A Review on Cancer Vaccines: A New Frontier in Immunotherapy and Precision Oncology

Nilesh Prabhakar Patil[1], Nikita Maruti Patil[2], Paresh Sopan Patil[3], Asst. Prof. Vishal V. Kalal[4]

Students[1,2,3] and Asst. Professor[4]

Jijamata Education Society's College of Pharmacy, Nandurbar, India

Abstract: *Cancer vaccines represent a groundbreaking approach in oncology, aiming to train the immune system to recognize and attack tumor-specific antigens, thereby providing a targeted and potentially long-lasting therapeutic effect. Over the past four decades, extensive research has explored various cancer vaccine strategies, yet their successful clinical translation remains a challenge due to several biological, technical, and logistical barriers. This review delves into the landscape of 360 clinical trials investigating different vaccine modalities, including peptide-based, dendritic cell (DC), RNA, DNA, and viral vector-based vaccines, each with distinct mechanisms, advantages, and limitations. Among these, peptide vaccines have garnered the most attention, comprising 34.2% of trials, particularly for cancers such as melanoma, lung, brain, and breast cancer. While peptide-based vaccines are relatively simple to manufacture and customize, their clinical efficacy is often constrained, necessitating the use of combination therapies to enhance immune response and overcome tumor evasion mechanisms. Similarly, DNA and RNA vaccines have gained momentum with the advent of advanced computational antigen prediction, personalized sequencing, and improved delivery technologies, positioning them as promising candidates for precision oncology. However, the path to clinical success is fraught with hurdles, including immune system suppression by tumors, manufacturing complexities, regulatory challenges, and ethical considerations associated with certain vaccine technologies. Furthermore, despite the theoretical advantages of cancer vaccines, their integration into mainstream oncology is hindered by inconsistent patient responses, the requirement for highly individualized treatment strategies, and the need for robust immune system activation to achieve sustained antitumor effects. This review critically examines these challenges while highlighting recent innovations that have the potential to reshape the field of cancer immunotherapy. As scientific advancements continue to refine antigen selection, vaccine formulation, and delivery methods, cancer vaccines hold the promise of becoming a vital component of multimodal cancer treatment strategies, especially when combined with immune checkpoint inhibitors, chemotherapy, and other emerging therapeutic approaches. By addressing the existing limitations and leveraging cutting-edge technologies, cancer vaccines could ultimately bridge the gap between preclinical potential and clinical efficacy, paving the way for a new era in cancer treatment.*

Keywords: Cancer Immunotherapy, Tumor-Specific Antigens, Peptide and RNA Vaccines, Immune Evasion Mechanisms, Precision Oncology

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