The Applied Biology & Chemistry Journal
https://www.theabcjournal.com
eISSN: 2582-8789
Editorial

Promising mRNA vaccine technology in combating infectious disease: a boon to futuristic game changer in medical science

Lalit Kumar Gautam [1, 2], Ritesh Kumar Shukla [3] ✉

[1]*Central Sophisticated Instrument Cell (CSIC), Post-Graduate Institute of Medical Education and Research (PGIMER), Chandigarh, India.*
[2]*Department of Anatomy and Cell Biology, University of Iowa, Iowa City, USA.*
[3]*Department of Zoology, St. Xavier's College, Ranchi, Jharkhand, India.*

Published March 31, 2024

In recent years, mRNA vaccines have emerged as a ground-breaking technology in the field of infectious disease prevention and providing a promising means of battling against the diverse range of pathogens [1]. The year 2023 witnessed the applauding cheer in the history of mRNA vaccines, when Nobel Prize for Physiology and Medicine was awarded to Drew Weissman and Katalin Kariko for their successful launching of mRNA vaccine against COVID-19 [2]. This editorial briefly explores the principles, developments in technology, and policy implications related to mRNA vaccines. Recent technological refinements have improved mRNA transport and stability by, resolving early issues including immunogenicity and degradation, supporting the safety and effectiveness of these vaccinations.

In the recent past, regulatory frameworks for effectiveness and safety of mRNA vaccines have been gradually improved, ensuring encouraging outcomes of clinical trials for a variety of infectious disorders, including COVID-19 and influenza as well as newly emerging viral epidemics. In addition, current research initiatives focus on enhancing mRNA delivery techniques and refining vaccine compositions to optimize immunogenicity and duration of protection [3]. However, the revolutionary effect of mRNA vaccines on the management of infectious diseases highlights the necessity of ongoing funding and cooperation in the fields of science, regulation, and public health. Accepting this paradigm change could lead to the dawning of a new age in global health security, one that is marked by quick reactions to new threats and fair access to interventions that can save lives.

The development of mRNA vaccines has been a remarkable journey characterized by decades of scientific inquiry and technological advancement. When mRNA vaccines were first developed in the 1990s, they were seen as a promising method for preventing infectious diseases because of their special capacity to stimulate immune responses by utilizing the body's own cellular machinery [3, 4]. The successful testing of mRNA vaccines against a variety of infectious pathogens, such as influenza, the Zika virus, and rabies, in preclinical models marked a significant turning point in the early 2000s [5]. These investigations demonstrated the viability and adaptability of mRNA-based strategies for inducing protective immunity.

The COVID-19 pandemic highlighted the importance of mRNA vaccines even further. Scientists used already-existing mRNA vaccine platforms to quickly create and distribute vaccines against SARS-CoV-2 in response to the unusually quick development of the novel coronavirus. Large-scale clinical trials revealed the mRNA vaccines from Pfizer-BioNTech and Moderna to be remarkably effective, providing promise for pandemic containment [6-8]. The technology of mRNA vaccines has great potential to treat a variety of infectious disorders. It is a vital weapon in the battle against new threats because of its adaptability, which enables quick adaptation to new infections. In addition, mRNA vaccines have the potential to be more advantageous than conventional vaccination modalities in terms of scalability, development speed, and precise antigen targeting.

mRNA vaccines development is an innovative approach of vaccination because they use the own cellular machinery of the body to create immune responses that defend against infections. This approach is remarkable since this vaccine doesn't enter the nucleus and therefore doesn't alter the DNA of the vaccinated person [9]. Rather the mRNA vaccine after expressing the viral protein, get quickly degraded by host's RNases.

✉
Dr. Ritesh Kumar Shukla
Department of Zoology,
St. Xavier's College, Ranchi,
Jharkhand, India.
E-mail: riteshshukla@sxcran.org

Citation: Gautam LK, Shukla RK (2024). Promising mRNA vaccine technology in combating infectious disease: a boon to futuristic game changer in medical science. *T Appl Biol Chem J*; 5(1):1-3. https://doi.org/10.52679/tabcj.2024.0001

The ability of mRNA vaccines to be developed and produced quickly is one of its main advantages. In contrast to conventional vaccinations, which frequently necessitate drawn-out procedures like viral propagation or protein purification, mRNA vaccines may be created and produced in a matter of weeks, providing unmatched flexibility in reaction to new threats. Furthermore, mRNA vaccines may provoke strong immune reactions against a variety of pathogens, such as bacteria, viruses, and even cancer cells [3]. Because of their adaptability, vaccine candidates can be quickly modified to combat new strains and variations, reducing the possibility of vaccination evasion.

Despite the unquestionable promise of mRNA vaccines, research efforts have been concentrated on issues pertaining to their stability and storage. Conventional mRNA formulations required strict cold chain conditions for storage and shipping because they were prone to breakdown at room temperature [10]. Recent years have seen a number of technological advancements that have made major progress towards improvising the stability of mRNA vaccines [11]. To enhance vaccine durability even more and make international distribution easier, alternative delivery techniques including freeze-drying or lyophilization are being devised.

Another area of focus in mRNA vaccine development is the optimization of immune responses to extend the period of protection. Adjuvants and immune modulators can be added to mRNA formulations to increase the strength and duration of vaccine-induced immunity [12]. Moreover, the utilization of mRNA as a delivery system for booster shots presents the possibility of quick and focused immunological memory reinforcement. These vaccines may be quickly rebuilt to target novel variants of concern, in contrast to classical immunizations that might need considerable re-engineering to match antigenic alterations [13]. This approach was implicated to develop vaccines against emergent COVID-19 variants like Delta and Omicron during the recent pandemic [14].

The safety and effectiveness of mRNA vaccines have been assessed through pivotal clinical trials, which has resulted in the FDA approving platforms that have been updated, like Pfizer-BioNTech and Moderna's COVID-19 platform. mRNA vaccines have demonstrated efficacy in responding to pandemics, and current clinical trials indicate that they may also be able to prevent a variety of viral illnesses, including as influenza, Zika, and respiratory syncytial virus (RSV) [4]. The vaccine research and authorization process adhere to the directions set up by regulatory bodies including the World Health Organization (WHO), the European Medicines Agency (EMA), and the U.S. Food and Drug Administration (FDA). The regulatory framework for mRNA vaccines assures preclinical testing, clinical trial methods, manufacturing standards, and checklist the post-approval monitoring criteria. As evidenced during COVID-19 pandemic, the emergency use authorization (EUA) was put in place by theses authorities to speed access to potentially life-saving vaccines while upholding strict safety standards.

Improving vaccination safety and efficacy requires optimizing mRNA delivery mechanisms. The developments in lipid nanoparticle (LNP) formulations, has allowed effective mRNA encapsulation and intracellular administration, which helped in overcoming the hurdles of immunogenicity and vaccine instability [15]. Strategic alterations to mRNA sequences also increase the efficacy of vaccine action by reducing unwanted immune reactions and increasing translation efficiency. Adjuvant integration, dose escalation trials, and antigen optimization are a few of the strategies used to improve vaccine safety and efficacy [12]. In order to ensure that mRNA vaccines are widely accepted and adopted, these efforts seek to minimize unpleasant reactions while eliciting strong and long-lasting immune responses.

Beyond the prevention of infectious diseases, mRNA technology has numerous therapeutic uses in cancer immunotherapy, regenerative medicine, and genetic abnormalities, to name just a few [14]. When assessing the safety, effectiveness, and viability of mRNA-based therapies in a range of patient populations, clinical studies are essential. The mRNA vaccines are being investigated as a potential tactic in cancer immunotherapy to elicit anti-tumor immune responses [16].

mRNA therapies also exhibit potential to treat genetic diseases by restoring protein expression through the use of functional mRNA molecules. This therapeutic advancement gave hope to people with unmet medical requirements since clinical studies for mRNA-based therapies of uncommon diseases, including Duchenne muscular dystrophy and cystic fibrosis, are currently underway [16]. Research is currently focused on optimizing mRNA delivery and modification procedures in order to maximize therapeutic efficacy and reduce off-target consequences. Improved encapsulation of the lipid nanoparticle and chemical alterations to the mRNA sequence to enhance immunogenicity, translation efficiency, and stability of mRNA, has positioned mRNA as promising therapeutic agent [17].

The conventional vaccine manufacturing entails laborious procedures like raising living organisms, whereas mRNA vaccines are made utilizing cell-free technologies, for quick and accurate synthesis [4, 18]. Because mRNA is synthetic, manufacturing techniques can be scaled up and down, and high-throughput production can be facilitated by automated systems. Moreover, the cell-free production of mRNA vaccines simplifies the regulatory approval processes and biosafety standards. The mRNA vaccines have a great deal of promise for large-scale production, and contemporary facilities are capable of producing millions of doses with efficiency.

In summary, the efficacy and potential of mRNA vaccines to tackle worldwide health issues have been underscored by their recent global use against infectious diseases like COVID-19. Clinical research examining the effectiveness of mRNA vaccines against respiratory syncytial virus (RSV), influenza, and the Zika virus highlight the adaptability and potential of this strategy in preventing averting a range of infectious diseases. Moreover, mRNA vaccines may also be used to treat hereditary problems and other non-communicable diseases like cancer. Continued research advancements in mRNA formulation and development of its novel delivery methods open up new avenues for vaccine production and medical innovation. Advancement of mRNA vaccine research will bring us to the era where infectious disease can be effectively contained and global health equity can be achieved.

References

[1] Freyn AW, Ramos da Silva JR, Rosado VC, et al. (2020). A multi-targeting, nucleoside-modified mRNA influenza virus vaccine provides broad protection in mice. *Mol Ther*; 28:1569–1584. [CrossRef] [PubMed]

[2] The Nobel Assembly at Karolinska Institutet [2023]. The Nobel Prize in Physiology or Medicine 2023. https://www.nobelprize.org/prizes/medicine/2023/press-release/ [accessed on February 10, 2024]

[3] Pardi N, Hogan MJ, Porter FW, Weissman D (2018). mRNA vaccines – a new era in vaccinology. *Nature Rev Drug Discov*; 17:261-279. [CrossRef]

[4] Gote V, Bolla PK, Kommineni N, Butreddy A, et al. (2023). A comprehensive review of mRNA vaccines. *Int J Mol Sci*; 24(3):2700. [CrossRef] [PubMed]

[5] Gu Z, Duan J, Yang N, Yang Y, Zhao X (2020). mRNA vaccines in the prevention and treatment of diseases. *MedComm*; 3(3):e167. [CrossRef] [PubMed]

[6] Jakson LA, Anderson EJ, Rouphael NG, et al. (2020). An mRNA vaccine against SARS-CoV-2 – Preliminary report. *N Engl J Med*; 383:1920-1931. [CrossRef] [PubMed]

[7] Rauch S, Roth N, Schwendt K, et al. (2020). mRNA based SARS-CoV-2 vaccine candidate CVnCoV induces high levels of virus neutralizing antibodies and mediates protection in rodents. *bioRxiv*. [CrossRef] [PubMed]

[8] Saini P (2020). COVID-19 pandemic: potential phase III vaccines in development. *T Appl Biol Chem J*; 1(1):21-33. [CrossRef]

[9] Abbasi J (2020). COVID-19 and mRNA vaccines – First large test for a new approach. *JAMA*; 324(12):1125-1127. [CrossRef]

[10] Uddin MN, Roni MA (2021). Challenges of storage and stability of mRNA-based COVID-19 vaccines. *Vaccines (Basil)*; 9(9):1033. [CrossRef] [PubMed]

[11] Liu T, Tian Y, Zheng A, Cui C (2022). Design strategies for and stability of mRNA-lipid nanoparticle COVID-19 vaccines. *Polymers (Basil)*; 14(19):4195. [CrossRef] [PubMed]

[12] Retnakumar SV, Bonam SR, Hu H, Bayry J (2023). Vaccines and vaccine adjuvants/ immunomodulators for infectious diseases. *Vaccines (Basel)*; 11(2):383. [CrossRef] [PubMed]

[13] Echaide M, de Erauso LC, Bocanegra A, et al. (2023). mRNA vaccines against SARS-CoV-2: Advantages and caveats. *Int J Mol Sci*; 24(6):5944. [CrossRef] [PubMed]

[14] Al Fayez N, Nassar MS, Alshehri AA, et al. (2023). Recent advancement in mRNA vaccine development and applications. *Pharmaceutics*; 15(17):1972. [CrossRef] [PubMed]

[15] Hou X, Zaks T, Langer R, et al. (2021). Lipid nanoparticles for mRNA delivery. *Nat Rev Mater*; 6:1078-1094. [CrossRef]

[16] Qin S, Tang X, Chen Y, Chen K, Fan N, et al. (2022). mRNA-based therapeutics: Powerful and versatile tools to combat diseases. Sig *Transduct Target Ther*; 7(1):166. [CrossRef] [PubMed]

[17] Warminski M, Mamot A, Depaix A, Kowalska J, Jemielity J (2023). Chemical modifications of mRNA ends for therapeutic applications. *Acc Chem Res*; 56(20):2814-2826. [CrossRef]

[18] Maruggi G, Zhang C, Li J, Ulmer JB, Yu D (2019). mRNA as a transformative technology for vaccine development to control infectious diseases. *Mol Ther*; 27(4):757-772. [CrossRef]

Citation: Gautam LK, Shukla RK (2024). Promising mRNA vaccine technology in combating infectious disease: a boon to futuristic game changer in medical science. *T Appl Biol Chem J*; 5(1):1-3. https://doi.org/10.52679/tabcj.2024.0001