yuan, S., Li, R., Ni, A., Chu, L., Ding, L., Sun, Y., Liu, X. Y., & Duan, Y. (2016). Oncolytic Adenovirus Complexes Coated with Lipids and Calcium Phosphate for Cancer Gene Therapy. *ACS nano*, 10(12), 11548–11560. <https://doi.org/10.1021/acsnano.6b06182>
 29. Kashiwa, H. K., & Mukai, C. D. (1971). Lipid-calcium-phosphate spherules in chondrocytes of developing long bones. *Clinical orthopaedics and related research*, 78, 223–229. <https://doi.org/10.1097/00003086-197107000-00019>
 30. Sethuraman, V., Janakiraman, K., Krishnaswami, V., Natesan, S., & Kandasamy, R. (2019). pH responsive delivery of lumefantrine with calcium phosphate nanoparticles loaded lipidic cubosomes for the site specific treatment of lung cancer. *Chemistry and physics of lipids*, 224, 104763. <https://doi.org/10.1016/j.chemphyslip.2019.03.016>
 31. Ke, C. H., Chiu, Y. H., Huang, K. C., & Lin, C. S. (2022). Exposure of Immunogenic Tumor Antigens in Surrendered Immunity and the Significance of Autologous Tumor Cell-Based Vaccination in Precision Medicine. *International journal of molecular sciences*, 24(1), 147. <https://doi.org/10.3390/ijms24010147>
 32. Ramirez-Valdez, R. A., Baharom, F., Khalilnezhad, A., Fussell, S. C., Hermans, D. J., Schrager, A. M., Tobin, K. K. S., Lynn, G. M., Khalilnezhad, S., Ginhoux, F., Van den Eynde, B. J., Leung, C. S. K., Ishizuka, A. S., &

- Seder, R. A. (2023). Intravenous heterologous prime-boost vaccination activates innate and adaptive immunity to promote tumor regression. *Cell reports*, 42(6), 112599. <https://doi.org/10.1016/j.celrep.2023.112599>
33. Jeong, M., Kim, H., Yoon, J., Kim, D. H., & Park, J. H. (2022). Coimmunomodulation of tumor and tumor-draining lymph nodes during in situ vaccination promotes antitumor immunity. *JCI insight*, 7(12), e146608. <https://doi.org/10.1172/jci.insight.146608>
 34. Mehdizadeh, R., Shariatpanahi, S. P., Goliaei, B., & Rüegg, C. (2023). Targeting myeloid-derived suppressor cells in combination with tumor cell vaccination predicts anti-tumor immunity and breast cancer dormancy: an in silico experiment. *Scientific reports*, 13(1), 5875. <https://doi.org/10.1038/s41598-023-32554-z>
 35. Medina-Echeverz, J., Hinterberger, M., Testori, M., Geiger, M., Giessel, R., Bathke, B., Kassub, R., Gräbnitz, F., Fiore, G., Wennier, S. T., Chaplin, P., Suter, M., Hochrein, H., & Lauterbach, H. (2019). Synergistic cancer immunotherapy combines MVA-CD40L induced innate and adaptive immunity with tumor targeting antibodies. *Nature communications*, 10(1), 5041. <https://doi.org/10.1038/s41467-019-12998-6>
 36. Clark, P. A., Sriramaneni, R. N., Bates, A. M., Jin, W. J., Jagodinsky, J. C., Hernandez, R., Le, T., Jeffery, J. J., Marsh, I. R., Grudzinski, J. J., Aluicio-Sarduy, E., Barnhart, T. E., Anderson, B. R., Chakravarty, I., Arthur, I. S., Kim, K., Engle, J. W., Bednarz, B. P., Weichert, J. P., & Morris, Z. S. (2021). Low-Dose Radiation Potentiates the Propagation of Anti-Tumor Immunity against Melanoma Tumor in the Brain after In Situ Vaccination at a Tumor outside the Brain. *Radiation research*, 195(6), 522–540. <https://doi.org/10.1667/RADE-20-00237.1>
 37. Kim, N. J., Yoon, J. H., Tuomi, A. C., Lee, J., & Kim, D. (2023). In-situ tumor vaccination by percutaneous ablative therapy and its synergy with immunotherapeutics: An update on combination therapy. *Frontiers in immunology*, 14, 1118845. <https://doi.org/10.3389/fimmu.2023.1118845>
 38. Varypataki, E. M., Hasler, F., Waeckerle-Men, Y., Vogel-Kindgen, S., Høgset, A., Kündig, T. M., Gander, B., Halin, C., & Johansen, P. (2019). Combined Photosensitization and Vaccination Enable CD8 T-Cell Immunity and Tumor Suppression Independent of CD4 T-Cell Help. *Frontiers in immunology*, 10, 1548. <https://doi.org/10.3389/fimmu.2019.01548>
 39. Dong, W., Du, J., Shen, H., Gao, D., Li, Z., Wang, G., Mu, X., & Liu, Q. (2010). Administration of embryonic stem cells generates effective antitumor immunity in mice with minor and heavy tumor load. *Cancer immunology, immunotherapy : CII*, 59(11), 1697–1705. <https://doi.org/10.1007/s00262-010-0899-9>
 40. Koido, S., Ito, M., Sagawa, Y., Okamoto, M., Hayashi, K., Nagasaki, E., Kan, S., Komita, H., Kamata, Y., & Homma, S. (2014). Vaccination with vascular progenitor cells derived from induced pluripotent stem cells elicits antitumor immunity targeting vascular and tumor cells. *Cancer immunology, immunotherapy : CII*, 63(5), 459–468. <https://doi.org/10.1007/s00262-014-1531-1>
 41. Accolla, R. S., & Tosi, G. (2013). Adequate antigen availability: a key issue for novel approaches to tumor vaccination and tumor immunotherapy. *Journal of neuroimmune pharmacology : the official journal of the Society on NeuroImmune Pharmacology*, 8(1), 28–36. <https://doi.org/10.1007/s11481-012-9423-7>
 42. Tong, W., Maira, M., Roychoudhury, R., Galan, A., Brahimi, F., Gilbert, M., Cunningham, A. M., Josephy, S., Pirvulescu, I., Moffett, S., & Saragovi, H. U. (2019). Vaccination with Tumor-Ganglioside Glycomimetics Activates a Selective Immunity that Affords Cancer Therapy. *Cell chemical biology*, 26(7), 1013–1026.e4. <https://doi.org/10.1016/j.chembiol.2019.03.018>
 43. Park, J., Hsueh, P. C., Li, Z., & Ho, P. C. (2023). Microenvironment-driven metabolic adaptations guiding CD8+ T cell anti-tumor immunity. *Immunity*, 56(1), 32–42. <https://doi.org/10.1016/j.immuni.2022.12.008>
 44. Castro Dopico, X., Ols, S., Loré, K., & Karlsson Hedestam, G. B. (2022). Immunity to SARS-CoV-2 induced by infection or vaccination. *Journal of internal medicine*, 291(1), 32–50. <https://doi.org/10.1111/joim.13372>
 45. Bevers, S., Kooijmans, S. A. A., Van de Velde, E., Evers, M. J. W., Seghers, S., Gitz-Francois, J. J. J. M., van Kronenburg, N. C. H., Fens, M. H. A. M., Mastrobattista, E., Hassler, L., Sork, H., Lehto, T., Ahmed, K. E., El Andaloussi, S., Fiedler, K., Breckpot, K., Maes, M., Van Hoorick, D., Bastogne, T., Schifflers, R. M., ... De Koker, S. (2022). mRNA-LNP vaccines tuned for systemic immunization induce strong antitumor immunity by engaging splenic immune cells. *Molecular therapy : the journal of the American Society of Gene Therapy*, 30(9), 3078–3094. <https://doi.org/10.1016/j.ymthe.2022.07.007>
 46. Schetters, S. T. T., Li, R. J. E., Kruijsen, L. J. W., Engels, S., Ambrosini, M., Garcia-Vallejo, J. J., Kalay, H., Unger, W. W. J., & van Kooyk, Y. (2020). Adaptable antigen matrix platforms for peptide vaccination strategies and T cell-mediated anti-tumor immunity. *Biomaterials*, 262, 120342. <https://doi.org/10.1016/j.biomaterials.2020.120342>

47. Bruni, L., Saura-Lázaro, A., Montoliu, A., Brotons, M., Alemany, L., Diallo, M. S., Afsar, O. Z., LaMontagne, D. S., Mosina, L., Contreras, M., Velandia-González, M., Pastore, R., Gacic-Dobo, M., & Bloem, P. (2021). HPV vaccination introduction worldwide and WHO and UNICEF estimates of national HPV immunization coverage 2010-2019. *Preventive medicine*, 144, 106399. <https://doi.org/10.1016/j.ypmed.2020.106399>
48. Li, S., Zhang, Q., Bai, H., Huang, W., Shu, C., Ye, C., Sun, W., & Ma, Y. (2019). Self-Assembled Nanofibers Elicit Potent HPV16 E7-Specific Cellular Immunity And Abolish Established TC-1 Graft Tumor. *International journal of nanomedicine*, 14, 8209–8219. <https://doi.org/10.2147/IJN.S214525>
49. Dolina, J. S., Lee, J., Brightman, S. E., McArdle, S., Hall, S. M., Thota, R. R., Zavala, K. S., Lanka, M., Ramamoorthy Premal, A. L., Greenbaum, J. A., Cohen, E. E. W., Peters, B., & Schoenberger, S. P. (2023). Linked CD4+/CD8+ T cell neoantigen vaccination overcomes immune checkpoint blockade resistance and enables tumor regression. *The Journal of clinical investigation*, 133(17), e164258. <https://doi.org/10.1172/JCI164258>
50. Kim, Y., Lee, S., & Jon, S. (2024). Liposomal Delivery of an Immunostimulatory CpG Induces Robust Antitumor Immunity and Long-Term Immune Memory by Reprogramming Tumor-Associated Macrophages. *Advanced healthcare materials*, 13(6), e2300549. <https://doi.org/10.1002/adhm.202300549>
51. Carter, J. A., Matta, B., Battaglia, J., Somerville, C., Harris, B. D., LaPan, M., Atwal, G. S., & Barnes, B. J. (2023). Identification of pan-cancer/testis genes and validation of therapeutic targeting in triple-negative breast cancer: Lin28a-based and Siglece-based vaccination induces antitumor immunity and inhibits metastasis. *Journal for immunotherapy of cancer*, 11(12), e007935. <https://doi.org/10.1136/jitc-2023-007935>
52. Liu, Y., Li, H., Zhao, H., Hao, Y., Van Herck, S., Xu, Z., Wang, G., Wang, X., Zhang, X., Ge, X., Li, X., Yang, A., Chen, H., Zou, J., Wang, W., De Geest, B. G., & Zhang, Z. (2022). In Situ Tumor Vaccination with Calcium-Linked Degradable Coacervate Nanocomplex Co-Delivering Photosensitizer and TLR7/8 Agonist to Trigger Effective Anti-Tumor Immune Responses. *Advanced healthcare materials*, 11(12), e2102781. <https://doi.org/10.1002/adhm.202102781>
53. Wang, H., Gan, M., Wu, B., Zeng, R., Wang, Z., Xu, J., Li, J., Zhang, Y., Cao, J., Chen, L., Di, D., Peng, S., Lei, J., Zhao, Y., Song, X., Yuan, T., Zhou, T., Liu, Q., Yi, J., Wang, X., ... Liu, L. (2023). Humoral and cellular immunity of two-dose inactivated COVID-19 vaccination in Chinese children: A prospective cohort study. *Journal of medical virology*, 95(1), e28380. <https://doi.org/10.1002/jmv.28380>
54. Zhao, X., Zhang, J., Chen, B., Ding, X., Zhao, N., & Xu, F. J. (2023). Rough Nanovaccines Boost Antitumor Immunity Through the Enhancement of Vaccination Cascade and Immunogenic Cell Death Induction. *Small methods*, 7(5), e2201595. <https://doi.org/10.1002/smt.202201595>
55. Luo, X., Qiu, Y., Dinesh, P., Gong, W., Jiang, L., Feng, X., Li, J., Jiang, Y., Lei, Y. L., & Chen, Q. (2021). The functions of autophagy at the tumour-immune interface. *Journal of cellular and molecular medicine*, 25(5), 2333–2341. <https://doi.org/10.1111/jcmm.16331>
56. Perciani, C. T., Liu, L. Y., Wood, L., & MacParland, S. A. (2021). Enhancing Immunity with Nanomedicine: Employing Nanoparticles to Harness the Immune System. *ACS nano*, 15(1), 7–20. <https://doi.org/10.1021/acsnano.0c08913>
57. Abascal, J., Oh, M. S., Licican, E. L., Dubinett, S. M., Salehi-Rad, R., & Liu, B. (2023). Dendritic Cell Vaccination in Non-Small Cell Lung Cancer: Remodeling the Tumor Immune Microenvironment. *Cells*, 12(19), 2404. <https://doi.org/10.3390/cells12192404>
58. McAuliffe, J., Chan, H. F., Noblecourt, L., Ramirez-Valdez, R. A., Pereira-Almeida, V., Zhou, Y., Pollock, E., Cappuccini, F., Redchenko, I., Hill, A. V., Leung, C. S. K., & Van den Eynde, B. J. (2021). Heterologous prime-boost vaccination targeting MAGE-type antigens promotes tumor T-cell infiltration and improves checkpoint blockade therapy. *Journal for immunotherapy of cancer*, 9(9), e003218. <https://doi.org/10.1136/jitc-2021-003218>
59. Morera-Díaz, Y., Canaán-Haden, C., Sánchez-Ramírez, J., Bequet-Romero, M., Gonzalez-Moya, I., Martínez, R., Falcón, V., Palenzuela, D., Ayala-Ávila, M., & Gavilondo, J. V. (2023). Active immunization with a structurally aggregated PD-L1 antigen breaks T and B immune tolerance in non-human primates and exhibits in vivo anti-tumoral effects in immunocompetent mouse tumor models. *Cancer letters*, 561, 216156. <https://doi.org/10.1016/j.canlet.2023.216156>
60. Femel, J., van Hooren, L., Herre, M., Cedervall, J., Saupe, F., Huijbers, E. J. M., Verboogen, D. R. J., Reichel, M., Thijssen, V. L., Griffioen, A. W., Hellman, L., Dimberg, A., & Olsson, A. K. (2022). Vaccination against galectin-1 promotes cytotoxic T-cell infiltration in melanoma and reduces tumor burden. *Cancer*

- immunology, immunotherapy : CII, 71(8), 2029–2040. <https://doi.org/10.1007/s00262-021-03139-4>
- Ishio, T., Tsukamoto, S., Yokoyama, E., Izumiyama, K., Saito, M., Muraki, H., Kobayashi, M., Mori, A., Morioka, M., & Kondo, T. (2023). Anti-CD20 antibodies and bendamustine attenuate humoral immunity to COVID-19 vaccination in patients with B-cell non-Hodgkin lymphoma. *Annals of hematology*, 102(6), 1421–1431. <https://doi.org/10.1007/s00277-023-05204-7>
61. Kershner, L. J., Choi, K., Wu, J., Zhang, X., Perrino, M., Salomonis, N., Shern, J. F., & Ratner, N. (2022). Multiple Nf1 Schwann cell populations reprogram the plexiform neurofibroma tumor microenvironment. *JCI insight*, 7(18), e154513. <https://doi.org/10.1172/jci.insight.154513>
 62. Top, K. A., Vaudry, W., Morris, S. K., Pham-Huy, A., Pernica, J. M., Tapiéro, B., Gantt, S., Price, V. E., Rassekh, S. R., Sung, L., McConnell, A., Rubin, E., Chawla, R., & Halperin, S. A. (2020). Waning Vaccine Immunity and Vaccination Responses in Children Treated for Acute Lymphoblastic Leukemia: A Canadian Immunization Research Network Study. *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America*, 71(9), e439–e448. <https://doi.org/10.1093/cid/ciaa163>
 63. Scheer, V., Goldammer, M., Flindt, S., van Zandbergen, G., & Hinz, T. (2020). Therapeutische Immunisierungen gegen Tumore und neurodegenerative Erkrankungen [Therapeutic vaccination for tumors and neurodegenerative diseases]. *Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz*, 63(11), 1373–1379. <https://doi.org/10.1007/s00103-020-03226-4>
 64. Chen, P. M., Pan, W. Y., Wu, C. Y., Yeh, C. Y., Korupalli, C., Luo, P. K., Chou, C. J., Chia, W. T., & Sung, H. W. (2020). Modulation of tumor microenvironment using a TLR-7/8 agonist-loaded nanoparticle system that exerts low-temperature hyperthermia and immunotherapy for in situ cancer vaccination. *Biomaterials*, 230, 119629. <https://doi.org/10.1016/j.biomaterials.2019.119629>
 65. Li, E., Butkovich, N., Tucker, J. A., Nelson, E. L., & Wang, S. W. (2023). Evaluating Anti-tumor Immune Responses of Protein Nanoparticle-Based Cancer Vaccines. *Methods in molecular biology* (Clifton, N.J.), 2671, 321–333. https://doi.org/10.1007/978-1-0716-3222-2_18
 66. Zhao, B., Kilian, M., Bunse, T., Platten, M., & Bunse, L. (2023). Tumor-reactive T helper cells in the context of vaccination against glioma. *Cancer cell*, 41(11), 1829–1834. <https://doi.org/10.1016/j.ccell.2023.09.013>
 67. Liu, G., Zhu, M., Zhao, X., & Nie, G. (2021). Nanotechnology-empowered vaccine delivery for enhancing CD8+ T cells-mediated cellular immunity. *Advanced drug delivery reviews*, 176, 113889. <https://doi.org/10.1016/j.addr.2021.113889>
 68. Carlson, P. M., Patel, R. B., Birstler, J., Rodriguez, M., Sun, C., Erbe, A. K., Bates, A. M., Marsh, I., Grudzinski, J., Hernandez, R., Pieper, A. A., Feils, A. S., Rakhmievich, A. L., Weichert, J. P., Bednarz, B. P., Sondel, P. M., & Morris, Z. S. (2023). Radiation to all macroscopic sites of tumor permits greater systemic antitumor response to in situ vaccination. *Journal for immunotherapy of cancer*, 11(1), e005463. <https://doi.org/10.1136/jitc-2022-005463>
 69. Vajari, M. K., Sanaei, M. J., Salari, S., Rezvani, A., Ravari, M. S., & Bashash, D. (2023). Breast cancer vaccination: Latest advances with an analytical focus on clinical trials. *International immunopharmacology*, 123, 110696. <https://doi.org/10.1016/j.intimp.2023.110696>
 70. Vieira, J. F., Peixoto, A. P., Murta, E. F. C., & Michelin, M. A. (2021). Prophylactic Dendritic Cell Vaccination in Experimental Breast Cancer Controls Immunity and Hepatic Metastases. *Anticancer research*, 41(7), 3419–3427. <https://doi.org/10.21873/anticancer.15129>
 71. Ngamcherdtrakul, W., Reda, M., Nelson, M. A., Wang, R., Zaidan, H. Y., Bejan, D. S., Hoang, N. H., Lane, R. S., Luoh, S. W., Leachman, S. A., Mills, G. B., Gray, J. W., Lund, A. W., & Yantasee, W. (2021). In Situ Tumor Vaccination with Nanoparticle Co-Delivering CpG and STAT3 siRNA to Effectively Induce Whole-Body Antitumor Immune Response. *Advanced materials* (Deerfield Beach, Fla.), 33(31), e2100628. <https://doi.org/10.1002/adma.202100628>
 72. Koeken, V. A. C. M., Qi, C., Mourits, V. P., de Bree, L. C. J., Moorlag, S. J. C. F. M., Sonawane, V., Lemmers, H., Dijkstra, H., Joosten, L. A. B., van Laarhoven, A., Xu, C. J., van Crevel, R., Netea, M. G., & Li, Y. (2022). Plasma metabolome predicts trained immunity responses after antituberculosis BCG vaccination. *PLoS biology*, 20(9), e3001765. <https://doi.org/10.1371/journal.pbio.3001765>
 73. Rahdan, S., Razavi, S. A., Shojaeian, S., Shokri, F., Amiri, M. M., & Zarnani, A. H. (2022). Immunization with placenta-specific 1 (plac1) induces potent anti-tumor responses and prolongs survival in a mouse model of melanoma. *Advances in medical sciences*, 67(2), 338–345. <https://doi.org/10.1016/j.advms.2022.08.002>
 74. Ammons, D. T., Guth, A., Rozental, A. J., Kurihara, J., Marolf, A. J., Chow, L., Griffin, J. F., 4th, Makii, R.,

- MacQuiddy, B., Boss, M. K., Regan, D. P., Frank, C., McGrath, S., Packer, R. A., & Dow, S. (2022). Reprogramming the Canine Glioma Microenvironment with Tumor Vaccination plus Oral Losartan and Propranolol Induces Objective Responses. *Cancer research communications*, 2(12), 1657–1667. <https://doi.org/10.1158/2767-9764.crc-22-0388>
75. Kostinov, M. P., Akhmatova, N. K., Karpocheva, S. V., Vlasenko, A. E., Polishchuk, V. B., & Kostinov, A. M. (2021). Vaccination Against Diphtheria and Tetanus as a Way to Activate Adaptive Immunity in Children with Solid Tumors. *Frontiers in immunology*, 12, 696816. <https://doi.org/10.3389/fimmu.2021.696816>
 76. Corradini, P., Agrati, C., Apolone, G., Mantovani, A., Giannarelli, D., Marasco, V., Bordoni, V., Sacchi, A., Matusali, G., Salvarani, C., Zinzani, P. L., Mantegazza, R., Tagliavini, F., Lupo-Stanghellini, M. T., Ciceri, F., Damian, S., Uccelli, A., Fenoglio, D., Silvestris, N., Baldanti, F., ... VAX4FRAIL Study Group (2023). Humoral and T-Cell Immune Response After 3 Doses of Messenger RNA Severe Acute Respiratory Syndrome Coronavirus 2 Vaccines in Fragile Patients: The Italian VAX4FRAIL Study. *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America*, 76(3), e426–e438. <https://doi.org/10.1093/cid/ciac404>
 77. Perrino, M. R., Ahmari, N., Hall, A., Jackson, M., Na, Y., Pundavela, J., Szabo, S., Woodruff, T. M., Dombi, E., Kim, M. O., Köhl, J., Wu, J., & Ratner, N. (2024). C5aR plus MEK inhibition durably targets the tumor milieu and reveals tumor cell phagocytosis. *Life science alliance*, 7(5), e202302229. <https://doi.org/10.26508/lsa.202302229>
 78. Schrezenmeier, E., Rincon-Arevalo, H., Jens, A., Stefanski, A. L., Hammett, C., Osmanodja, B., Koch, N., Zukunft, B., Beck, J., Oellerich, M., Proß, V., Stahl, C., Choi, M., Bachmann, F., Liefeldt, L., Glander, P., Schütz, E., Bornemann-Kolatzki, K., López Del Moral, C., Schrezenmeier, H., ... Budde, K. (2022). Temporary antimetabolite treatment hold boosts SARS-CoV-2 vaccination-specific humoral and cellular immunity in kidney transplant recipients. *JCI insight*, 7(9), e157836. <https://doi.org/10.1172/jci.insight.157836>
 79. Jiang, C., Kumar, A., Yu, Z., Shipman, T., Wang, Y., McKay, R. M., Xing, C., & Le, L. Q. (2023). Basement membrane proteins in extracellular matrix characterize NF1 neurofibroma development and response to MEK inhibitor. *The Journal of clinical investigation*, 133(12), e168227. <https://doi.org/10.1172/JCI168227>
 80. Xu, Y. Y., Chen, Q. H., Liu, Y., Ji, C., Du, J., Li, M. Y., Shen, H. P., Zhang, X. C., Che, X. R., & Zhao, G. (2024). *Zhonghua yu fang yi xue za zhi* [Chinese journal of preventive medicine], 58(1), 87–91. <https://doi.org/10.3760/cma.j.cn112150-20230213-00101>
 81. Cho, H., Binder, J., Weeratna, R., Dermeyer, M., Dai, S., Boccia, A., Li, W., Li, S., Jooss, K., Merson, J., & Hollingsworth, R. E. (2023). Preclinical development of a vaccine-based immunotherapy regimen (VBIR) that induces potent and durable T cell responses to tumor-associated self-antigens. *Cancer immunology, immunotherapy : CII*, 72(2), 287–300. <https://doi.org/10.1007/s00262-022-03245-x>
 82. Liu, H. Y., Altman, A., Canonigo-Balancio, A. J., & Croft, M. (2023). Experimental Melanoma Immunotherapy Model Using Tumor Vaccination with a Hematopoietic Cytokine. *Journal of visualized experiments : JoVE*, (192), 10.3791/64082. <https://doi.org/10.3791/64082>
 83. Flies, A. S., Flies, E. J., Fox, S., Gilbert, A., Johnson, S. R., Liu, G. S., Lyons, A. B., Patchett, A. L., Pemberton, D., & Pye, R. J. (2020). An oral bait vaccination approach for the Tasmanian devil facial tumor diseases. *Expert review of vaccines*, 19(1), 1–10. <https://doi.org/10.1080/14760584.2020.1711058>
 84. Huang, X., Zhang, G., Bai, X., & Liang, T. (2020). Reviving the role of MET in liver cancer therapy and vaccination: an autophagic perspective. *Oncoimmunology*, 9(1), 1818438. <https://doi.org/10.1080/2162402X.2020.1818438>
 85. Wan, J., Ren, L., Li, X., He, S., Fu, Y., Xu, P., Meng, F., Xian, S., Pu, K., & Wang, H. (2023). Photoactivatable nanoagonists chemically programmed for pharmacokinetic tuning and in situ cancer vaccination. *Proceedings of the National Academy of Sciences of the United States of America*, 120(8), e2210385120. <https://doi.org/10.1073/pnas.2210385120>
 86. Hosseinalizadeh, H., Rahmati, M., Ebrahimi, A., & O'Connor, R. S. (2023). Current Status and Challenges of Vaccination Therapy for Glioblastoma. *Molecular cancer therapeutics*, 22(4), 435–446. <https://doi.org/10.1158/1535-7163.MCT-22-0503>
 87. van Dam, K. P. J., Volkers, A. G., Wiese, L., Stalman, E. W., Kummer, L. Y. L., van Kempen, Z. L. E., Killestein, J., Tas, S. W., Boekel, L., Wolbink, G. J., van der Kooi, A. J., Raaphorst, J., Takkenberg, R. B., D'Haens, G. R. A. M., Spuls, P. I., Bekkenk, M. W., Musters, A. H., Post, N. F., Bosma, A. L., Hilhorst, M.

- L., ... T2B! Immunity against SARS-CoV-2 study group (2023). Primary SARS-CoV-2 infection in patients with immune-mediated inflammatory diseases: long-term humoral immune responses and effects on disease activity. *BMC infectious diseases*, 23(1), 332. <https://doi.org/10.1186/s12879-023-08298-6>
88. Hall, V. G., & Teh, B. W. (2023). COVID-19 Vaccination in Patients With Cancer and Patients Receiving HSCT or CAR-T Therapy: Immune Response, Real-World Effectiveness, and Implications for the Future. *The Journal of infectious diseases*, 228(Suppl 1), S55–S69. <https://doi.org/10.1093/infdis/jiad174>
 89. Doukas, P. G., St Pierre, F., Karmali, R., Mi, X., Boyer, J., Nieves, M., Ison, M. G., Winter, J. N., Gordon, L. I., & Ma, S. (2023). Humoral Immunity After COVID-19 Vaccination in Chronic Lymphocytic Leukemia and Other Indolent Lymphomas: A Single-Center Observational Study. *The oncologist*, 28(10), e930–e941. <https://doi.org/10.1093/oncolo/oyad121>
 90. He, Y., Cheng, C., Liu, Y., Chen, F. M., Chen, Y., Yang, C., Zhao, Z., Dawulieti, J., Shen, Z., Zhang, Y., Du, J. Z., Guan, S., & Shao, D. (2024). Intravenous Senescent Erythrocyte Vaccination Modulates Adaptive Immunity and Splenic Complement Production. *ACS nano*, 18(1), 470–482. <https://doi.org/10.1021/acsnano.3c07943>
 91. Hartmann, A. K., Bartneck, J., Pielenhofer, J., Meiser, S. L., Arnold-Schild, D., Klein, M., Stassen, M., Schild, H., Muth, S., Probst, H. C., Langguth, P., Grabbe, S., & Radsak, M. P. (2023). Optimized dithranol-imiquimod-based transcutaneous immunization enables tumor rejection. *Frontiers in immunology*, 14, 1238861. <https://doi.org/10.3389/fimmu.2023.1238861>
 92. Del Poeta, G., Laureana, R., Bomben, R., Rossi, F. M., Pozzo, F., Zaina, E., Cattarossi, I., Varaschin, P., Nanni, P., Boschian Boschin, R., Nunzi, A., Postorino, M., Pasqualone, G., Brisotto, G., Steffan, A., Muraro, E., Zucchetto, A., Del Principe, M. I., & Gattei, V. (2023). COVID-19 vaccination: Evaluation of humoral and cellular immunity after the booster dose in chronic lymphocytic leukemia patients. *Hematological oncology*, 41(3), 559–562. <https://doi.org/10.1002/hon.3121>
 93. Andorko, J. I., Tsai, S. J., Gammon, J. M., Carey, S. T., Zeng, X., Gosselin, E. A., Edwards, C., Shah, S. A., Hess, K. L., & Jewell, C. M. (2022). Spatial delivery of immune cues to lymph nodes to define therapeutic outcomes in cancer vaccination. *Biomaterials science*, 10(16), 4612–4626. <https://doi.org/10.1039/d2bm00403h>
 94. Zhang, Y., Sriramaneni, R. N., Clark, P. A., Jagodinsky, J. C., Ye, M., Jin, W., Wang, Y., Bates, A., Kerr, C. P., Le, T., Allawi, R., Wang, X., Xie, R., Havighurst, T. C., Chakravarty, I., Rakhmilevich, A. L., O'Leary, K. A., Schuler, L. A., Sondel, P. M., Kim, K., ... Morris, Z. S. (2022). Multifunctional nanoparticle potentiates the in situ vaccination effect of radiation therapy and enhances response to immune checkpoint blockade. *Nature communications*, 13(1), 4948. <https://doi.org/10.1038/s41467-022-32645-x>
 95. Bukhari, S. I., Jehan, F., & Belgaumi, A. (2024). Global Immunization Crisis Amid the COVID-19 Pandemic: Implications for Pediatric Oncology. *JCO global oncology*, 10, e2300477. <https://doi.org/10.1200/GO.23.00477>
 96. Alonso-Miguel, D., Valdivia, G., Guerrero, D., Perez-Alenza, M. D., Pantelyushin, S., Alonso-Diez, A., Beiss, V., Fiering, S., Steinmetz, N. F., Suarez-Redondo, M., Vom Berg, J., Peña, L., & Arias-Pulido, H. (2022). Neoadjuvant in situ vaccination with cowpea mosaic virus as a novel therapy against canine inflammatory mammary cancer. *Journal for immunotherapy of cancer*, 10(3), e004044. <https://doi.org/10.1136/jitc-2021-004044>
 97. Lam, B., Kung, Y. J., Lin, J., Tseng, S. H., Tu, H. F., Huang, C., Lee, B., Velarde, E., Tsai, Y. C., Villasmil, R., Park, S. T., Xing, D., Hung, C. F., & Wu, T. C. (2024). In situ vaccination via tissue-targeted cDC1 expansion enhances the immunogenicity of chemoradiation and immunotherapy. *The Journal of clinical investigation*, 134(1), e171621. <https://doi.org/10.1172/JCI171621>
 98. Eini, L., Naseri, M., Karimi-Busheri, F., Bozorgmehr, M., Ghods, R., & Madjd, Z. (2023). Preventive cancer stem cell-based vaccination modulates tumor development in syngeneic colon adenocarcinoma murine model. *Journal of cancer research and clinical oncology*, 149(7), 4101–4116. <https://doi.org/10.1007/s00432-022-04303-8>
 99. Peng, S., Chen, S., Hu, W., Mei, J., Zeng, X., Su, T., Wang, W., Chen, Z., Xiao, H., Zhou, Q., Li, B., Xie, Y., Hu, H., He, M., Han, Y., Tang, L., Ma, Y., Li, X., Zhou, X., Dai, Z., ... Kuang, M. (2022). Combination Neoantigen-Based Dendritic Cell Vaccination and Adoptive T-Cell Transfer Induces Antitumor Responses Against Recurrence of Hepatocellular Carcinoma. *Cancer immunology research*, 10(6), 728–744. <https://doi.org/10.1158/2326-6066.CIR-21-0931>
 100. Zandvakili, R., Basirjafar, P., Masoumi, J., Zainodini, N., Taghipour, Z., Khorramdelazad, H., Yousefi, S.,

- Tavakoli, T., Safdel, S., Gheitasi, M., Ayoobi, F., & Jafarzadeh, A. (2023). Vaccination with celecoxib-treated dendritic cells improved cellular immune responses in an animal breast cancer model. *Advances in medical sciences*, 68(1), 157–168. <https://doi.org/10.1016/j.advms.2023.03.002>
101. Shou, J., Mo, F., Zhang, S., Lu, L., Han, N., Liu, L., Qiu, M., Li, H., Han, W., Ma, D., Guo, X., Guo, Q., Huang, Q., Zhang, X., Ye, S., Pan, H., Chen, S., & Fang, Y. (2022). Combination treatment of radiofrequency ablation and peptide neoantigen vaccination: Promising modality for future cancer immunotherapy. *Frontiers in immunology*, 13, 1000681. <https://doi.org/10.3389/fimmu.2022.1000681>
 102. Niavarani, S. R., St-Cyr, G., Daniel, L., Lawson, C., Giguère, H., Alkayyal, A. A., & Tai, L. H. (2023). Heterologous prime-boost cellular vaccination induces potent antitumor immunity against triple negative breast cancer. *Frontiers in immunology*, 14, 1098344. <https://doi.org/10.3389/fimmu.2023.1098344>
 103. Domingos-Pereira, S., Roh, V., Hiou-Feige, A., Galliverti, G., Simon, C., Tolstonog, G. V., & Nardelli-Haeffliger, D. (2021). Vaccination with a nanoparticle E7 vaccine can prevent tumor recurrence following surgery in a human papillomavirus head and neck cancer model. *Oncoimmunology*, 10(1), 1912473. <https://doi.org/10.1080/2162402X.2021.1912473>
 104. Sunil, V., Mozhi, A., Zhan, W., Teoh, J. H., Ghode, P. B., Thakor, N. V., & Wang, C. H. (2022). In-situ vaccination using dual responsive organelle targeted nanoreactors. *Biomaterials*, 290, 121843. <https://doi.org/10.1016/j.biomaterials.2022.121843>
 105. Ellingsen, E. B., O'Day, S., Mezheyeuski, A., Gromadka, A., Clancy, T., Kristedja, T. S., Milhem, M., & Zakharia, Y. (2023). Clinical Activity of Combined Telomerase Vaccination and Pembrolizumab in Advanced Melanoma: Results from a Phase I Trial. *Clinical cancer research : an official journal of the American Association for Cancer Research*, 29(16), 3026–3036. <https://doi.org/10.1158/1078-0432.CCR-23-0416>
 106. Repáraz, D., Ruiz, M., Silva, L., Aparicio, B., Egea, J., Guruceaga, E., Ajona, D., Senent, Y., Conde, E., Navarro, F., Barace, S., Alignani, D., Hervás-Stubbs, S., Lasarte, J. J., Llopiz, D., & Sarobe, P. (2022). Gemcitabine-mediated depletion of immunosuppressive dendritic cells enhances the efficacy of therapeutic vaccination. *Frontiers in immunology*, 13, 991311. <https://doi.org/10.3389/fimmu.2022.991311>
 107. Ghanaat, M., Kaboosi, H., Negahdari, B., Fattahi, E., & Malekshahi, Z. V. (2023). Heterologous Prime-boost Vaccination Using Adenovirus and Albumin Nanoparticles as Carriers for Human Papillomavirus 16 E7 Epitope. *Current pharmaceutical biotechnology*, 24(9), 1195–1203. <https://doi.org/10.2174/1389201023666220922122531>
 108. Clark, P. A., Sriramaneni, R. N., Jin, W. J., Jagodinsky, J. C., Bates, A. M., Jaquish, A. A., Anderson, B. R., Le, T., Lubin, J. A., Chakravarty, I., Arthur, I. S., Heinze, C. M., Guy, E. I., Kler, J., Klar, K. A., Carlson, P. M., Kim, K. M., Kuo, J. S., & Morris, Z. S. (2020). In situ vaccination at a peripheral tumor site augments response against melanoma brain metastases. *Journal for immunotherapy of cancer*, 8(2), e000809. <https://doi.org/10.1136/jitc-2020-000809>
 109. Mair, M. J., Berger, J. M., Berghoff, A. S., Starzer, A. M., Ortmayr, G., Puhr, H. C., Steindl, A., Perkmann, T., Haslacher, H., Strassl, R., Tobudic, S., Lamm, W. W., Raderer, M., Mitterer, M., Fuereder, T., Fong, D., & Preusser, M. (2022). Humoral Immune Response in Hematooncological Patients and Health Care Workers Who Received SARS-CoV-2 Vaccinations. *JAMA oncology*, 8(1), 106–113. <https://doi.org/10.1001/jamaoncol.2021.5437>
 110. Son, H. Y., Jeong, H. K., Apostolopoulos, V., & Kim, C. W. (2022). MUC1 expressing tumor growth was retarded after human mucin 1 (MUC1) plasmid DNA immunization. *International journal of immunopathology and pharmacology*, 36, 3946320221112358. <https://doi.org/10.1177/03946320221112358>
 111. Shin, H., & Na, K. (2020). Cancer-Targetable pH-Sensitive Zinc-Based Immunomodulators Combined with Photodynamic Therapy for in Situ Vaccination. *ACS biomaterials science & engineering*, 6(6), 3430–3439. <https://doi.org/10.1021/acsbiomaterials.0c00379>
 112. Pol, J. G., Bridle, B. W., & Lichty, B. D. (2020). Detection of Tumor Antigen-Specific T-Cell Responses After Oncolytic Vaccination. *Methods in molecular biology (Clifton, N.J.)*, 2058, 191–211. https://doi.org/10.1007/978-1-4939-9794-7_12
 113. Friedrich, R. E., Nörner, L. K. N., & Hagel, C. (2022). Peripheral Nerve Sheath Tumors in Patients With Neurofibromatosis Type 1: Morphological and Immunohistochemical Study. *Anticancer research*, 42(3), 1247–1261. <https://doi.org/10.21873/anticancer.15592>
 114. He, T., Shi, Y., Kou, X., Shen, M., Liang, X., Li, X., Wu, R., You, Y., Wu, Q., & Gong, C. (2023). Antigenicity and adjuvanticity co-reinforced personalized cell vaccines based on self-adjuvanted hydrogel for post-

- surgical cancer vaccination. *Biomaterials*, 301, 122218. <https://doi.org/10.1016/j.biomaterials.2023.122218>
115. Figueiredo, J. C., Merin, N. M., Hamid, O., Choi, S. Y., Lemos, T., Cozen, W., Nguyen, N., Finster, L. J., Foley, J., Darrah, J., Gong, J., Paquette, R., Mita, A. C., Vescio, R., Mehmi, I., Basho, R., Tourtellotte, W. G., Huynh, C. A., Melmed, G. Y., Braun, J., ... Merchant, A. (2021). Longitudinal SARS-CoV-2 mRNA Vaccine-Induced Humoral Immune Responses in Patients with Cancer. *Cancer research*, 81(24), 6273–6280. <https://doi.org/10.1158/0008-5472.CAN-21-3554>
 116. Bakhtadze, S., Lim, M., Craiu, D., & Cazacu, C. (2021). Vaccination in acute immune-mediated/inflammatory disorders of the central nervous system. *European journal of paediatric neurology : EJPN : official journal of the European Paediatric Neurology Society*, 34, 118–122. <https://doi.org/10.1016/j.ejpn.2021.07.011>
 117. Radbruch, A., & Melchers, F. (2024). Warum die Regeneration von immunologischer Toleranz durch Impfen schwierig ist [Why the regeneration of immunological tolerance by vaccination is difficult]. *Zeitschrift für Rheumatologie*, 83(2), 105–111. <https://doi.org/10.1007/s00393-023-01453-z>
 118. Li, Y., Luo, Y., Hou, L., Huang, Z., Wang, Y., & Zhou, S. (2023). Antigen-Capturing Dendritic-Cell-Targeting Nanoparticles for Enhanced Tumor Immunotherapy Based on Photothermal-Therapy-Induced In Situ Vaccination. *Advanced healthcare materials*, 12(22), e2202871. <https://doi.org/10.1002/adhm.202202871>
 119. Liu, X., Su, Q., Song, H., Shi, X., Zhang, Y., Zhang, C., Huang, P., Dong, A., Kong, D., & Wang, W. (2021). PolyTLR7/8a-conjugated, antigen-trapping gold nanorods elicit anticancer immunity against abscopal tumors by photothermal therapy-induced in situ vaccination. *Biomaterials*, 275, 120921. <https://doi.org/10.1016/j.biomaterials.2021.120921>
 120. Patenaude, R., Yasmin-Karim, S., Peng, Y., Wucherpennig, K. W., Ngwa, W., Kheir, J. N., & Polizzotti, B. D. (2023). Injectable Oxygen Microparticles Boost Radiation-Mediated In Situ Vaccination and Systemic Antitumor Immune Responses. *International journal of radiation oncology, biology, physics*, 116(4), 906–915. <https://doi.org/10.1016/j.ijrobp.2022.12.051>
 121. Salewski, I., Gladbach, Y. S., Kuntoff, S., Irmscher, N., Hahn, O., Junghanss, C., & Maletzki, C. (2020). In vivo vaccination with cell line-derived whole tumor lysates: neoantigen quality, not quantity matters. *Journal of translational medicine*, 18(1), 402. <https://doi.org/10.1186/s12967-020-02570-y>
 122. Stegmann, T., Wiekmeijer, A. S., Kwappenberg, K., van Duikeren, S., Bhoelan, F., Bemelman, D., Beenakker, T. J. M., Krebber, W. J., Arens, R., & Melief, C. J. M. (2023). Enhanced HPV16 E6/E7+ tumor eradication via induction of tumor-specific T cells by therapeutic vaccination with virosomes presenting synthetic long peptides. *Cancer immunology, immunotherapy : CII*, 72(8), 2851–2864. <https://doi.org/10.1007/s00262-023-03462-y>
 123. Jackson, K., Samaddar, S., Markiewicz, M. A., & Bansal, A. (2023). Vaccination-Based Immunoprevention of Colorectal Tumors: A Primer for the Clinician. *Journal of clinical gastroenterology*, 57(3), 246–252. <https://doi.org/10.1097/MCG.0000000000001808>
 124. Trabbic, K. R., Whalen, K., Abarca-Heideman, K., Xia, L., Temme, J. S., Edmondson, E. F., Gildersleeve, J. C., & Barchi, J. J., Jr (2019). A Tumor-Selective Monoclonal Antibody from Immunization with a Tumor-Associated Mucin Glycopeptide. *Scientific reports*, 9(1), 5662. <https://doi.org/10.1038/s41598-019-42076-2>
 125. Preusser, M., & van den Bent, M. J. (2023). Autologous tumor lysate-loaded dendritic cell vaccination (DCVax-L) in glioblastoma: Breakthrough or fata morgana?. *Neuro-oncology*, 25(4), 631–634. <https://doi.org/10.1093/neuonc/noac281>
 126. Szallasi, Z., Prosz, A., Sztupinski, Z., & Moldvay, J. (2024). Are tumor-associated carbohydrates the missing link between the gut microbiome and response to immune checkpoint inhibitor treatment in cancer?. *Oncoimmunology*, 13(1), 2324493. <https://doi.org/10.1080/2162402X.2024.2324493>
 127. Fan, Q., Ma, Q., Bai, J., Xu, J., Fei, Z., Dong, Z., Maruyama, A., Leong, K. W., Liu, Z., & Wang, C. (2020). An implantable blood clot-based immune niche for enhanced cancer vaccination. *Science advances*, 6(39), eabb4639. <https://doi.org/10.1126/sciadv.abb4639>
 128. Caldera, F., Farraye, F. A., Necela, B. M., Cogen, D., Saha, S., Wald, A., Daoud, N. D., Chun, K., Grimes, I., Lutz, M., Van Helden, S. R., Swift, M. D., Virk, A., Bharucha, A. E., Patel, T. C., Gores, G. J., Chumsri, S., Hayney, M. S., & Knutson, K. L. (2023). Higher Cell-Mediated Immune Responses in Patients With Inflammatory Bowel Disease on Anti-TNF Therapy After COVID-19 Vaccination. *Inflammatory bowel diseases*, 29(8), 1202–1209. <https://doi.org/10.1093/ibd/izac193>
 129. Shahgolzari, M., Pazhouhandeh, M., Milani, M., Fiering, S., & Khosroushahi, A. Y. (2021). Alfalfa mosaic virus nanoparticles-based in situ vaccination induces antitumor immune responses in breast cancer

- model. *Nanomedicine* (London, England), 16(2), 97–107. <https://doi.org/10.2217/nmm-2020-0311>
130. Zhao, Z., Ukidve, A., Krishnan, V., Fehnel, A., Pan, D. C., Gao, Y., Kim, J., Evans, M. A., Mandal, A., Guo, J., Muzykantov, V. R., & Mitragotri, S. (2021). Systemic tumour suppression via the preferential accumulation of erythrocyte-anchored chemokine-encapsulating nanoparticles in lung metastases. *Nature biomedical engineering*, 5(5), 441–454. <https://doi.org/10.1038/s41551-020-00644-2>
 131. Nosan, G., Paro-Panjan, D., Ihan, A., Kopitar, A. N., Čučnik, S., & Avčin, T. (2019). Vaccine immune response, autoimmunity and morbidity after neonatal blood exchange transfusion. *Vaccine*, 37(30), 4076–4080. <https://doi.org/10.1016/j.vaccine.2019.05.077>
 132. Cerna, K., Duricova, D., Hindos, M., Hindos Hrebackova, J., Lukas, M., Machkova, N., Hrubá, V., Mitrova, K., Kubickova, K., Kastylova, K., Teplan, V., & Lukas, M. (2022). Cellular and Humoral Immune Responses to SARS-CoV-2 Vaccination in Inflammatory Bowel Disease Patients. *Journal of Crohn's & colitis*, 16(9), 1347–1353. <https://doi.org/10.1093/ecco-jcc/jjac048>
 133. Osborne, N., Sundseth, R., Burks, J., Cao, H., Liu, X., Kroemer, A. H., Sutton, L., Cato, A., & Smith, J. P. (2019). Gastrin vaccine improves response to immune checkpoint antibody in murine pancreatic cancer by altering the tumor microenvironment. *Cancer immunology, immunotherapy : CII*, 68(10), 1635–1648. <https://doi.org/10.1007/s00262-019-02398-6>
 134. Elizondo, C. R., Bright, J. D., & Bright, R. K. (2022). Vaccination with a shared oncogenic tumor-self antigen elicits a population of CD8+ T cells with a regulatory phenotype. *Human vaccines & immunotherapeutics*, 18(6), 2108656. <https://doi.org/10.1080/21645515.2022.2108656>
 135. Chung, D. J., Shah, G. L., Devlin, S. M., Ramanathan, L. V., Doddi, S., Pessin, M. S., Hoover, E., Marcello, L. T., Young, J. C., Boutemine, S. R., Serrano, E., Sharan, S., Momotaj, S., Margetich, L., Bravo, C. D., Papanicolaou, G. A., Kamboj, M., Mato, A. R., Roeker, L. E., Hultcrantz, M., ... Knorr, D. A. (2021). Disease- and Therapy-Specific Impact on Humoral Immune Responses to COVID-19 Vaccination in Hematologic Malignancies. *Blood cancer discovery*, 2(6), 568–576. <https://doi.org/10.1158/2643-3230.BCD-21-0139>
 136. Toret, E., Yel, S. E., Suman, M., Duzenli Kar, Y., Ozdemir, Z. C., Dinleyici, M., & Bor, O. (2021). Immunization status and re-immunization of childhood acute lymphoblastic leukemia survivors. *Human vaccines & immunotherapeutics*, 17(4), 1132–1135. <https://doi.org/10.1080/21645515.2020.1802975>
 137. Oketch, S. Y., Ochomo, E. O., Orwa, J. A., Mayieka, L. M., & Abdullahi, L. H. (2023). Communication strategies to improve human papillomavirus (HPV) immunisation uptake among adolescents in sub-Saharan Africa: a systematic review and meta-analysis. *BMJ open*, 13(4), e067164. <https://doi.org/10.1136/bmjopen-2022-067164>
 138. Ellingsen, E. B., Aamdal, E., Guren, T., Lilleby, W., Brunsvig, P. F., Mangsbo, S. M., Aamdal, S., Hovig, E., Mensali, N., Gaudernack, G., & Inderberg, E. M. (2022). Durable and dynamic hTERT immune responses following vaccination with the long-peptide cancer vaccine UV1: long-term follow-up of three phase I clinical trials. *Journal for immunotherapy of cancer*, 10(5), e004345. <https://doi.org/10.1136/jitc-2021-004345>
 139. Wagner, A., Garner-Spitzer, E., Schötta, A. M., Orola, M., Wessely, A., Zwazl, I., Ohradanova-Repic, A., Weseslindtner, L., Tajti, G., Gebetsberger, L., Kratzer, B., Tomosel, E., Kutschera, M., Tobudic, S., Pickl, W. F., Kundi, M., Stockinger, H., Novacek, G., Reinisch, W., Zielinski, C., ... Wiedermann, U. (2022). SARS-CoV-2-mRNA Booster Vaccination Reverses Non-Responsiveness and Early Antibody Waning in Immunocompromised Patients - A Phase Four Study Comparing Immune Responses in Patients With Solid Cancers, Multiple Myeloma and Inflammatory Bowel Disease. *Frontiers in immunology*, 13, 889138. <https://doi.org/10.3389/fimmu.2022.889138>
 140. Wieske, L., Stalman, E. W., van Dam, P. J. K., Kummer, L. Y., Steenhuis, M., van Kempen, Z. L. E., Killestein, J., Volkers, A. G., Tas, S. W., Boekel, L., Wolbink, G., Van der Kooi, A., Raaphorst, J., Löwenberg, M., Takkenberg, B., D'Haens, G. R. A. M., Spuls, P. I., Bekkenk, M. W., Musters, A. H., Post, N. F., ... T2B! immunity against SARS-CoV-2 study group (2023). Persistence of seroconversion at 6 months following primary immunisation in patients with immune-mediated inflammatory diseases. *Annals of the rheumatic diseases*, 82(6), 883–885. <https://doi.org/10.1136/ard-2022-223464>
 141. Melssen, M. M., Pollack, K. E., Meneveau, M. O., Smolkin, M. E., Pinczewski, J., Koeppel, A. F., Turner, S. D., Sol-Church, K., Hickman, A., Deacon, D. H., Petroni, G. R., & Slingluff, C. L., Jr (2021). Characterization and comparison of innate and adaptive immune responses at vaccine sites in melanoma vaccine clinical trials. *Cancer immunology, immunotherapy : CII*, 70(8), 2151–2164. <https://doi.org/10.1007/s00262-020-02844-w>
 142. Ogasawara, M., Miyashita, M., Yamagishi, Y., & Ota, S. (2022). Wilms' tumor 1 peptide-loaded dendritic

- cell vaccination in patients with relapsed or refractory acute leukemia. Therapeutic apheresis and dialysis : official peer-reviewed journal of the International Society for Apheresis, the Japanese Society for Apheresis, the Japanese Society for Dialysis Therapy, 26(3), 537–547. <https://doi.org/10.1111/1744-9987.13828>
143. Xi, X., Ye, T., Wang, S., Na, X., Wang, J., Qing, S., Gao, X., Wang, C., Li, F., Wei, W., & Ma, G. (2020). Self-healing microcapsules synergetically modulate immunization microenvironments for potent cancer vaccination. *Science advances*, 6(21), eaay7735. <https://doi.org/10.1126/sciadv.aay7735>
 144. Shi, Y., Zhu, C., Liu, Y., Lu, Y., Li, X., Qin, B., Luo, Z., Luo, L., Jiang, M., Zhang, J., Guan, G., Zheng, C., & You, J. (2021). A Vaccination with Boosted Cross Presentation by ER-Targeted Antigen Delivery for Anti-Tumor Immunotherapy. *Advanced healthcare materials*, 10(8), e2001934. <https://doi.org/10.1002/adhm.202001934>
 145. Aleman, A., van Kesteren, M., Zajdman, A. K., Srivastava, K., Cognigni, C., Mischka, J., Chen, L. Y., Upadhyaya, B., Serebryakova, K., Nardulli, J. R., Lyttle, N., Kappes, K., Jackson, H., Gleason, C. R., Oostenink, A., Cai, G. Y., Van Oekelen, O., PVI/MM/Seronet Study Group, van Bakel, H., Sordillo, E. M., ... Parekh, S. (2023). Cellular mechanisms associated with sub-optimal immune responses to SARS-CoV-2 bivalent booster vaccination in patients with Multiple Myeloma. *EBioMedicine*, 98, 104886. <https://doi.org/10.1016/j.ebiom.2023.104886>
 146. Pasqualetti, F., & Zanotti, S. (2023). Nonrandomised controlled trial in recurrent glioblastoma patients: the promise of autologous tumour lysate-loaded dendritic cell vaccination. *British journal of cancer*, 129(6), 895–896. <https://doi.org/10.1038/s41416-023-02194-1>
 147. Goradel, N. H., Negahdari, B., Mohajel, N., Malekshahi, Z. V., Shirazi, M. M. A., & Arashkia, A. (2021). Heterologous administration of HPV16 E7 epitope-loaded nanocomplexes inhibits tumor growth in mouse model. *International immunopharmacology*, 101(Pt B), 108298. <https://doi.org/10.1016/j.intimp.2021.108298>
 148. Holm-Yildiz, S., Dysgaard, T., Krag, T., Pedersen, B. S., Hamm, S. R., Pérez-Alós, L., Hansen, C. B., Pries-Heje, M. M., Heftdal, L. D., Hasselbalch, R. B., Fogh, K., Madsen, J. R., Frikke-Schmidt, R., Hilsted, L. M., Sørensen, E., Ostrowski, S. R., Bundgaard, H., Garred, P., Iversen, K., Nielsen, S. D., ... Vissing, J. (2023). Humoral immune response to COVID-19 vaccine in patients with myasthenia gravis. *Journal of neuroimmunology*, 384, 578215. <https://doi.org/10.1016/j.jneuroim.2023.578215>
 149. Bersanelli, M., Buti, S., De Giorgi, U., Di Maio, M., Giannarelli, D., Pignata, S., & Banna, G. L. (2019). State of the art about influenza vaccination for advanced cancer patients receiving immune checkpoint inhibitors: When common sense is not enough. *Critical reviews in oncology/hematology*, 139, 87–90. <https://doi.org/10.1016/j.critrevonc.2019.05.003>
 150. Dykman, L. A., Staroverov, S. A., Kozlov, S. V., Fomin, A. S., Chumakov, D. S., Gabalov, K. P., Kozlov, Y. S., Soldatov, D. A., & Khlebtsov, N. G. (2022). Immunization of Mice with Gold Nanoparticles Conjugated to Thermostable Cancer Antigens Prevents the Development of Xenografted Tumors. *International journal of molecular sciences*, 23(22), 14313. <https://doi.org/10.3390/ijms232214313>
 151. Valanparambil, R. M., Carlisle, J., Linderman, S. L., Akthar, A., Millett, R. L., Lai, L., Chang, A., McCook-Veal, A. A., Switchenko, J., Nasti, T. H., Saini, M., Wieland, A., Manning, K. E., Ellis, M., Moore, K. M., Foster, S. L., Floyd, K., Davis-Gardner, M. E., Edara, V. V., Patel, M., ... Ahmed, R. (2022). Antibody Response to COVID-19 mRNA Vaccine in Patients With Lung Cancer After Primary Immunization and Booster: Reactivity to the SARS-CoV-2 WT Virus and Omicron Variant. *Journal of clinical oncology : official journal of the American Society of Clinical Oncology*, 40(33), 3808–3816. <https://doi.org/10.1200/JCO.21.02986>
 152. Mair, M. J., Berger, J. M., Mitterer, M., Gansterer, M., Bathke, A. C., Trutschnig, W., Berghoff, A. S., Perkmann, T., Haslacher, H., Lamm, W. W., Raderer, M., Tobudic, S., Fuereder, T., Buratti, T., Fong, D., & Preusser, M. (2022). Third dose of SARS-CoV-2 vaccination in hemato-oncological patients and health care workers: immune responses and adverse events - a retrospective cohort study. *European journal of cancer (Oxford, England : 1990)*, 165, 184–194. <https://doi.org/10.1016/j.ejca.2022.01.019>
 153. Meneveau, M. O., Kumar, P., Lynch, K. T., Patel, S. P., & Slingluff, C. L. (2022). The vaccine-site microenvironment: impacts of antigen, adjuvant, and same-site vaccination on antigen presentation and immune signaling. *Journal for immunotherapy of cancer*, 10(3), e003533. <https://doi.org/10.1136/jitc-2021-003533>
 154. Wankhede, D., Grover, S., & Hofman, P. (2023). Determinants of humoral immune response to SARS-CoV-2 vaccines in solid cancer patients: A systematic review and meta-analysis. *Vaccine*, 41(11), 1791–1798.

- <https://doi.org/10.1016/j.vaccine.2023.01.072>
155. Faustini, S. E., Hall, A., Brown, S., Roberts, S., Hill, H., Stamataki, Z., (PITCH) consortium, Jenner, M. W., Owen, R. G., Pratt, G., Cook, G., Richter, A., Drayson, M. T., Kaiser, M. F., & Heaney, J. L. J. (2023). Immune responses to COVID-19 booster vaccinations in intensively anti-CD38 antibody treated patients with ultra-high-risk multiple myeloma: results from the Myeloma UK (MUK) nine OPTIMUM trial. *British journal of haematology*, 201(5), 845–850. <https://doi.org/10.1111/bjh.18714>
 156. Meza, L., Zengin, Z., Salgia, S., Malhotra, J., Karczewska, E., Dorff, T., Tripathi, A., Ely, J., Kelley, E., Mead, H., Hsu, J., Dizman, N., Salgia, N., Chawla, N., Chehrazi-Raffle, A., Muddasani, R., Govindarajan, A., Rock, A., Liu, S., Salgia, R., ... Pal, S. K. (2023). Twelve-Month Follow-up of the Immune Response After COVID-19 Vaccination in Patients with Genitourinary Cancers: A Prospective Cohort Analysis. *The oncologist*, 28(9), e748–e755. <https://doi.org/10.1093/oncolo/oyad067>
 157. Deng, M. Y., Debus, J., & König, L. (2023). Verlängerung des Gesamtüberlebens durch die Impfung von autologen tumorlysatsbeladenen dendritischen Zellen (DCVax-L) bei Patienten mit neu diagnostiziertem und rezidivierendem Glioblastom [Association of autologous tumor lysate-loaded dendritic cell vaccination with extension of survival among patients with newly diagnosed and recurrent glioblastoma]. *Strahlentherapie und Onkologie : Organ der Deutschen Röntgengesellschaft ... [et al]*, 199(3), 327–329. <https://doi.org/10.1007/s00066-023-02049-x>
 158. Souan, L., Abdel-Razeq, H., Al Zughbieh, M., Al Badr, S., & Sughayer, M. A. (2023). Comparative Assessment of the Kinetics of Cellular and Humoral Immune Responses to COVID-19 Vaccination in Cancer Patients. *Viruses*, 15(7), 1439. <https://doi.org/10.3390/v15071439>
 159. Yang, J., Eresen, A., Shangguan, J., Ma, Q., Yaghmai, V., & Zhang, Z. (2021). Irreversible electroporation ablation overcomes tumor-associated immunosuppression to improve the efficacy of DC vaccination in a mice model of pancreatic cancer. *Oncoimmunology*, 10(1), 1875638. <https://doi.org/10.1080/2162402X.2021.1875638>
 160. Pedrazzoli, P., Lasagna, A., Cassaniti, I., Ferrari, A., Bergami, F., Silvestris, N., Sapuppo, E., Di Maio, M., Cinieri, S., & Baldanti, F. (2022). Vaccination for herpes zoster in patients with solid tumors: a position paper on the behalf of the Associazione Italiana di Oncologia Medica (AIOM). *ESMO open*, 7(4), 100548. <https://doi.org/10.1016/j.esmoop.2022.100548>
 161. MacKerracher, A., Sommershof, A., & Groettrup, M. (2022). PLGA particle vaccination elicits resident memory CD8 T cells protecting from tumors and infection. *European journal of pharmaceutical sciences : official journal of the European Federation for Pharmaceutical Sciences*, 175, 106209. <https://doi.org/10.1016/j.ejps.2022.106209>
 162. Barrière, J., Re, D., Peyrade, F., & Carles, M. (2021). Current perspectives for SARS-CoV-2 vaccination efficacy improvement in patients with active treatment against cancer. *European journal of cancer (Oxford, England : 1990)*, 154, 66–72. <https://doi.org/10.1016/j.ejca.2021.06.008>
 163. Zhuang, W. H., & Wang, Y. P. (2020). Analysis of the immunity effects after enhanced hepatitis B vaccination on patients with lymphoma. *Leukemia & lymphoma*, 61(2), 357–363. <https://doi.org/10.1080/10428194.2019.1672053>
 164. Storti, P., Marchica, V., Vescovini, R., Franceschi, V., Russo, L., Notarfranchi, L., Raimondi, V., Toscani, D., Burroughs Garcia, J., Costa, F., Dalla Palma, B., Iannozzi, N. T., Sammarelli, G., Donofrio, G., & Giuliani, N. (2022). Immune response to SARS-CoV-2 mRNA vaccination and booster dose in patients with multiple myeloma and monoclonal gammopathies: impact of Omicron variant on the humoral response. *Oncoimmunology*, 11(1), 2120275. <https://doi.org/10.1080/2162402X.2022.2120275>
 165. Mitchell, D. K., Burgess, B., White, E. E., Smith, A. E., Sierra Potchanant, E. A., Mang, H., Hickey, B. E., Lu, Q., Qian, S., Bessler, W., Li, X., Jiang, L., Brewster, K., Temm, C., Horvai, A., Albright, E. A., Fishel, M. L., Pratilas, C. A., Angus, S. P., Clapp, D. W., ... Rhodes, S. D. (2024). Spatial Gene-Expression Profiling Unveils Immuno-oncogenic Programs of NF1-Associated Peripheral Nerve Sheath Tumor Progression. *Clinical cancer research : an official journal of the American Association for Cancer Research*, 30(5), 1038–1053. <https://doi.org/10.1158/1078-0432.CCR-23-2548>
 166. Martin, S. D., Nziza, N., Miozzo, P., Bartsch, Y., Farkas, E. J., Kane, A. S., Boal, L. H., Friedmann, A., Alter, G., & Yonker, L. M. (2023). Humoral profiling of pediatric patients with cancer reveals robust immunity following anti-SARS-CoV-2 vaccination superior to natural infection. *Pediatric blood & cancer*, 70(8), e30473. <https://doi.org/10.1002/pbc.30473>
 167. Rensink, M. J., van Laarhoven, H. W. M., & Holleman, F. (2021). Cocoon vaccination for influenza in

- patients with a solid tumor: a retrospective study. *Supportive care in cancer : official journal of the Multinational Association of Supportive Care in Cancer*, 29(7), 3657–3666. <https://doi.org/10.1007/s00520-020-05883-2>
168. Iavarone, M., Tosetti, G., Facchetti, F., Topa, M., Er, J. M., Hang, S. K., Licari, D., Lombardi, A., D'Ambrosio, R., Degasperi, E., Loglio, A., Oggioni, C., Perbellini, R., Caccia, R., Bandera, A., Gori, A., Ceriotti, F., Scudeller, L., Bertolotti, A., & Lampertico, P. (2023). Spike-specific humoral and cellular immune responses after COVID-19 mRNA vaccination in patients with cirrhosis: A prospective single center study. *Digestive and liver disease : official journal of the Italian Society of Gastroenterology and the Italian Association for the Study of the Liver*, 55(2), 160–168. <https://doi.org/10.1016/j.dld.2022.09.010>
 169. Shakibapour, M., Kefayat, A., Reza Mofid, M., Shojaie, B., Mohamadi, F., Maryam Sharafi, S., Mahmoudzadeh, M., & Yousofi Darani, H. (2021). Anti-cancer immunoprotective effects of immunization with hydatid cyst wall antigens in a non-immunogenic and metastatic triple-negative murine mammary carcinoma model. *International immunopharmacology*, 99, 107955. <https://doi.org/10.1016/j.intimp.2021.107955>
 170. Oltmanns, F., Vieira Antão, A., Irrgang, P., Viherlehto, V., Jörg, L., Schmidt, A., Wagner, J. T., Rückert, M., Flohr, A. S., Geppert, C. I., Frey, B., Bayer, W., Gravekamp, C., Tenbusch, M., Gaip, U., & Lapuente, D. (2024). Mucosal tumor vaccination delivering endogenous tumor antigens protects against pulmonary breast cancer metastases. *Journal for immunotherapy of cancer*, 12(3), e008652. <https://doi.org/10.1136/jitc-2023-008652>
 171. Patchett, A. L., Tovar, C., Blackburn, N. B., Woods, G. M., & Lyons, A. B. (2021). Mesenchymal plasticity of devil facial tumour cells during in vivo vaccine and immunotherapy trials. *Immunology and cell biology*, 99(7), 711–723. <https://doi.org/10.1111/imcb.12451>
 172. Masoumi, J., Jafarzadeh, A., Tavakoli, T., Basirjafar, P., Zandvakili, R., Javan, M. R., Taghipour, Z., & Moazzeni, S. M. (2022). Inhibition of apelin/APJ axis enhances the potential of dendritic cell-based vaccination to modulate TH1 and TH2 cell-related immune responses in an animal model of metastatic breast cancer. *Advances in medical sciences*, 67(1), 170–178. <https://doi.org/10.1016/j.advms.2022.02.006>
 173. Kim, J., Jeong, J., Lee, C. M., Lee, D. W., Kang, C. K., Choe, P. G., Kim, N. J., Oh, M. D., Lee, C. H., Park, W. B., Lee, K. H., & Im, S. A. (2022). Prospective longitudinal analysis of antibody response after standard and booster doses of SARS-COV2 vaccination in patients with early breast cancer. *Frontiers in immunology*, 13, 1028102. <https://doi.org/10.3389/fimmu.2022.1028102>
 174. Lyski, Z. L., Kim, M. S., Xthona Lee, D., Raué, H. P., Raghunathan, V., Griffin, J., Ryan, D., Brunton, A. E., Curlin, M. E., Slifka, M. K., Messer, W. B., & Spurgeon, S. E. (2022). Cellular and humoral immune response to mRNA COVID-19 vaccination in subjects with chronic lymphocytic leukemia. *Blood advances*, 6(4), 1207–1211. <https://doi.org/10.1182/bloodadvances.2021006633>
 175. Jung, E., Mao, C., Bhatia, M., Koellhoffer, E. C., Fiering, S. N., & Steinmetz, N. F. (2023). Inactivated Cowpea Mosaic Virus for In Situ Vaccination: Differential Efficacy of Formalin vs UV-Inactivated Formulations. *Molecular pharmaceutics*, 20(1), 500–507. <https://doi.org/10.1021/acs.molpharmaceut.2c00744>
 176. Cecil, D. L., Liao, J. B., Dang, Y., Coveler, A. L., Kask, A., Yang, Y., Childs, J. S., Higgins, D. M., & Disis, M. L. (2021). Immunization with a Plasmid DNA Vaccine Encoding the N-Terminus of Insulin-like Growth Factor Binding Protein-2 in Advanced Ovarian Cancer Leads to High-level Type I Immune Responses. *Clinical cancer research : an official journal of the American Association for Cancer Research*, 27(23), 6405–6412. <https://doi.org/10.1158/1078-0432.CCR-21-1579>
 177. Taylor, A. C., Hopkins, L. W., & Moore, G. (2021). Increasing human papillomavirus immunization in the primary care setting. *The Nurse practitioner*, 46(10), 37–42. <https://doi.org/10.1097/01.NPR.0000790528.06533.66>
 178. Stumpf, J., Anders, L., Siepmann, T., Schwöbel, J., Karger, C., Lindner, T., Faulhaber-Walter, R., Langer, T., Escher, K., Anding-Rost, K., Seidel, H., Hüther, J., Pistrosch, F., Martin, H., Schewe, J., Stehr, T., Meistring, F., Paliege, A., Schneider, D., Bast, I., ... Hugo, C. (2024). 9-Month observational Dia-Vacc study of vaccine type influence on SARS-CoV-2 immunity in dialysis and kidney transplant patients. *Vaccine*, 42(2), 120–128. <https://doi.org/10.1016/j.vaccine.2023.12.034>
 179. Purshouse, K., Thomson, J. P., Vallet, M., Alexander, L., Bonisteel, I., Brennan, M., Cameron, D. A., Figueroa, J. D., Furrie, E., Haig, P., Heck, M., McCaughan, H., Mitchell, P., McVicar, H., Primrose, L., Silva, I., Templeton, K., Wilson, N., & Hall, P. S. (2023). The Scottish COVID Cancer Immunity Prevalence Study: A

- Longitudinal Study of SARS-CoV-2 Immune Response in Patients Receiving Anti-Cancer Treatment. *The oncologist*, 28(3), e145–e155. <https://doi.org/10.1093/oncolo/oyac257>
180. Bacova, B., Kohutova, Z., Zubata, I., Gaherova, L., Kucera, P., Heizer, T., Mikesova, M., Karel, T., & Novak, J. (2023). Cellular and humoral immune response to SARS-CoV-2 mRNA vaccines in patients treated with either Ibrutinib or Rituximab. *Clinical and experimental medicine*, 23(2), 371–379. <https://doi.org/10.1007/s10238-022-00809-0>
 181. Ukidve, A., Zhao, Z., Fehnel, A., Krishnan, V., Pan, D. C., Gao, Y., Mandal, A., Muzykantov, V., & Mitragotri, S. (2020). Erythrocyte-driven immunization via biomimicry of their natural antigen-presenting function. *Proceedings of the National Academy of Sciences of the United States of America*, 117(30), 17727–17736. <https://doi.org/10.1073/pnas.2002880117>
 182. Müller, K. E., Dohos, D., Sipos, Z., Kiss, S., Dembrovszky, F., Kovács, N., Solymár, M., Erőss, B., Hegyi, P., & Sarlós, P. (2022). Immune response to influenza and pneumococcal vaccines in adults with inflammatory bowel disease: A systematic review and meta-analysis of 1429 patients. *Vaccine*, 40(13), 2076–2086. <https://doi.org/10.1016/j.vaccine.2022.02.027>
 183. Debie, Y., Van Audenaerde, J. R. M., Vandamme, T., Croes, L., Teuwen, L. A., Verbruggen, L., Vanhoutte, G., Marcq, E., Verheggen, L., Le Blon, D., Peeters, B., Goossens, M. E., Pannus, P., Ariën, K. K., Anguille, S., Janssens, A., Prenen, H., Smits, E. L. J., Vulsteke, C., Lion, E., ... van Dam, P. A. (2023). Humoral and Cellular Immune Responses against SARS-CoV-2 after Third Dose BNT162b2 following Double-Dose Vaccination with BNT162b2 versus ChAdOx1 in Patients with Cancer. *Clinical cancer research : an official journal of the American Association for Cancer Research*, 29(3), 635–646. <https://doi.org/10.1158/1078-0432.CCR-22-2185>
 184. Salmon, C., Conus, F., Parent, M. É., Benedetti, A., & Rousseau, M. C. (2020). Association between Bacillus Calmette-Guerin (BCG) vaccination and lymphoma risk: A systematic review and meta-analysis. *Cancer epidemiology*, 65, 101696. <https://doi.org/10.1016/j.canep.2020.101696>
 185. Gharibi, Z., Rahdar, M., Pirestani, M., Tavalla, M., & Tabandeh, M. R. (2021). The Immunization of Protoscolices P29 DNA Vaccine on Experimental Cystic Echinococcosis in Balb/c Mice. *Acta parasitologica*, 66(4), 1114–1121. <https://doi.org/10.1007/s11686-021-00367-7>
 186. Ishida, E., Lee, J., Campbell, J. S., Chakravarty, P. D., Katori, Y., Ogawa, T., Johnson, L., Mukhopadhyay, A., Faquin, W. C., Lin, D. T., Wirth, L. J., Pierce, R. H., & Pai, S. I. (2019). Intratumoral delivery of an HPV vaccine elicits a broad anti-tumor immune response that translates into a potent anti-tumor effect in a preclinical murine HPV model. *Cancer immunology, immunotherapy : CII*, 68(8), 1273–1286. <https://doi.org/10.1007/s00262-019-02357-1>
 187. Aleman, A., Van Oekelen, O., Upadhyaya, B., Beach, K., Kogan Zajdman, A., Alshammery, H., Serebryakova, K., Agte, S., Kappes, K., Gleason, C. R., Srivastava, K., PVI/MM/Seronet Study Group, Almo, S., Cordon-Cardo, C., Krammer, F., Merad, M., Jagannath, S., Wajnberg, A., Simon, V., & Parekh, S. (2022). Augmentation of humoral and cellular immune responses after third-dose SARS-CoV-2 vaccination and viral neutralization in myeloma patients. *Cancer cell*, 40(5), 441–443. <https://doi.org/10.1016/j.ccell.2022.03.013>
 188. Hou, X., Shi, Y., Kang, X., Rousu, Z., Li, D., Wang, M., Ainiwaer, A., Zheng, X., Wang, M., Jiensihan, B., Li, L., Li, J., Wang, H., & Zhang, C. (2022). Echinococcus granulosus: The establishment of the metacestode in the liver is associated with control of the CD4+ T-cell-mediated immune response in patients with cystic echinococcosis and a mouse model. *Frontiers in cellular and infection microbiology*, 12, 983119. <https://doi.org/10.3389/fcimb.2022.983119>
 189. Campal-Espinosa, A. C., Junco-Barranco, J. A., Fuentes-Aguilar, F., Calzada-Aguilera, L., Rivacoba-Betancourt, A., Rodríguez-Bueno, R. H., Bover-Campal, A. C., Bover-Fuentes, E. E., González, L., de Quesada, L., Alvarez, A., & Garay-Pérez, H. E. (2023). Influence of Humoral Response Against GnRH, Generated by Immunization with a Therapeutic Vaccine Candidate on the Evolution of Patients with Castration-Sensitive Prostate Adenocarcinoma. *Technology in cancer research & treatment*, 22, 15330338231207318. <https://doi.org/10.1177/15330338231207318>
 190. Behrendt, D., Burger, D., Gremmes, S., Szunyog, K., Röthmeier, S., & Sieme, H. (2021). Active immunisation against GnRH as treatment for unilateral granulosa theca cell tumour in mares. *Equine veterinary journal*, 53(4), 740–745. <https://doi.org/10.1111/evj.13352>
 191. Lehrnbecher, T., Sack, U., Speckmann, C., Groll, A. H., Boldt, A., Siebald, B., Hettmer, S., Demmerath, E. M., Reemtsma, J., Schenk, B., Ciesek, S., Klusmann, J. H., Jassoy, C., & Hoehl, S. (2023). Longitudinal

- Immune Response to 3 Doses of Messenger RNA Vaccine Against Coronavirus Disease 2019 (COVID-19) in Pediatric Patients Receiving Chemotherapy for Cancer. *Clinical infectious diseases : an official publication of the Infectious Diseases Society of America*, 76(3), e510–e513. <https://doi.org/10.1093/cid/ciac570>
192. Cobanoglu, O., Delval, L., Ferrari, D., Deruyter, L., Heumel, S., Wolowczuk, I., Hussein, A., Menevse, A. N., Bernard, D., Beckhove, P., Alves, F., & Trottein, F. (2023). Depletion of preexisting B-cell lymphoma 2-expressing senescent cells before vaccination impacts antigen-specific antitumor immune responses in old mice. *Aging cell*, 22(12), e14007. <https://doi.org/10.1111/accel.14007>
 193. Kallionpää, R. A., Peltonen, S., Le, K. M., Martikkala, E., Jääskeläinen, M., Fazeli, E., Riihilä, P., Haapaniemi, P., Rokka, A., Salmi, M., Leivo, I., & Peltonen, J. (2024). Characterization of Immune Cell Populations of Cutaneous Neurofibromas in Neurofibromatosis 1. *Laboratory investigation; a journal of technical methods and pathology*, 104(1), 100285. <https://doi.org/10.1016/j.labinv.2023.100285>
 194. Borgogna, C., Bruna, R., Griffante, G., Martuscelli, L., De Andrea, M., Ferrante, D., Patriarca, A., Mahmoud, A. M., Ucciero, M. A. M., Gaidano, V., Marchetti, M., Rapezzi, D., Lai, M., Pistello, M., Ladetto, M., Massaia, M., Gaidano, G., & Gariglio, M. (2022). Induction of robust humoral immunity against SARS-CoV-2 after vaccine administration in previously infected haematological cancer patients. *British journal of haematology*, 199(3), 463–467. <https://doi.org/10.1111/bjh.18429>
 195. Kang, C. K., Kim, H. R., Song, K. H., Keam, B., Choi, S. J., Choe, P. G., Kim, E. S., Kim, N. J., Kim, Y. J., Park, W. B., Kim, H. B., & Oh, M. D. (2020). Cell-Mediated Immunogenicity of Influenza Vaccination in Patients With Cancer Receiving Immune Checkpoint Inhibitors. *The Journal of infectious diseases*, 222(11), 1902–1909. <https://doi.org/10.1093/infdis/jiaa291>
 196. Viana, J. H. M., Pereira, N. E. S., Faria, O. A. C., Dias, L. R. O., Oliveira, E. R., Fernandes, C. A. C., & Siqueira, L. G. B. (2021). Active immunization against GnRH as an alternative therapeutic approach for the management of Bos indicus oocyte donors diagnosed with chronic cystic ovarian disease. *Theriogenology*, 172, 133–141. <https://doi.org/10.1016/j.theriogenology.2021.06.014>
 197. Martins-Branco, D., Nader-Marta, G., Tecic Vuger, A., Debie, V., Ameye, L., Brandão, M., Punie, K., Loizidou, A., Willard-Gallo, K., Spilleboudt, C., Awada, A., Piccart, M., & de Azambuja, E. (2023). Immune response to anti-SARS-CoV-2 prime-vaccination in patients with cancer: a systematic review and meta-analysis. *Journal of cancer research and clinical oncology*, 149(7), 3075–3080. <https://doi.org/10.1007/s00432-022-04185-w>
 198. Vanni, A., Salvati, L., Mazzoni, A., Lamacchia, G., Capone, M., Francalanci, S., Kiros, S. T., Cosmi, L., Puccini, B., Ciceri, M., Sordi, B., Rossolini, G. M., Annunziato, F., Maggi, L., & Liotta, F. (2023). Bendamustine impairs humoral but not cellular immunity to SARS-CoV-2 vaccination in rituximab-treated B-cell lymphoma-affected patients. *Frontiers in immunology*, 14, 1322594. <https://doi.org/10.3389/fimmu.2023.1322594>
 199. Titova, E., Kan, V. W., Lozy, T., Ip, A., Shier, K., Prakash, V. P., Starolis, M., Ansari, S., Goldgirsh, K., Kim, S., Pelliccia, M. C., Mccutchen, A., Megalla, M., Gunning, T. S., Kaufman, H. W., Meyer, W. A., 3rd, & Perlin, D. S. (2024). Humoral and cellular immune responses against SARS-CoV-2 post-vaccination in immunocompetent and immunocompromised cancer populations. *Microbiology spectrum*, 12(3), e0205023. <https://doi.org/10.1128/spectrum.02050-23>
 200. Weitgasser, L., Mahrhofer, M., & Schoeller, T. (2021). Potential immune response to breast implants after immunization with COVID-19 vaccines. *Breast (Edinburgh, Scotland)*, 59, 76–78. <https://doi.org/10.1016/j.breast.2021.06.002>
 201. Aurisicchio, L., Fridman, A., Mauro, D., Sheloditna, R., Chiappori, A., Bagchi, A., & Ciliberto, G. (2020). Safety, tolerability and immunogenicity of V934/V935 hTERT vaccination in cancer patients with selected solid tumors: a phase I study. *Journal of translational medicine*, 18(1), 39. <https://doi.org/10.1186/s12967-020-02228-9>
 202. Xu, P., Ma, J., Zhou, Y., Gu, Y., Cheng, X., Wang, Y., Wang, Y., & Gao, M. (2024). Radiotherapy-Triggered In Situ Tumor Vaccination Boosts Checkpoint Blockaded Immune Response via Antigen-Capturing Nanoadjuvants. *ACS nano*, 18(1), 1022–1040. <https://doi.org/10.1021/acsnano.3c10225>
 203. Peeters, M., Verbruggen, L., Teuwen, L., Vanhoutte, G., Vande Kerckhove, S., Peeters, B., Raats, S., Van der Massen, I., De Keersmaecker, S., Debie, Y., Huizing, M., Pannus, P., Neven, K., Ariën, K. K., Martens, G. A., Van Den Bulcke, M., Roelant, E., Desombere, I., Anguille, S., Goossens, M., ... van Dam, P. (2021). Reduced humoral immune response after BNT162b2 coronavirus disease 2019 messenger RNA vaccination in cancer

- patients under antineoplastic treatment. *ESMO open*, 6(5), 100274. <https://doi.org/10.1016/j.esmoop.2021.100274>
204. Lövgren, T., Wolodarski, M., Wickström, S., Edbäck, U., Wallin, M., Martell, E., Markland, K., Blomberg, P., Nyström, M., Lundqvist, A., Jacobsson, H., Ullenhag, G., Ljungman, P., Hansson, J., Masucci, G., Tell, R., Poschke, I., Adamson, L., Mattsson, J., & Kiessling, R. (2020). Complete and long-lasting clinical responses in immune checkpoint inhibitor-resistant, metastasized melanoma treated with adoptive T cell transfer combined with DC vaccination. *Oncoimmunology*, 9(1), 1792058. <https://doi.org/10.1080/2162402X.2020.1792058>
 205. Enssle, J. C., Campe, J., Büchel, S., Moter, A., See, F., Griebbaum, K., Rieger, M. A., Wolf, S., Ballo, O., Steffen, B., Serve, H., Rabenau, H. F., Widera, M., Bremm, M., Huenecke, S., Ciesek, S., von Metzler, I., & Ullrich, E. (2022). Enhanced but variant-dependent serological and cellular immune responses to third-dose BNT162b2 vaccination in patients with multiple myeloma. *Cancer cell*, 40(6), 587–589. <https://doi.org/10.1016/j.ccell.2022.05.003>
 206. Enssle, J. C., Campe, J., Büchel, S., Moter, A., See, F., Griebbaum, K., Rieger, M. A., Wolf, S., Ballo, O., Steffen, B., Serve, H., Rabenau, H. F., Widera, M., Bremm, M., Huenecke, S., Ciesek, S., von Metzler, I., & Ullrich, E. (2022). Enhanced but variant-dependent serological and cellular immune responses to third-dose BNT162b2 vaccination in patients with multiple myeloma. *Cancer cell*, 40(6), 587–589. <https://doi.org/10.1016/j.ccell.2022.05.003>
 207. Alimam, S., Ann Timms, J., Harrison, C. N., Dillon, R., Mare, T., DeLavallade, H., Radia, D., Woodley, C., Francis, Y., Sanchez, K., Kordasti, S., & McLornan, D. P. (2021). Altered immune response to the annual influenza A vaccine in patients with myeloproliferative neoplasms. *British journal of haematology*, 193(1), 150–154. <https://doi.org/10.1111/bjh.17096>
 208. Zou, Z., Guo, L., Mautner, V., Smeets, R., Kiuwe, L., & Friedrich, R. E. (2020). Propranolol Specifically Suppresses the Viability of Tumorous Schwann Cells Derived from Plexiform Neurofibromas In Vitro. *In vivo (Athens, Greece)*, 34(3), 1031–1036. <https://doi.org/10.21873/in vivo.11872>
 209. Mohan, M., Nagavally, S., Shah N, N. N., Michaelis, L., Chhabra, S., Souza, A. D., Abedin, S., Runaas, L., Guru Murthy, G. S., Longo, W., Hamadani, M., Dhakal, B., Hari, P., & Fenske, T. S. (2022). Shorter Interval between Treatment and COVID Immunization Is Associated With Poor Seroconversion in Patients with Hematological Malignancies. *Clinical lymphoma, myeloma & leukemia*, 22(7), e495–e497. <https://doi.org/10.1016/j.clml.2022.01.010>
 210. Meena, J., Kumar, R., Singh, M., Ahmed, A., & Panda, A. K. (2020). Modulation of immune response and enhanced clearance of *Salmonella typhi* by delivery of Vi polysaccharide conjugate using PLA nanoparticles. *European journal of pharmaceuticals and biopharmaceutics : official journal of Arbeitsgemeinschaft für Pharmazeutische Verfahrenstechnik e.V*, 152, 270–281. <https://doi.org/10.1016/j.ejpb.2020.05.023>
 211. Suzuki, T., Kusumoto, S., Kamezaki, Y., Hashimoto, H., Nishitarumizu, N., Nakanishi, Y., Kato, Y., Kawai, A., Matsunaga, N., Ebina, T., Nakamura, T., Marumo, Y., Oiwa, K., Kinoshita, S., Narita, T., Ito, A., Inagaki, A., Ri, M., Komatsu, H., Aritsu, T., ... Iida, S. (2023). A comprehensive evaluation of humoral immune response to second and third SARS-CoV-2 mRNA vaccination in patients with malignant lymphoma. *International journal of hematology*, 117(6), 900–909. <https://doi.org/10.1007/s12185-023-03550-w>
 212. Cerda, C., Martínez-Valdebenito, C., Barriga, F., Contreras, M., Vidal, M., Moreno, R., Claverie, X., Contreras, P., Huenuman, L., García, T., Rathnasighe, R., Medina, R., Ferrés, M., & Le Corre, N. (2020). Respuesta inmune humoral inducida por la vacuna influenza en niños con diagnóstico de leucemia linfoblástica aguda [Humoral immune response induced by influenza vaccine in children with acute lymphoblastic leukemia]. *Revista chilena de infectología : organo oficial de la Sociedad Chilena de Infectología*, 37(2), 138–146. <https://doi.org/10.4067/s0716-10182020000200138>
 213. He, Y., Chen, D., Fu, Y., Huo, X., Zhao, F., Yao, L., Zhou, X., Qi, P., Yin, H., Cao, L., Ling, H., & Zeng, T. (2023). Immunization with Tp0954, an adhesin of *Treponema pallidum*, provides protective efficacy in the rabbit model of experimental syphilis. *Frontiers in immunology*, 14, 1130593. <https://doi.org/10.3389/fimmu.2023.1130593>
 214. Dahiya, S., Luetkens, T., Lutfi, F., Avila, S., Iraguha, T., Margiotta, P., Hankey, K. G., Lesho, P., Law, J. Y., Lee, S. T., Baddley, J., Kocoglu, M., Yared, J. A., Hardy, N. M., Rapoport, A. P., & Atanackovic, D. (2022). Impaired immune response to COVID-19 vaccination in patients with B-cell malignancies after CD19 CAR

- T-cell therapy. *Blood advances*, 6(2), 686–689. <https://doi.org/10.1182/bloodadvances.2021006112>
215. Barber, V. S., Peckham, N., Duley, L., Francis, A., Abhishek, A., Moss, P., Cook, J. A., & Parry, H. M. (2023). Protocol for a multicentre randomised controlled trial examining the effects of temporarily pausing Bruton tyrosine kinase inhibitor therapy to coincide with SARS-CoV-2 vaccination and its impact on immune responses in patients with chronic lymphocytic leukaemia. *BMJ open*, 13(9), e077946. <https://doi.org/10.1136/bmjopen-2023-077946>
 216. Kanjanapan, Y., Blinman, P., Underhill, C., Karikios, D., Segelov, E., & Yip, D. (2021). Medical Oncology Group of Australia position statement: COVID-19 vaccination in patients with solid tumours. *Internal medicine journal*, 51(6), 955–959. <https://doi.org/10.1111/imj.15339>
 217. Fang, S., Agostinis, P., Salven, P., & Garg, A. D. (2020). Decoding cancer cell death-driven immune cell recruitment: An in vivo method for site-of-vaccination analyses. *Methods in enzymology*, 636, 185–207. <https://doi.org/10.1016/bs.mie.2019.04.013>
 218. Stumpf, J., Klimova, A., Mauer, R., Steglich, A., Gembardt, F., Martin, H., Glombig, G., Frank, K., Tonn, T., & Hugo, C. (2022). Equivalent humoral and cellular immune response but different side effect rates following SARS-CoV-2 vaccination in peritoneal and haemodialysis patients using messenger RNA vaccines. *Nephrology, dialysis, transplantation : official publication of the European Dialysis and Transplant Association - European Renal Association*, 37(4), 796–798. <https://doi.org/10.1093/ndt/gfab324>
 219. Lozano-Rodríguez, R., Terrón-Arcos, V., Montalbán-Hernández, K., Casavilla-Dueñas, J. C., Bergón-Gutierrez, M., Pascual-Iglesias, A., Quiroga, J. V., Aguirre, L. A., Pérez de Diego, R., Vela-Olmo, C., López-Morejón, L., Martín-Quirós, A., Del Balzo-Castillo, Á., Peinado-Quesada, M. A., García-Garrido, M. A., Gómez-Lage, L., Herrero-Benito, C., Llorente-Fernández, I., Martín-Miguel, G., Torrejón, M., ... López-Collazo, E. (2022). Prior SARS-CoV-2 infection balances immune responses triggered by four EMA-approved COVID-19 vaccines: An observational study. *Clinical and translational medicine*, 12(5), e869. <https://doi.org/10.1002/ctm2.869>
 220. Boerenkamp, L. S., Pothast, C. R., Dijkland, R. C., van Dijk, K., van Gorkom, G. N. Y., van Loo, I. H. M., Wieten, L., Halkes, C. J. M., Heemskerk, M. H. M., & Van Elssen, C. H. M. J. (2022). Increased CD8 T-cell immunity after COVID-19 vaccination in lymphoid malignancy patients lacking adequate humoral response: An immune compensation mechanism?. *American journal of hematology*, 97(12), E457–E461. <https://doi.org/10.1002/ajh.26729>
 221. Choi, D. K., Strzepka, J. T., Hunt, S. R., Tannenbaum, V. L., & Jang, I. E. (2020). Vaccination in pediatric cancer survivors: Vaccination rates, immune status, and knowledge regarding compliance. *Pediatric blood & cancer*, 67(10), e28565. <https://doi.org/10.1002/pbc.28565>
 222. Xing, Y., Yang, J., Yao, P., Xie, L., Liu, M., & Cai, Y. (2024). Comparison of the immune response and protection against the experimental *Toxoplasma gondii* infection elicited by immunization with the recombinant proteins BAG1, ROP8, and BAG1-ROP8. *Parasite immunology*, 46(2), e13023. <https://doi.org/10.1111/pim.13023>
 223. Sesques, P., Bachy, E., Ferrant, E., Safar, V., Gossez, M., Morfin-Sherpa, F., Venet, F., & Ader, F. (2022). Immune response to three doses of mRNA SARS-CoV-2 vaccines in CD19-targeted chimeric antigen receptor T cell immunotherapy recipients. *Cancer cell*, 40(3), 236–237. <https://doi.org/10.1016/j.ccell.2022.01.010>
 224. Seban, R. D., Champion, L., Yeh, R., Schwartz, L. H., & Dercle, L. (2021). Assessing immune response upon systemic RNA vaccination on [18F]-FDG PET/CT for COVID-19 vaccine and then for immuno-oncology?. *European journal of nuclear medicine and molecular imaging*, 48(11), 3351–3352. <https://doi.org/10.1007/s00259-021-05468-z>
 225. Moulik, N. R., Mandal, P., Chandra, J., Bansal, S., Jog, P., Sanjay, S., Shah, N., & Arora, R. S. (2019). Immunization of Children with Cancer in India Treated with Chemotherapy - Consensus Guideline from the Pediatric Hematology-Oncology Chapter and the Advisory Committee on Vaccination and Immunization Practices of the Indian Academy of Pediatrics. *Indian pediatrics*, 56(12), 1041–1048.
 226. Motwani, K. K., Hashash, J. G., Farraye, F. A., Kappelman, M. D., Weaver, K. N., Zhang, X., Long, M. D., & Cross, R. K. (2023). Impact of Holding Immunosuppressive Therapy in Patients with Inflammatory Bowel Disease Around mRNA COVID-19 Vaccine Administration on Humoral Immune Response and Development of COVID-19 Infection. *Journal of Crohn's & colitis*, 17(10), 1681–1688. <https://doi.org/10.1093/ecco-jcc/jjad085>
 227. Safavi, A., Kefayat, A., Ghahremani, F., Mahdevar, E., & Moshtaghian, J. (2019). Immunization using male

- germ cells and gametes as rich sources of cancer/testis antigens for inhibition of 4T1 breast tumors' growth and metastasis in BALB/c mice. *International immunopharmacology*, 74, 105719. <https://doi.org/10.1016/j.intimp.2019.105719>
228. Lundstrom K. (2021). Immune Responses of Alphavirus Vaccination in Patients with HPV-Induced Cancers. *Molecular therapy : the journal of the American Society of Gene Therapy*, 29(2), 415–416. <https://doi.org/10.1016/j.ymthe.2021.01.008>
 229. Oosting, S. F., van der Veldt, A. A. M., Fehrman, R. S. N., Bhattacharya, A., van Binnendijk, R. S., GeurtsvanKessel, C. H., Dingemans, A. C., Smit, E. F., Hiltermann, T. J. N., den Hartog, G., Jalving, M., Westphal, T. T., de Wilt, F., Ernst, S. M., Boerma, A., van Zijl, L., Rimmelzwaan, G. F., Kvistborg, P., van Els, C. A. C. M., Rots, N. Y., ... de Vries, E. G. E. (2023). Factors associated with long-term antibody response after COVID-19 vaccination in patients treated with systemic treatment for solid tumors. *ESMO open*, 8(4), 101599. <https://doi.org/10.1016/j.esmoop.2023.101599>
 230. Óskarsson, Ý., Thors, V., Vias, R. D., Lúðvíksson, B. R., Brynjólfsson, S. F., Giancchetti, E., Razzano, I., Montomoli, E., Gísli Jónsson, Ó., & Haraldsson, Á. (2024). Adequate immune responses to vaccines after chemotherapy for leukaemia diagnosed in childhood. *Acta paediatrica (Oslo, Norway : 1992)*, 113(3), 606–614. <https://doi.org/10.1111/apa.17070>
 231. Cole, G., Ali, A. A., McErlean, E., Mulholland, E. J., Short, A., McCrudden, C. M., McCaffrey, J., Robson, T., Kett, V. L., Coulter, J. A., Dunne, N. J., Donnelly, R. F., & McCarthy, H. O. (2019). DNA vaccination via RALA nanoparticles in a microneedle delivery system induces a potent immune response against the endogenous prostate cancer stem cell antigen. *Acta biomaterialia*, 96, 480–490. <https://doi.org/10.1016/j.actbio.2019.07.003>
 232. Kleebayoon, A., & Wiwanitkit, V. (2023). Comment on: Humoral profiling of pediatric patients with cancer reveals robust immunity following anti-SARS-CoV-2 vaccination superior to natural infection. *Pediatric blood & cancer*, 70(10), e30509. <https://doi.org/10.1002/pbc.30509>
 233. Woodfield, M. C., Carpenter, P. A., & Pergam, S. A. (2020). Shots, Not Moonshots-The Importance of Broad Population Immunization to Patients Who Undergo Cancer Treatment. *JAMA oncology*, 6(1), 23–24. <https://doi.org/10.1001/jamaoncol.2019.4572>
 234. Veinalde R. (2020). Evaluation of Oncolytic Virus-Induced Therapeutic Tumor Vaccination Effects in Murine Tumor Models. *Methods in molecular biology (Clifton, N.J.)*, 2058, 213–227. https://doi.org/10.1007/978-1-4939-9794-7_13
 235. Ryu, H. H., Chang, K., Kim, N., Lee, H. S., Hwang, S. W., Park, S. H., Yang, D. H., Byeon, J. S., Myung, S. J., Yang, S. K., & Ye, B. D. (2021). Insufficient vaccination and inadequate immunization rates among Korean patients with inflammatory bowel diseases. *Medicine*, 100(45), e27714. <https://doi.org/10.1097/MD.00000000000027714>
 236. Wang, W., Li, X., Qin, X., Miao, Y., Zhang, Y., Li, S., Yao, R., Yang, Y., Yu, L., Zhu, H., Song, L., Mao, S., Wang, X., Chen, J., Feng, H., & Li, Y. (2023). Germline Neurofibromin 1 mutation enhances the anti-tumour immune response and decreases juvenile myelomonocytic leukaemia tumorigenicity. *British journal of haematology*, 202(2), 328–343. <https://doi.org/10.1111/bjh.18851>
 237. Ginefra, P., Lorusso, G., & Vannini, N. (2020). Innate Immune Cells and Their Contribution to T-Cell-Based Immunotherapy. *International journal of molecular sciences*, 21(12), 4441. <https://doi.org/10.3390/ijms21124441>
 238. Alicke, B., Totpal, K., Schartner, J. M., Berkley, A. M., Lehar, S. M., Capietto, A. H., Cubas, R. A., & Gould, S. E. (2020). Immunization associated with primary tumor growth leads to rejection of commonly used syngeneic tumors upon tumor rechallenge. *Journal for immunotherapy of cancer*, 8(2), e000532. <https://doi.org/10.1136/jitc-2020-000532>
 239. Song, X., Jiang, Y., Zhang, W., Elfawal, G., Wang, K., Jiang, D., Hong, H., Wu, J., He, C., Mo, X., & Wang, H. (2022). Transcutaneous tumor vaccination combined with anti-programmed death-1 monoclonal antibody treatment produces a synergistic antitumor effect. *Acta biomaterialia*, 140, 247–260. <https://doi.org/10.1016/j.actbio.2021.11.033>
 240. Muhammad, Q., Jang, Y., Kang, S. H., Moon, J., Kim, W. J., & Park, H. (2020). Modulation of immune responses with nanoparticles and reduction of their immunotoxicity. *Biomaterials science*, 8(6), 1490–1501. <https://doi.org/10.1039/c9bm01643k>
 241. Fujii, S. I., & Shimizu, K. (2019). Immune Networks and Therapeutic Targeting of iNKT Cells in Cancer. *Trends in immunology*, 40(11), 984–997. <https://doi.org/10.1016/j.it.2019.09.008>
 242. Ollila, T. A., Masel, R. H., Reagan, J. L., Lu, S., Rogers, R. D., Paiva, K. J., Taher, R., Burguera-Couce, E.,

- Zayac, A. S., Yakirevich, I., Niroula, R., Barth, P., & Olszewski, A. J. (2022). Seroconversion and outcomes after initial and booster COVID-19 vaccination in adults with hematologic malignancies. *Cancer*, 128(18), 3319–3329. <https://doi.org/10.1002/cnecr.34354>
242. Mao, C., Beiss, V., Ho, G. W., Fields, J., Steinmetz, N. F., & Fiering, S. (2022). In situ vaccination with cowpea mosaic virus elicits systemic antitumor immunity and potentiates immune checkpoint blockade. *Journal for immunotherapy of cancer*, 10(12), e005834. <https://doi.org/10.1136/jitc-2022-005834>
 243. You, W., Ouyang, J., Cai, Z., Chen, Y., & Wu, X. (2022). Comprehensive Analyses of Immune Subtypes of Stomach Adenocarcinoma for mRNA Vaccination. *Frontiers in immunology*, 13, 827506. <https://doi.org/10.3389/fimmu.2022.827506>
 244. Elizondo, C. R., Bright, J. D., Byrne, J. A., & Bright, R. K. (2020). Analysis of the CD8+ IL-10+ T cell response elicited by vaccination with the oncogenic tumor-self protein D52. *Human vaccines & immunotherapeutics*, 16(6), 1413–1423. <https://doi.org/10.1080/21645515.2019.1689746>
 245. Sangeeta, K., & Yenugu, S. (2022). Ablation of the sperm-associated antigen 11A (SPAG11A) protein by active immunization promotes epididymal oncogenesis in the rat. *Cell and tissue research*, 389(1), 115–128. <https://doi.org/10.1007/s00441-022-03623-y>
 246. Rakshit, S., Adiga, V., Ahmed, A., Parthiban, C., Chetan Kumar, N., Dwarkanath, P., Shivalingaiah, S., Rao, S., D'Souza, G., Dias, M., Maguire, T. J. A., Doores, K. J., Zoodma, M., Geckin, B., Dasgupta, P., Babji, S., van Meijgaarden, K. E., Joosten, S. A., Ottenhoff, T. H. M., Li, Y., ... Vyakarnam, A. (2022). Evidence for the heterologous benefits of prior BCG vaccination on COVISHIELD™ vaccine-induced immune responses in SARS-CoV-2 seronegative young Indian adults. *Frontiers in immunology*, 13, 985938. <https://doi.org/10.3389/fimmu.2022.985938>
 247. Xu, H., Zhao, F., Wu, D., Zhang, Y., Bao, X., Shi, F., Cai, Y., & Dou, J. (2023). Eliciting effective tumor immunity against ovarian cancer by cancer stem cell vaccination. *Biomedicine & pharmacotherapy = Biomedecine & pharmacotherapie*, 161, 114547. <https://doi.org/10.1016/j.biopha.2023.114547>
 248. Takeshita, K., Ishiwada, N., Takeuchi, N., Ohkusu, M., Ohata, M., Hino, M., Hishiki, H., Takeda, Y., Sakaida, E., Takahashi, Y., Shimojo, N., & Hamada, H. (2022). Immunogenicity and safety of routine 13-valent pneumococcal conjugate vaccination outside recommended age range in patients with hematological malignancies and solid tumors. *Vaccine*, 40(9), 1238–1245. <https://doi.org/10.1016/j.vaccine.2022.01.056>
 249. Fitzpatrick, T., Alsager, K., Sadarangani, M., Pham-Huy, A., Murguía-Favela, L., Morris, S. K., Seow, C. H., Piché-Renaud, P. P., Jadavji, T., Vanderkooi, O. G., Top, K. A., Constantinescu, C., & Special Immunization Clinic Network investigators (2023). Immunological effects and safety of live rotavirus vaccination after antenatal exposure to immunomodulatory biologic agents: a prospective cohort study from the Canadian Immunization Research Network. *The Lancet. Child & adolescent health*, 7(9), 648–656. [https://doi.org/10.1016/S2352-4642\(23\)00136-0](https://doi.org/10.1016/S2352-4642(23)00136-0)
 250. Mezzapelle, R., De Marchis, F., Passera, C., Leo, M., Brambilla, F., Colombo, F., Casalgrandi, M., Preti, A., Zambrano, S., Castellani, P., Ertassi, R., Silingardi, M., Caprioglio, F., Basso, V., Boldorini, R., Carretta, A., Sanvito, F., Rena, O., Rubartelli, A., Sabatino, L., ... Bianchi, M. E. (2021). CXCR4 engagement triggers CD47 internalization and antitumor immunization in a mouse model of mesothelioma. *EMBO molecular medicine*, 13(6), e12344. <https://doi.org/10.15252/emmm.202012344>
 251. Jindra, C., Hainisch, E. K., Rümmele, A., Wolschek, M., Muster, T., & Brandt, S. (2021). Influenza virus vector iNS1 expressing bovine papillomavirus 1 (BPV1) antigens efficiently induces tumour regression in equine sarcoid patients. *PloS one*, 16(11), e0260155. <https://doi.org/10.1371/journal.pone.0260155>
 252. Huang, M., Xiong, D., Pan, J., Zhang, Q., Wang, Y., Myers, C. R., Johnson, B. D., Hardy, M., Kalyanaraman, B., & You, M. (2022). Prevention of Tumor Growth and Dissemination by In Situ Vaccination with Mitochondria-Targeted Atovaquone. *Advanced science (Weinheim, Baden-Wurttemberg, Germany)*, 9(12), e2101267. <https://doi.org/10.1002/advs.202101267>

253. Abdolkarimi, B., Amanati, A., Molavi Vardanjani, H., Jamshidi, S., & Tabaeian, S. A. P. (2022). Antibody waning after immunosuppressive chemotherapy and immunomodulators, re-immunization considerations in pediatric patients with malignancy and chronic immune thrombocytopenic purpura. *BMC infectious diseases*, 22(1), 657. <https://doi.org/10.1186/s12879-022-07647-1>
254. Ota, S., Miyashita, M., Yamagishi, Y., & Ogasawara, M. (2021). Baseline immunity predicts prognosis of pancreatic cancer patients treated with WT1 and/or MUC1 peptide-loaded dendritic cell vaccination and a standard chemotherapy. *Human vaccines & immunotherapeutics*, 17(12), 5563–5572. <https://doi.org/10.1080/21645515.2021.2003645>

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