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Opinion Article

Development and Testing of a Nanoparticle-Based Vaccine against Viral Infections in Pigs

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ABOUT THE STUDY

Viral infections are major threats to the health and productivity of pigs, causing significant economic losses to the swine industry worldwide. Some of the important viral pathogens affecting pigs include Porcine Reproductive and Respiratory Syndrome Virus (PRRSV), Swine Influenza Virus (SIV), Porcine Epidemic Diarrhoea Virus (PEDV), Porcine Circovirus Type 2 (PCV2), African Swine Fever Virus (ASFV), Foot and Mouth Disease Virus (FMDV), etc. These viruses can cause severe morbidity, mortality, reproductive failure, growth retardation, immunosuppression, and zoonotic transmission. Current vaccines against these viruses are either inactivated or modified-live virus vaccines, which have limitations such as variable efficacy, safety concerns, interference with maternal antibodies, lack of cross-protection against diverse strains and subtypes, inability to differentiate infected from vaccinated animals (DIVA), and potential for reversion to virulence or recombination. Therefore, there is a need for novel vaccine strategies that can overcome these challenges and induce broad and long-lasting immunity against porcine viral infections.

Nanoparticles (NPs) are small particles with sizes ranging from 1 to 1000 nm that have unique physicochemical properties and biological interactions. NPs can be generated from various materials such as virus-like particles (VLPs), biodegradable and biocompatible polymers, liposomes, metals, etc. NPs can serve as effective vaccine delivery platforms for antigens derived from viral pathogens. NPs can enhance the stability, solubility, bioavailability, and immunogenicity of antigens by protecting them from degradation, facilitating their uptake by antigen-presenting cells (APCs), and targeting them to specific immune cells or tissues. NPs can also act as adjuvants by activating innate immune receptors such as Toll-Like Receptors (TLRs) and stimulating pro-inflammatory cytokines and chemokine's. NPs can be administered through various routes such as intramuscular, subcutaneous, oral, intranasal, etc., depending on the desired immune response.

Several studies have demonstrated the potential of NP-based vaccines against porcine viral infections in animal models. For example:

Vaccine development has had a major effect on lowering the viral infectious disease load in both people and animals. However, there are still many diseases for which there are no vaccines or which require significant enhancements over current ones. Nanoparticles (NPs)-based technologies have sparked considerable interest in the creation of new vaccine options over inactivated viral or subunit soluble antigens in recent decades. Nano vaccines are made by enclosing vaccine components within the NPs or by decorating the particle surface with virus antigens. Antigens are protected from photolytic degradation by NPs, which increases bioavailability and allows for gradual and prolonged antigen release. When compared to soluble antigen vaccines, all of these characteristics aid in the induction of improved immune reactions. In summary, NPs can enhance antigen adsorption and uptake by APCs; they can also facilitate antigen processing mechanisms; they can induce DC maturation and promote antigen cross-presentation to $CD8^+$ T cells *via* MHC class I; and they can induce the production of differentiate cytokines that regulate humoral and cellular immune responses. APCs easily phagocytize NPs-loaded antigens but not watery antigens. Furthermore, when compared to micro particles (>1000 nm), dendritic cells (DCs), the important actor in bridging innate and adaptive immunity, selectively internalise NPs. When Poly Lactic-co-Glycolic Acid (PLGA) particles encapsulating ovalbumin of sizes 300 nm to 17 m were tested on rat bone-marrow derived dendritic cells, 300 nm particles were taken up more effectively than bigger ones. In comparison to soluble antigens and bigger particles, 300 nm PLGA NPs resulted in increased activation of DCs and stronger antigen specific T cell responses in immunised rodents.

Virus infections have a major effect on the global swine business. The use of available immunisations has undoubtedly aided in the achievement of firm control over some swine viral illnesses

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such as Food and Mouth Disease, Transmissible Gastroenteritis, Classical Swine Fever, and Pseudorabies. Vaccination also contributed to a reduction in clinical symptoms and an increase in production metrics in PCV2-associated illness. However, for many other porcine viruses, further improvements in existing vaccine platforms and the development of novel vaccine delivery systems are required to: (1) induce better mucosal and cell-mediated immunity; (2) protect against emerging and re-emerging strains; (3) broaden immunity (heterologous, cross-genotype, and hetero-subtypic); and (4) distinguish between infected and vaccinated animals. VLPs, biodegradable polymers, and liposomes are NPs-based vaccine delivery platforms with great potential because they (1) protect vaccine antigens from degradation; (2) facilitate antigen uptake and processing by APCs; (3) impart adjuvant potential; (4) can be used in mucosal and other alternate routes of immunisation; and (5) induce effective mucosal and cellular cross-protective (broader) immunity.