Immunization 2050: from eradication to precision. Looking ahead to the next 25 years

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Reflecting on the history of public health, immunization stands out as the most cost-effective intervention in medical history. Over the last 50 years, we have witnessed undeniable milestones: the eradication of smallpox and a dramatic reduction in infant mortality from infectious diseases. Vaccines bolstered the global increase in life expectancy and fueled the economic development of nations.[1]

Nowadays, however, the maternal and child scientific community stands at a crossroads. While we occupy the threshold of a biotechnological revolution accelerated by the COVID-19 pandemic, we also face an unprecedented crisis of confidence. The future of immunization will not be defined solely by new molecules, but by our ability to harmonize systems biology with equitable access, shielding the mother-infant dyad.[2]

We have broken definitively with the 20th-century empirical approach – the classic "isolate, inactivate, and inject". In the next 25 years, vaccinology will be, above all, rational and computational. Recent reviews indicate that artificial intelligence is already accelerating antigen identification from years to months, enabling a just-in-time response to emerging threats.[3]

The pandemic served as a "baptism of fire" that validated messenger RNA technology (mRNA). This platform ushered in a new paradigm: we will no longer deliver the pathogen itself, but rather the "instruction manual" for the body to produce the target protein. The profound lesson of this technology was its plasticity and safety. Even with the identification of rare events by global surveillance, the risk-benefit ratio remained robustly in favor of vaccination.[4]

For maternal and child health, the plug-and-play nature of mRNA is transformative. It promises to phase-out the cumbersome production of egg-based influenza vaccines and realize the vision of combined vaccines (Influenza + COVID19 + RSV), thereby simplifying immunization schedules.

But the final frontier of this technology transcends viruses and bacteria. The coming decades will witness the rise of "therapeutic vaccines" in the field of oncology. The proof of concept was further established with the 2024 publication in *The Lancet* of the KEYNOTE-942 study results on melanoma, demonstrating a significant reduction in recurrence,[5] and 2023 *Nature* study, which presented promising data on pancreatic cancer.[6]

RSV vaccines are reshaping prenatal care. Recent data confirm that maternal immunization against RSV dramatically reduces infant hospitalizations for severe respiratory illness during the first six months of life.[7]

Looking ahead to 2050 hinges on the maturation of microneedle patches, whose new biodegradable polymers enable stability outside the cold chain.[8]

We must address vaccine hesitancy as a complex threat. Recent behavioral research indicates that combating misinformation requires structured interventions and an analysis of the communication outcomes of digital strategies.[9]

As outlined in the World Health Organization's Immunization Agenda 2030, trust is the true "social capital" that will sustain the eradication of diseases in the years to come.[10]

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Author's contribution

The author conceptualized the article and declares no conflict of interest.

Data availability

All datasets supporting the results of this study are included in the article.

References

1. Pollard AJ, Bijker EM. A guide to vaccinology: from basic principles to new developments. Nat Rev Immunol. 2021; 21 (2): 83-100.
2. Quincer EM, Cranmer LM, Kamidani S. Prenatal maternal immunization for infant protection: a review of the vaccines recommended, infant immunity and future research directions. Pathogens. 2024 Feb; 13 (3): 200.
3. Rappuoli R, De Gregorio E, Del Giudice G, Phogat S, Pecetta S, Pizza M, *et al*. Vaccinology in the post-COVID-19 era. Proc Natl Acad Sci U S A. 2021; 118 (3): e2020368118.
4. Chaudhary N, Weissman D, Whitehead KA. mRNA vaccines for infectious diseases: principles, delivery, and clinical translation. Nat Rev Drug Discov. 2021; 20: 817-38.
5. Weber JS, Carlino MS, Khattak A, Meniawy T, Ansstas G, Taylor MH, *et al*. Individualized neoantigen therapy mRNA-4157 (V940) plus pembrolizumab versus pembrolizumab monotherapy in advanced melanoma (KEYNOTE-942): a randomised, open-label, phase 2b study. Lancet. 2024; 403 (10427): 632-44.
6. Rojas LA, Sethna Z, Soares KC, Olcese C, Pang N, Patterson E, *et al*. Personalized RNA neoantigen vaccines stimulate T cells in pancreatic cancer. Nature. 2023; 618 (7963): 144-50.
7. Manca T, Baylis F, Munoz FM, Top KA. Prioritise research on vaccines for pregnant and breastfeeding women. Lancet. 2022 Mar; 399 (10328): 890-3
8. Jose J, Khot KB, Shastry P, Gopan G, Bandiwadekar A, Thomas SP, *et al*. Recent advancements in microneedle-based vaccine delivery. Int J Surg. 2022 Nov; 107: 106973.
9. Hoes E, Aitken B, Zhang J, Gackowski T, Wojcieszak M. Prominent misinformation interventions reduce misperceptions but increase scepticism. Nat Hum Behav. 2024; 8: 1545-53.
10. World Health Organization (WHO). Immunization Agenda 2030: A Global Strategy to Leave No One Behind. Geneva: WHO; 2020. [access in 2026 Jan 3]. Available from: https://www.who.int/teams/immunization-vaccines-and-biologicals/strategies/ia2030

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