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Nanoparticles in vaccine delivery: The tiny transporters

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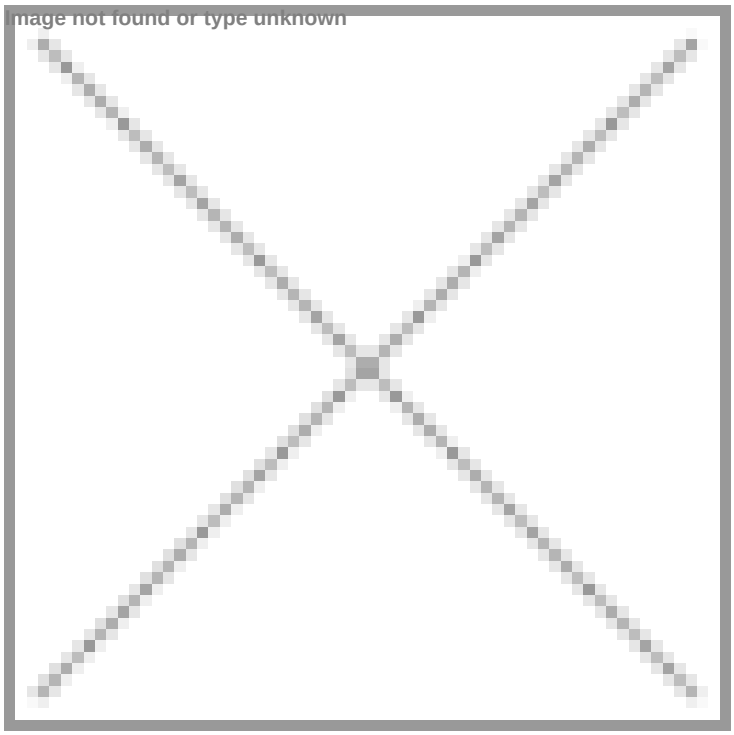

Vaccines represent one of the most significant advancements in public health. While conventional vaccines have been highly successful, global health scenario demands more efficient and safer vaccine platforms. In this context, nanoparticles (NPs) have emerged as transformative players in vaccine delivery, acting as “tiny transporters” that enhance immune responses and ensure targeted delivery.

A wide range of nanoparticles have been designed to address the specific challenges of vaccines namely antigen stability, cellular uptake, immune activation, and manufacturing scalability. As a result, some of the world’s biggest pharmaceutical companies and research institutes are shaping these tiny transporters in vaccines.

For instance, Moderna and BioNTech/Pfizer used the lipid nanoparticle technology to develop the COVID-19 mRNA vaccines, proving that these nanocarriers can deliver fragile genetic material safely and effectively. GlaxoSmithKline (GSK) has used liposome-based platforms in vaccines such as Mosquirix for malaria, while Merck has deployed the virus-like particles (VLPs) for HPV and hepatitis B vaccines.

Moderna and BioNTech are also using nanoparticle-based vaccine technology for several infectious diseases including respiratory syncytial virus (RSV), Zika virus, rabies, and herpes simplex virus.

On the other hand, Altamira Therapeutics is collaborating with Univercells Group to test its SemaPhore nanoparticle platform

designed to deliver RNA safely and effectively. Next generation lipid particles developed by researchers at the Massachusetts Institute of Technology (MIT) have achieved similar antibody responses in animal studies using one-hundredth of the conventional dose that would lower the cost and toxicity.

Hopewell Therapeutics and Foxcroft Therapeutics are evaluating tissue-targeting lipid nanoparticles for cancer vaccines. Scientists at the National Center for Nanoscience and Technology in China have used artificial intelligence (AI) to develop an ionizable lipid based on three-dimensional shape that showed markedly higher mRNA delivery efficiency and prominent anti-tumour effects in preclinical models.

Self-assembling polymer nanoparticles that form at room temperature designed by researchers at the University of Chicago Pritzker School of Molecular Engineering can simplify manufacturing and improve protein vaccine delivery.

Nanoparticles are also being investigated in therapeutic cancer vaccines. For example, nanoparticle formulation of doxorubicin (Doxil by Janssen Pharmaceuticals) is being used for ovarian cancer, Kaposi sarcoma, and multiple myeloma. It allows preferential accumulation in tumour cells allowing enhanced efficacy and reducing cardiotoxicity. mRNA cancer vaccines (e.g. mRNA-4157 by Moderna and Merck & Co.) have also been used in melanoma immunotherapy where lipid nanoparticles are used to deliver tumours specific antigens.

Although large-scale manufacturing, long-term stability, regulatory approval, and cost of nanoparticles pose significant challenges, nanoparticles mark a paradigm shift in vaccine delivery. With continued research and innovation, nanoparticles can play a crucial role in shaping preventive medicine.

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