Vaccine Therapy for Non-Small Cell Lung Cancer

Yi Lyu[1], Sutong Li[2] and Haoze Li[3]
[1]*Shihezi University, Shihezi, Xinjiang, China*
[2]*Wuhan University of Technology, Wuhan, China*
[3]*High School Attached to Northeast Normal University International Curriculum Center, Jilin, China*

Keywords: Non-Small Cell Lung Cancer (NSCLC), Cancer Vaccine, mRNA Vaccine.

Abstract: Lung cancer is a leading cause of cancer-related mortality, with non-small cell lung cancer (NSCLC) being the most common and a major global health concern. While traditional treatments such as radiotherapy, chemotherapy, and surgery have shown some effectiveness, challenges like tumor heterogeneity, drug resistance, and significant side effects continue to result in poor prognosis and limited survival improvement. In contrast, vaccine therapy presents a promising alternative, offering a favorable safety profile, the potential for long-lasting immune responses, and the ability to reshape the tumor microenvironment. This approach provides renewed hope for NSCLC patients. This review explores the immune evasion mechanisms employed by NSCLC and discusses the principles, advantages, and progress of various vaccine types, aiming to offer insights into the future development of vaccine-based treatment strategies for NSCLC.

1 INTRODUCTION

In recent years, the global incidence and mortality rates of cancer have continued to rise. According to the 2024 cancer statistics, it is estimated that there will be 226,650 new cases of lung cancer in the United States, with approximately 124,730 deaths (Siegel et al.,2015) Lung cancer remains the leading cause of cancer-related deaths worldwide (18.7%) (Bray et al.,2022), posing a significant public health challenge. Lung cancer can be classified into non-small cell lung cancer (NSCLC) and small cell lung cancer (SCLC), with NSCLC accounting for about 85% of all lung cancer cases. NSCLC is further divided into three subtypes: adenocarcinoma, large cell carcinoma, and squamous cell carcinoma, with adenocarcinoma being the most common type. Among the risk factors for NSCLC, long-term exposure to air pollution, prior radiation therapy to the lungs, and family history are non-modifiable, while smoking, radon exposure, and asbestos are other important controllable risk factors. Due to the lack of early diagnosis and the late onset of symptoms during disease progression, the majority of NSCLC patients are diagnosed at advanced or metastatic stages, resulting in poor prognosis (Lahiri et al.,2023). Currently, various treatment strategies such as surgery, radiotherapy, chemotherapy, and even targeted therapy are widely used for NSCLC treatment. Although these methods have controlled tumor progression to some extent, they are associated with significant side effects (Xu et al.,2024), including hair loss, organ toxicity, secondary tumors, and drug resistance, and their therapeutic efficacy remains limited. In this context, vaccine therapy, as an innovative approach to activate specific anti-tumor immune responses, has gradually become a cutting-edge research direction in NSCLC treatment.

The core mechanism of vaccine therapy lies in delivering tumor-associated antigens (TAAs) or neoantigens to activate host antigen-presenting cells (APCs), thereby initiating an immune response mediated by cytotoxic T lymphocytes (CTLs) against tumors (García-Pardo et al.,2022). Compared to traditional immunotherapies, vaccine therapy offers several advantages, such as enhanced immunogenicity through epitope optimization and the induction of long-term immune memory to prevent tumor recurrence. Particularly when targeting specific tumor antigens, vaccines can provide more accurate immune responses, avoiding the side effects of systemic immunity. With continuous optimization in vaccine design, immunotherapy has demonstrated great potential in improving patients' quality of life and extending survival. Given these advantages, vaccine therapy, as an emerging approach in cancer treatment, has gradually gained clinical attention and application. Therefore, this article aims to provide an

Lyu, Y., Li, S. and Li, H.
Vaccine Therapy for Non-Small Cell Lung Cancer.
DOI: 10.5220/0014488500004933

In *Proceedings of the 1st International Conference on Biomedical Engineering and Food Science (BEFS 2025)*, pages 345-351
ISBN: 978-989-758-789-4

overview of the current research progress in NSCLC vaccine therapy, focusing on the principles, mechanisms, and clinical potential of mRNA vaccines, Oncolytic virus vaccines, and personalized neoantigen vaccines in the treatment of NSCLC.

2 MECHANISMS OF IMMUNE EVASION AND IMMUNOTHERAPY IN NSCLC

In recent years, studies have found that although the human immune system can generate specific anti-tumor immune responses, many tumors can still progressively grow and persist within the body, evading attacks from the host's immune system or preventing the body from mounting an effective immune response, ultimately leading to the death of the host. The tumor microenvironment (TME) is a significant factor contributing to tumor immune evasion. The TME consists of tumor parenchymal cells, stromal cells, various immune cells, and a range of membrane-bound or secreted bioactive substances, such as VEGF. These components not only promote the growth of surrounding blood vessels to supply nutrients to the tumor but also directly act on tumor cells (Zhao et al.,2022). Additionally, within the tumor microenvironment, immunosuppressive cells such as regulatory T cells (Tregs), tumor-associated macrophages (TAMs), and myeloid-derived suppressor cells (MDSCs) create an immunosuppressive environment. These cells can directly inhibit cytotoxic immune cells from attacking cancer cells or indirectly release inhibitory factors that downregulate immune cell function (Madeddu et al., 2022). This results in tumor cells becoming insensitive to immune responses, evading immune surveillance, and continuing to grow or even metastasize.

Currently, immune checkpoint inhibitors (ICIs) such as PD-1/PD-L1 inhibitors are widely used in clinical treatment. They aim to block the tumor's suppression of immune cells to exert anti-tumor activity. However, their efficacy is limited due to the low response rates in advanced NSCLC patients and the inherent and acquired resistance mechanisms of tumor cells to ICIs. In contrast, vaccine therapy offers potential advantages by targeting multiple antigenic epitopes, reducing the likelihood of tumor resistance. It can also broadly activate the host's immune defense mechanisms and enhance the clearance of tumor cells, demonstrating promising applications in NSCLC treatment research (Mamdani et al., 2022).

3 MECHANISM AND ADVANTAGES OF mRNA VACCINES

mRNA vaccines innovatively activate the host's adaptive immune response by delivering genetic information encoding pathogen-specific antigens. Their mechanism of action relies on the host cell's natural protein synthesis system—the modified mRNA carried by the vaccine is delivered to the cytoplasm, where it directly utilizes the ribosome translation system to produce the target antigen protein. This "endogenous expression" strategy breaks through the traditional exogenous antigen delivery model of conventional vaccines, simulating the natural infection process to achieve antigen presentation. This approach not only stimulates the production of neutralizing antibodies but also induces T-cell immune responses. Notably, this technology platform completely avoids the complex processes required in traditional vaccine development, such as pathogen amplification, culture, and antigen purification, reducing the vaccine development cycle from several years to a few weeks. This not only provides a rapid response advantage in addressing emerging infectious diseases but also holds significant potential for rapidly evolving tumor antigens (Wu et al.,2024). In terms of safety, mRNA vaccines do not carry the potential risk of genomic integration and do not require handling live pathogens, thereby reducing biosafety concerns. More importantly, mRNA vaccines can be flexibly customized according to individual patient differences. Particularly in tumor immunotherapy, if timely updates to target new antigens are needed, the design and preparation can be completed in the shortest time possible. These advantages make mRNA vaccines highly promising in both infectious disease prevention and tumor immunotherapy.

To minimize the likelihood of inflammatory responses caused by exogenous mRNA, lipid nanoparticles (LNPs) are currently commonly used as the mRNA delivery system. LNPs consist of four main components: ionizable lipids, cholesterol, helper phospholipids, and PEG-modified lipids. These components work together to form a sophisticated system that both protects mRNA and efficiently delivers it to target cells. Ionizable lipids (such as ALC-0315) are one of the core components of LNPs. They remain neutral at physiological pH, helping to reduce systemic toxicity, but become protonated in the acidic endosomal environment, facilitating the release of mRNA. Cholesterol acts as

a structural stabilizer, enhancing the integrity of the nanoparticles by modulating membrane fluidity. Helper phospholipids (such as DSPC) promote the formation of lipid bilayers, optimizing the assembly process of the particles. PEG-modified lipids reduce particle aggregation through steric hindrance and regulate pharmacokinetic properties. This delivery mechanism enables mRNA vaccines to achieve cell-specific uptake through receptor-mediated endocytosis. When LNPs enter target cells, the ionizable lipids undergo conformational changes triggered by the acidic endosomal environment, interacting with endosomal membrane phospholipids to facilitate the release of mRNA into the cytoplasm. Subsequently, the mRNA is translated into antigen proteins by ribosomes in the cytoplasm and presented to T cells via MHC class I and II molecules, thereby inducing robust humoral and cellular immune responses.

4 mRNA VACCINES IN CLINICAL TRIALS FOR NSCLC TREATMENT

4.1 CCV9201 and CV9202 Vaccine

In the design of tumor-associated antigens, the CV9201 vaccine encodes five TAAs: NY-ESO-1, MAGE-C1, MAGE-C2, Survivin, and TPBG. The CV9202 vaccine expands on CV9201 by including six antigens (adding 5T4 and MUC1). CV9201 Vaccine: In a Phase I/IIa clinical trial involving 46 patients with advanced NSCLC, CV9201 successfully induced multiple antigen-specific immune responses, including T-cell activation and antibody production (Lang et al., 2022). Vaccine: In a Phase Ib trial involving 26 patients with stage IV NSCLC, antigen-specific immune responses were detected, supporting its immune activation potential. Both trials demonstrated good tolerability with no serious adverse events reported, although significant tumor regression was not observed, necessitating further clinical validation. Notably, in the CV9201 trial, when combined with local radiotherapy, six patients showed local tumor regression, and the frequency of antigen-specific T cells in peripheral blood increased 4-8 times. Preliminary data from the CV9202 trial combined with anti-CTLA-4 therapy showed a disease control rate (DCR) of 54%, though larger sample sizes are needed for validation (Sebastian et al., 2022).

4.2 RO7198457 Vaccine

The RO7198457 vaccine is a personalized neoantigen-specific immunotherapy (Individualized Neoantigen-Specific Immunotherapy, iNeST) based on RNA-lipoplex (RNA-Lipo) technology, targeting up to 20 patient-specific neoantigens. In patients with metastatic solid tumors, this vaccine has demonstrated a manageable toxicity profile (Zhang et al., 2020)， Additionally, it can induce robust neoantigen-specific T-cell responses, with increased T-cell infiltration observed in the tumor microenvironment in some patients. Currently, a Phase II trial combining RO7198457 with PD-1/PD-L1 inhibitors is underway, aiming to overcome the immunosuppressive tumor microenvironment and further enhance clinical efficacy.

4.3 KRAS and ALK Driver Gene Vaccines

Neoantigens derived from KRAS mutations are highly immunogenic, but their efficacy requires overcoming the suppressive tumor microenvironment (Voena et al., 2015). Currently, clinical trials (NCT05202561, NCT05254184) are exploring the therapeutic potential of KRAS vaccines in combination with immune checkpoint inhibitors. The ALK rearrangement vaccine is a DNA vaccine targeting the intracellular domain of ALK. In mouse models, it has demonstrated the ability to induce tumor-specific cytotoxic responses. Although still in the preparatory Phase I stage, if its safety and immunogenicity are confirmed, its combination with other immunotherapies could provide new treatment options for ALK-positive NSCLC patients (Sankar et al., 2021; Kim et al., 2021).

5 mRNA VACCINES IN CLINICAL TRIALS FOR NSCLC TREATMENT

5.1 Principles and Types of Oncolytic Viruses

With continuous in-depth research into the mechanisms of virus-host interactions, viruses have emerged as a promising tool for cancer treatment. Oncolytic viruses (OVs) primarily refer to naturally occurring or genetically modified viruses that can selectively infect and lyse tumor cells while inducing immune responses. Currently, common oncolytic

viruses are mainly divided into two types: DNA viruses (such as the herpes simplex virus T-VEC, the only FDA-approved oncolytic virus) (Conry et al., 2018) and RNA viruses (such as measles virus and reovirus). DNA viruses, due to their larger genomes, can carry more exogenous genes or undergo genetic editing, thereby enhancing therapeutic activity. Additionally, compared to RNA viruses, DNA viruses have more stable genomes with lower mutation rates, making them suitable for long-term treatment. Beyond the aforementioned viruses, various other types of viruses are under clinical investigation to elucidate their therapeutic efficacy and safety in humans (Macedo et al., 2020).

5.2 The Role of Oncolytic Viruses in Immunotherapy

Oncolytic viruses (OVs) play a significant role in cancer treatment, primarily through direct oncolytic effects and induction and enhancement of anti-tumor immune responses (Ma et al., 2023). Direct oncolysis is the initial process in the treatment, where the tumor selectivity of oncolytic viruses is enhanced by modifying certain protein structures, allowing them to bind to virus-specific receptors on the tumor surface and enter the cells. Due to the inactivation of the p53 pathway and defects in the interferon (IFN) signaling pathway in tumor cells (Xu et al.,2024,Hemminki et al.,2020)，an effective antiviral response cannot be initiated, leading to unrestricted viral replication. After the tumor cells are lysed, the released progeny viruses continue to infect neighboring tumor cells, creating an "oncolytic cascade effect." Simultaneously, damaged tumor cells release damage-associated molecular patterns (DAMPs) and tumor-associated antigens (TAAs). These signaling molecules are captured and presented by antigen-presenting cells (such as DCs) to CD8+ T cells, thereby initiating a specific immune response. Notably, the tumor microenvironment (TME) provides ample conditions for tumor proliferation, differentiation, and metastasis. Due to the presence of a large number of inhibitory cells and cytokines, tumors are not sensitive to the body's immune cells and exhibit weak immune systems. However, the PAMPs, DAMPs, and TAAs released by oncolytic virus (OV)-mediated tumor cell lysis can recruit various immune cells such as NK cells, macrophages, and neutrophils, thereby reversing the tumor microenvironment(Melcher et al.,2021). One study reported that Coxsackievirus B5/Faulkner (CV-B5/F) demonstrated potential oncolytic effects in a non-small cell lung cancer (NSCLC) animal model by inducing apoptosis and autophagy (Cui et al., 2023). In addition to direct oncolysis, CV-B5/F can also induce a systemic anti-tumor response and recruit specific T cell infiltration. For refractory NSCLC cells, the combination of CV-B5/F with DNA-dependent protein kinase (DNA-PK) or ataxia-telangiectasia mutated (ATM) inhibitors significantly enhances the oncolytic effect.

5.3 Combination of Oncolytic Virus Vaccines with Other Therapies

Given that oncolytic viruses possess dual effects—direct oncolysis and enhanced immune response, as well as the ability to improve the tumor microenvironment—combining oncolytic viruses with other immunotherapeutic methods may significantly enhance treatment efficacy. Chimeric antigen receptor (CAR)-T cell therapy, as a revolutionary treatment strategy, has made remarkable progress in anti-tumor therapy. However, the dense stroma of solid tumors (such as collagen deposition and fibrosis), abnormal vascular structures, and immunosuppressive factors in the tumor microenvironment hinder the infiltration and function of CAR-T cells. Oncolytic viruses can disrupt tumor tissue, reduce stromal density, and provide physical pathways for CAR-T cells. Additionally, by inducing the release of pro-inflammatory factors (such as IL-2 and IL-12) and reversing immunosuppressive signals in the tumor microenvironment, oncolytic viruses can directly activate CAR-T cells, enhancing their proliferation and effector capabilities (Hemminki et al., 2020).

6 PERSONALIZED NEOANTIGEN VACCINES

The goal of innovative cancer vaccines targeting novel antigens is to induce highly specific immune responses while minimizing autoimmune risks. Next-generation sequencing technologies have enabled researchers to systematically examine how neoantigen peptides activate CD8+ T cells and to uncover significant increases in CD4+ T cell and NK cell proliferation. These insights deepen our understanding of the complex mechanisms underlying antitumor immune responses and underscore their potential biomedical applications. Notably, the binding affinity of a neoantigen to MHC molecules, alongside the diversity of HLA genotypes, is crucial for identifying immunogenic targets.

Evidence suggests that only a small fraction of somatic mutations predicted through mutational spectrum analysis ultimately function as immunogenic neoantigens. This finding highlights new possibilities for optimizing the efficacy and efficiency of multi-peptide cancer vaccines.

Unbiased whole-genome or whole-exome sequencing provides an irreplaceable foundation for identifying promising neoantigens by revealing the complete “epitope landscape.” Moreover, messenger RNA (mRNA) technology offers a highly adaptable platform with a relatively short development cycle for producing therapeutic cancer vaccines. As a versatile antigen-delivery vector, mRNA excels in designing vaccines that target unique tumor-specific mutations. Such personalized designs allow for the induction of potent immune responses that can precisely eliminate malignant cells while sparing healthy tissues, potentially improving therapeutic outcomes.

7 FUTURE DEVELOPMENT AND CHALLENGES

7.1 Establishment of Animal Models of HIV Infection

Establishing cross-species animal models for HIV infection is essential for advancing our understanding of HIV/AIDS pathogenesis. However, HIV-1 is species-specific and only infects humans and a few non-human primates, making it challenging to study in traditional animal models such as mice. A recent study successfully created a mouse model capable of being infected with HIV-1. By introducing the CD4, CCR5, and CyclinT1 genes into the mouse leukemia cell line L1210 using lentiviral vectors, the researchers enabled these cells to express the necessary receptors and co-receptors for HIV infection. Fluorescence analysis and sequencing confirmed the significant expression of CD4, CCR5, and CyclinT1 proteins in the transgenic cells, and HIV-1 RNA was detected in the culture medium, indicating successful virus entry and replication. This model provides a critical platform for studying HIV-1 cross-species infection and offers new directions for HIV vaccine development, antiviral drug screening, and further exploration of HIV/AIDS pathogenesis (Karuppusamy et al., 2021).

7.2 Cases of AIDS Cure

The "Berlin Patient," Timothy Ray Brown, became the first person in the world to be cured of AIDS following a bone marrow transplant in 2007. Brown, who was also battling leukemia, received a transplant from a donor with the CCR5Δ32 mutation, which naturally blocks HIV entry into cells. After the procedure, not only was Brown’s leukemia successfully treated, but HIV was undetectable in his body, effectively achieving a "double cure." Similarly, the "London Patient," Adam Castillejo, underwent a hematopoietic stem cell transplant for Hodgkin's lymphoma in 2016, receiving cells with the CCR5Δ32 mutation. After discontinuing antiretroviral therapy, HIV remained undetectable in his body for several years, with no recurrence of the infection.

These two groundbreaking cases highlight the potential of CCR5 gene modification for both controlling and potentially curing HIV. However, the procedures involved—particularly bone marrow transplants—are highly complex, risky, and prone to serious complications. Moreover, finding matching donors is exceedingly difficult, limiting the widespread applicability of this treatment. While these cases offer hope and insight for CCR5 gene editing in HIV treatment, they remain exceptional cases and do not yet represent a practical, widely accessible solution. Nonetheless, they provide invaluable direction for ongoing research into CCR5 gene editing and its potential to prevent or cure HIV infection.

7.3 Safety and Drug Resistance Issues

The clinical translation of vaccine therapies requires a delicate balance between immune activation effects and safety risks. For example, mRNA vaccines, which rely on lipid nanoparticle (LNP) delivery systems, may cause transient inflammatory reactions, typically manifesting as fever or localized tissue redness. The use of oncolytic virus vectors requires vigilance against potential systemic diffusion-related toxicity. Additionally, repeated immune stimulation may lead to functional exhaustion of antigen-specific T cells, characterized by upregulation of immune checkpoint molecule co-expression, thereby weakening the persistence of immune responses. In terms of tumor resistance, epigenetic silencing of target antigens or reprogramming of the immunosuppressive microenvironment are the main mechanisms of immune escape. The former involves the loss of key antigen presentation components (such

as MHC complex subunits), while the latter is associated with abnormal activation of immunosuppressive factor networks. To overcome these limitations, studies have shown that combining epigenetic modulators with vaccines can synergistically reshape the immune microenvironment, and multi-antigen targeting designs can reduce the probability of clonal escape. In the future, integrating high-resolution molecular mapping technologies (such as single-cell sequencing) with dynamic vaccine design platforms is expected to enable real-time tracking and precise intervention in tumor adaptive evolution pathways.

8 CONCLUSION

In conclusion, non-small cell lung cancer (NSCLC) remains a leading global health concern, with existing therapies—such as surgery, radiotherapy, and chemotherapy—facing significant limitations due to tumor heterogeneity, drug resistance, and adverse effects. Vaccine-based strategies, including mRNA platforms, demonstrate considerable promise in eliciting robust antitumor immune responses and reshaping the tumor microenvironment. Clinical studies on vaccines such as CV901, CV90, RO7198457, and those targeting KRAS or ALK mutations indicate that these approaches can induce detectable immune responses and confer certain therapeutic benefits; however, additional research is required to achieve more pronounced tumor regression. Efforts to optimize vaccine efficacy highlight the potential of combined approaches—for example, the co-administration of mRNA vaccines with oncolytic viruses and the development of bispecific vaccines. Although timely manufacturing poses logistical challenges, integrating genomic and multi-omics data into vaccine design can enable the rapid development of personalized and precise immunotherapies for NSCLC. Moreover, strategies involving epigenetic regulation, multi-antigen targeting, and high-resolution molecular profiling hold promise in mitigating safety risks and drug resistance. Ultimately, harnessing these advances may transform current treatment paradigms for NSCLC and spark innovative applications in the clinical arena. Nevertheless, several hurdles remain for neoantigen-based therapies, including the accurate prediction of immunogenicity and the optimization of in vivo transfection efficiency. Overcoming these challenges is crucial for realizing the full therapeutic potential of vaccine-based strategies for NSCLC.

AUTHORS CONTRIBUTION

All the authors contributed equally and their names were listed in alphabetical order.

REFERENCES

Bray F, Laversanne M, Sung H, et al. 2024. Global cancer statistics 2022: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA: a cancer journal for clinicians*, 74(3), 229–263.

Conry RM, Westbrook B, McKee S, Norwood TG. 2018. Talimogene laherparepvec: First in class oncolytic virotherapy. *Human vaccines & immunotherapeutics*, 14(4), 839–846.

Cui B, Song L, Wang Q, et al. 2023. Non-small cell lung cancers (NSCLCs) oncolysis using coxsackievirus B5 and synergistic DNA-damage response inhibitors. *Signal transduction and targeted therapy*, *8*(1), 366.

García-Pardo, Miguel et al. 2022. Vaccine Therapy in Non-Small Cell Lung Cancer. *Vaccines*, *10*(5), 740.

Hemminki, O., Dos Santos, J. M., & Hemminki, A. 2020. Oncolytic viruses for cancer immunotherapy. *Journal of hematology & oncology*, *13*(1), 84.

Kim, C. G., Sang, Y. B., Lee, J. H., & Chon, H. J. 2021. Combining Cancer Vaccines with Immunotherapy: Establishing a New Immunological Approach. *International journal of molecular sciences*, *22*(15), 8035.

Lahiri A, Maji A, Potdar PD, et al. 2023. Lung cancer immunotherapy: progress, pitfalls, and promises. *Molecular cancer*, *22*(1), 40.

Lang, Franziska et al. 2022. Identification of neoantigens for individualized therapeutic cancer vaccines. *Nature reviews. Drug discovery*, *21*(4), 261–282.

Ma, Rui et al. 2023. The emerging field of oncolytic virus-based cancer immunotherapy. *Trends in cancer*, 9(2), 122–139.

Macedo, Nicholas et al. 2020. Clinical landscape of oncolytic virus research in 2020. *Journal for immunotherapy of cancer*, 8(2), e001486.

Madeddu, Clelia et al. 2022. EGFR-Mutated Non-Small Cell Lung Cancer and Resistance to Immunotherapy: Role of the Tumor Microenvironment. *International journal of molecular sciences*, 23(12), 6489.

Mamdani, Hirva et al. 2022. Immunotherapy in Lung Cancer: Current Landscape and Future Directions. *Frontiers in immunology*, *13*, 823618.

Melcher, A., Harrington, K., & Vile, R. 2021. Oncolytic virotherapy as immunotherapy. Science (New York, N.Y.), 374(6573), 1325–1326.

Sankar, K., Nagrath, S., & Ramnath, N. 2021. Immunotherapy for *ALK*-Rearranged Non-Small Cell Lung Cancer: Challenges Inform Promising Approaches. *Cancers*, *13*(6), 1476.

Sebastian, Martin et al. 2019. A phase I/IIa study of the mRNA-based cancer immunotherapy CV9201 in patients with stage IIIB/IV non-small cell lung cancer. *Cancer immunology, immunotherapy*: CII, 68(5), 799–812.

Siegel, Rebecca L et al. 2025. Cancer statistics, 2025. *CA: a cancer journal for clinicians*, 75(1), 10–45.

Voena, Claudia et al. 2015. Efficacy of a Cancer Vaccine against ALK-Rearranged Lung Tumors. Cancer immunology research, 3(12), 1333–1343.

Wu, Z., Sun, W., & Qi, H. 2024. Recent Advancements in mRNA Vaccines: From Target Selection to Delivery Systems. *Vaccines*, 12(8), 873.

Xu, J., Tian, L., Qi, W., Lv, Q., & Wang, T. 2024. Advancements in NSCLC: From Pathophysiological Insights to Targeted Treatments. *American journal of clinical oncology*, *47*(6), 291–303.

Xu, Lihua et al. 2024. Oncolytic vaccinia virus and cancer immunotherapy. *Frontiers in immunology*, 14, 1324744.

Zhang, Ying et al. 2020. Cancer vaccines: Targeting KRAS-driven cancers. *Expert review of vaccines*, *19*(2), 163–173.

Zhao, Yueshui et al. 2022. VEGF/VEGFR-Targeted Therapy and Immunotherapy in Non-small Cell Lung Cancer: Targeting the Tumor Microenvironment. *International journal of biological sciences*, *18*(9), 3845–3858.