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DNA vaccines as a new strategy to combat infectious diseases

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Abstract

Advances in vaccine technology have led to the development of gene vaccination, a significant breakthrough in the 21st century. This method delivers specific portions of pathogen DNA or mRNA to induce immunity, eliminating pathogenicity risks associated with traditional vaccines. DNA vaccination involves injecting plasmids containing DNA sequences for protective antigens, inducing immunity against specific infectious agents. Compared to conventional vaccines, DNA vaccines represent a leap forward in technology, offering promising strategies for combating various diseases with improved efficacy and safety profiles. Their scalability, stability, and design flexibility make them particularly promising as vaccines, providing benefits like strong immune responses and simplified manufacturing processes. Despite possible challenges, research is still being done to improve DNA vaccines for general use.

Introduction

Historical vaccines, categorized into various types, such as live attenuated, inactivated vaccines, subunit/recombinant vaccines, face limitations like complex preparation and limited efficacy. Traditional vaccines, effective in inducing immune responses, encounter challenges when dealing with certain diseases. Despite benefits, vaccines carry risks such as potential adverse immune responses. Subunit and recombinant vaccines are safer but face challenges with low immunogenicity.

DNA vaccination, introduced in the early 1990s, has seen a breakthrough with the approval of the Indian ZyCovD vaccine in 2021 for combating SARS-CoV-2. This vaccination method entails injecting a plasmid containing DNA sequences for protective antigens, inducing immunity against specific infectious agents. This method eliminates pathogenicity risks. Initially, DNA vaccines relied solely on plasmid DNA, triggering antigen-specific immune responses. Recent advancements include the use of self-adjuvant nanomaterials to enhance immunogenicity. DNA vaccines prompt antigen presentation primarily through the MHC class I pathway, activating CD8+ cells for robust immune responses. This contrasts with conventional vaccines, which needs endocytosis and intracellular processing, since the pathogen is exogenous. While transfection rates may be low, intramuscularly vaccinated animals show antigen production for up to six months. In essence, DNA vaccines represent a significant leap in vaccination technology, offering a promising strategy for combating various diseases with improved efficacy and safety profiles.

Delivery of DNA vaccine

Naked DNA delivery to cells results in inconsistent gene expression, leading to the development of viral vector-based DNA delivery systems. These vectors exploit viral infectivity and replication for gene expression. Various nucleic acid delivery systems, including viral, mechanical, electrical, and chemical methods, have been successful in overcoming low immunogenicity associated with DNA vaccines. Nanocarriers enhance DNA stability and targeted tissue delivery. Although it is difficult to get DNA vaccines past cellular barriers, innovations in delivery system technology appear encouraging for very effective DNA vaccinations.

Viral vectors in DNA vaccine delivery

Viral vectors have played major role in gene therapy since the 1980s, offering effective means to deliver and express foreign genes. These vectors possess high transfection rate and can enter cells, overcoming endosomal barriers to deliver DNA into the cytosol. Their structured composition and nuclear localization signal proteins enable efficient recognition of nuclear transport proteins for DNA delivery to the nucleus, facilitating gene expression. Adenovirus is a non-enveloped double-stranded DNA virus with various types, including conditionally replicating Ad, replication-defective Ad, and helper-dependent Ad. Recombinant adeno-associated virus (rAAV), a non-enveloped single-stranded DNA virus, has been extensively modified for gene therapy. LVs, unlike most RVs, can infect both dividing and non-dividing cells, making them versatile for gene therapy applications. The maximum cargo size for adenovirus, rAAV, and RV is 37 kb, 14 kb, and 9 kb, respectively.

Non-viral delivery systems for DNA vaccine

Non-viral delivery systems, particularly nanoparticle (NP) based, have emerged as alternative gene delivery methods. NPs encapsulate DNA through electrostatic interaction or chemical bonding, enhancing therapeutic efficacy and overcoming challenges in gene therapy. They can be modified to promote cellular uptake, reduce toxicity, and target specific cell types, making them effective.

Liposomes, lipid bilayer micro-vesicles, are versatile carriers for hydrophilic and hydrophobic compounds, including DNA vaccines. Cationic liposomes form complexes with DNA, enhancing transfection efficiency, albeit with challenges like short half-life and cytotoxicity, addressed through PEGylation and other

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modifications. Polyethyleneimine (PEI), a cationic polymer, efficiently delivers DNA due to its strong electrostatic interaction and "proton sponge" effect. Chitosan, a positively charged biopolymer, offers biocompatibility and sustained release for DNA vaccines, with potential for improved transfection efficiency through modifications and control of parameters. PLGA, a negatively charged copolymer, provides controlled release and protection for DNA vaccines. Exosomes, natural nanocarriers, exhibit low immunogenicity and extended circulation, making them promising for DNA vaccine delivery. Virus-like particles (VLPs), mimicking native viruses, effectively deliver DNA vaccines, enhancing stability and cellular uptake. Microalgae, like Chlamydomonas reinhardtii, offer advantages such as safety, scalability, post-translational modifications, stability, and environmental friendliness for DNA vaccine production. Electroporation disrupts cell membranes to facilitate DNA entry, significantly enhancing transgene expression and overcoming delivery barriers. Other physical delivery systems like gene guns propel nucleic acid-coated carriers towards cells, offering alternative approaches for gene delivery in research and vaccination.

Advantages of DNA vaccines

Gene therapy, especially through DNA vaccines, promises to transform medicine with its stability, high-yield, cost-effectiveness, and ease of manufacturing. These vaccines, when equipped with efficient delivery systems, trigger immune responses effectively. Key considerations for optimal delivery include cost, cell selectivity, and safety. DNA vaccines, incorporating chimeric cytokine genes alongside antigen plasmids, enhance immune responses. Moreover, DNA vaccines induce both humoral and cellular immunity, crucial for combating diseases like cancer and viral infections. Mimicking natural infections, they induce T cell responses efficiently. Despite potential delays, they generate lasting immunity, unaffected by maternal antibodies in young animals.

Disadvantages of DNA vaccines

DNA vaccines pose concerns regarding the integration of genetic material into the host genome, potentially leading to mutations. However, current data suggest integration occurs at low rates compared to spontaneous mutations. Adjuvants and nanocarrier modifications enhance immune responses, while gene therapy faces hurdles such as rapid DNA degradation and poor uptake by target cells. Challenges include optimizing delivery systems and addressing concerns like antibiotic resistance and antigen tolerance. Either viral and non-viral vectors are utilized for DNA vaccine delivery, each with its own limitations. Compared to recombinant protein vaccines, DNA vaccines induce strong cellular but weaker humoral immune responses and may require booster doses.

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Conclusion

DNA vaccines represent a significant leap forward in vaccination technology, offering enhanced efficacy and safety over traditional vaccines. Despite facing challenges like low immunogenicity and genetic integration concerns, DNA vaccines boast robust immune responses and streamlined manufacturing processes. Moreover, DNA vaccines hold immense potential for gene therapy, especially in controlling and prevention of newly emerging and challenging diseases. While obstacles persist, ongoing research and advancements in delivery technologies promise to expand the reach of DNA vaccines, paving the way for their widespread application in disease prevention and management.

References:

Kozak, M. and Hu, J., 2024. DNA Vaccines: Their Formulations, Engineering and Delivery. *Vaccines*, *12*(1), p.71.

Lu, B., Lim, J.M., Yu, B., Song, S., Neeli, P., Sobhani, N., K, P., Bonam, S.R., Kurapati, R., Zheng, J. and Chai, D., 2024. The next-generation DNA vaccine platforms and delivery systems: advances, challenges and prospects. *Frontiers in immunology*, *15*, p.1332939.

Quinn. P. J. , Markey,B. K. Leonard,F. C. Fitzpatrick, E. S. Fanning, S. 2015.Concise review of veterinary microbiology. ISBN: 978-1-118-80270-0

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