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Short Communication

Aging and the Immune System: Immunosenescence and Vaccine Response

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DESCRIPTION

Aging is accompanied by a gradual decline in immune function, a process known as immunosenescence. This phenomenon affects both innate and adaptive immunity, leading to increased susceptibility to infections, chronic inflammation and reduced vaccine efficacy. Understanding the mechanisms underlying immunosenescence and exploring strategies to enhance immune responses in older adults is important for improving health outcomes and extending lifespan [1].

Immunosenescence: Mechanisms and consequences

Immunosenescence results from cumulative biological changes that impair immune cell function, leading to diminished responses to pathogens and vaccines.

Innate immunity decline: Altered macrophage and neutrophil function: Aging reduces phagocytic activity, delaying pathogen clearance and increasing infection susceptibility.

Reduced Natural Killer (NK) cell cytotoxicity: NK cells become less effective at targeting infected or malignant cells, weakening immune surveillance [2].

Chronic inflammation (Inflammaging): Age-related systemic inflammation, driven by persistent activation of inflammatory pathways, contributes to tissue damage and immune dysregulation.

Adaptive immunity impairments: Thymic involution and T cell reduction: The shrinking thymus leads to fewer naïve T cells, restricting the ability to combat novel pathogens.

Accumulation of senescent T cells: Aging results in an overrepresentation of memory T cells with reduced functionality, limiting immune flexibility [3].

Decline in B cell function: Aging decreases B cell diversity and antibody production, impairing humoral immunity and vaccine effectiveness.

Impact of immunosenescence on vaccine response

The aging immune system exhibits reduced responsiveness to vaccines, which has critical implications for public health, particularly for older adults susceptible to infectious diseases such as influenza, pneumococcal pneumonia and COVID-19.

Factors contributing to weakened vaccine efficacy:

Impaired antigen presentation: Reduced efficiency of dendritic cells results in suboptimal activation of T and B cells [4].

Lowered antibody production: Declining B cell responses lead to weaker and shorter-lived antibody-mediated immunity.

Delayed and weakened T cell responses: The diminished function of naïve T cells reduces the overall effectiveness of cellular immunity.

Inflammaging and immune dysregulation: Persistent low-grade inflammation interferes with vaccine-induced immune responses.

Strategies to enhance vaccine responses in older adults

To counteract immunosenescence, various strategies have been developed to optimize vaccine efficacy in aging populations.

Adjuvanted and high-dose vaccines: Adjuvants (e.g., MF59, AS03): These immune-stimulating compounds enhance antigen presentation and immune activation.

High-dose vaccines: Vaccines with increased antigen content (e.g., high-dose influenza vaccine) elicit stronger immune responses [5].

Booster vaccination strategies

Frequent boosters: Additional vaccine doses help reinforce immunity in older adults with waning immune memory.

Heterologous boosting: Using different vaccine formulations may enhance broad immune protection [6,7].

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Lifestyle and nutritional interventions

Regular physical activity: Exercise enhances immune function and improves vaccine responses.

Adequate nutrition: Ensuring sufficient intake of protein, vitamins (e.g., D, C and E) and minerals (e.g., zinc) supports immune resilience [8].

Targeting inflammaging and immune modulation

Senolytics and anti-inflammatory agents: Removing senescent cells or reducing chronic inflammation may restore immune function.

Metformin and rapamycin: These drugs show potential in modulating immune aging and enhancing vaccine responses [9,10].

CONCLUSION

Aging leads to immunosenescence, which diminishes immune responses and reduces vaccine efficacy. However, targeted interventions, including advanced vaccine formulations, booster strategies, lifestyle modifications and immune-modulating therapies, offer potential methods for mitigating these effects. Continued research in immunology and aging will be critical in developing innovative solutions to protect the elderly from infectious diseases and improve overall health outcomes.

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