Title: Recent advances in human papillomavirus vaccines and therapeutic strategies: Combating cervical and non-cervical cancers

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Abastact: Human papillomaviruses (HPV) are a major cause of several cancers, particularly cervical cancer, and remain a serious public health challenge, particularly in low-resource countries. In addition to cervical cancer, HPV is linked to vulvar, vaginal, penile, anal, and oropharyngeal cancers, especially in men. The integration of HPV into the human genome plays a key role in cancer development. This review highlights the progress in HPV vaccination and new treatment approaches for non-cervical HPV-related cancers. Current vaccines provide strong protection against cervical cancer, and next-generation vaccines aim to protect against more types of cancer-causing HPV. New immunotherapy strategies, such as DNA-based vaccines and antigen-specific immunotherapy, are being developed to more effectively target HPV-driven cancers. Promising methods, such as CRISPR/Cas9 gene editing, therapeutic vaccines, and immune checkpoint inhibitors, have shown success in early research and clinical trials. Among these, DNA vaccines stand out as cost-effective and scalable solutions for treating HPV-related tumors. This review also explores the biology of HPV-related cancers, global trends, and the latest advances in prevention and treatment. To reduce the burden of HPV-related diseases, a combined approach involving vaccination, early detection, and personalized treatment is essential. Ongoing research on therapeutic vaccines, gene therapies, and immune-based treatments could greatly improve the management of HPV-related cancers, potentially lowering their global impact. Expanding these innovations in clinical practice may significantly reduce the global burden of HPV-related malignancies.

Keywords: Cervical cancer Gene editing Human papillomavirus Immunotherapy Prophylactic vaccines Therapeutic vaccines

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