Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

Spotlight on Neutralizing Antibodies of Mrna-1273 and BNT162b2 Mrna Vaccines against SARS-Cov 2 Omicron

Ramdas Bhat[1*], Preeti Shanbhag[2]

[1]Assistant professor, Departement of Pharmacology, Srinivas college of Pharmacy, Valachil, Post farangipete, Mangalore, Karnataka, India.*
[2]Pg scholar, Departement of Pharmacology, Srinivas college of Pharmacy, Valachil, Post farangipete, Mangalore, Karnataka, India.

Corresponding Email: [1]Ramdas21@gmail.com*

Received: 29 May 2023 **Accepted:** 14 August 2023 **Published:** 30 September 2023

Abstract: ***The emergence of the Omicron variant of SARS-CoV-2 has raised concerns about the effectiveness of existing COVID-19 vaccines. Initially, spike protein was identified as a key target for vaccine development, leading to the creation of mRNA vaccines like Pfizer-BioNTech and Moderna, which have shown high efficacy. The immune response to SARS-CoV-2 involves both innate and adaptive systems, with B and T lymphocytes playing crucial roles. Protein-based subunit vaccines have also demonstrated effectiveness. However, the ongoing evolution of the virus necessitates the exploration of strategies such as developing new vaccines, updating existing ones, and administering booster shots. Ongoing research and adaptation of vaccination strategies are essential in the battle against COVID-19.***

Keywords: ***SARS-Cov-2 Infection, SARS-Cov-2 Omicron Variant, Mrna Encoding Viral Antigens, BNT162b2 Mrna Vaccine.***

1. INTRODUCTION

Concerns have been expressed concerning the SARS-CoV-2 Omicron variant's potential to circumvent the immunity offered by earlier vaccines as a result of its appearance. Understanding how these vaccines stimulate the production of neutralising antibodies and their potential efficacy against Omicron is crucial as researchers continue to investigate the effectiveness of neutralising antibodies produced by mRNA-1273 and BNT162b2 mRNA vaccines against this variant. There have been fatalities and substantial economic hardship as a result of the COVID-19 epidemic.[1] A key preventative intervention against the virus that caused the pandemic, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), is

Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

vaccination. In these trying times, COVID-19 vaccines have shown to be extremely beneficial in lowering the risk of serious disease, hospitalisation, and death. It is crucial to remember that COVID-19 vaccinations may not offer full protection and are not infallible. These vaccines' creation is a significant scientific accomplishment that has prevented deaths and lessened the pandemic's effects. SARS-CoV-2 is a member of the coronavirus family, and in the previous 20 years, there have been outbreaks of extremely virulent beta-coronaviruses including SARS-CoV-1 and MERS-CoV.[2] The disastrous COVID-19 pandemic was caused by the appearance of SARS-CoV-2 in late 2019. Natural infection or vaccination have both been used to start the process of establishing worldwide herd immunity. Regarding the type and persistence of immunity following natural infection, concerns still exist. With the introduction of COVID-19 vaccines, including mRNA and viral vector vaccines, optimism of a return to normal has increased. Despite this, the distribution of vaccines globally is still uneven, leaving a sizable percentage of the population unprotected.[3] The discovery of SARS-CoV-2 mutations, which can decrease the efficacy of vaccinations and natural immunity, has made the fight against COVID-19 even more challenging. The Spike protein, a vital part of the virus, is frequently mutated in these versions. Adapting vaccination tactics requires a thorough understanding of the mechanisms underlying variation development and their effects on vaccines and immunity. In this thorough analysis, we study the innate and vaccine-induced immune responses to SARS-CoV-2, evaluate the impact of new variations on vaccination effectiveness, and discuss potential future therapeutic approaches.[4] By looking more deeply into these intricate facets of the pandemic, we add to the body of information needed to direct the ongoing COVID-19 struggle. Concerns have now been raised about the SARS-CoV-2 Omicron variant's capacity to circumvent the immunity offered by earlier vaccinations. The efficiency of the mRNA-1273 and BNT162b2 mRNA vaccines' neutralising antibodies against this variation is a topic of active research. Neutralising antibodies can protect against infection and are essential in blocking viral entrance into cells.[5] This study examines the possible efficacy of mRNA vaccines against the highly contagious Omicron variant by examining how mRNA-1273 and BNT162b2 induce the formation of neutralising antibodies. By examining the latest research, we can gain valuable insights into the potential of these vaccines to combat this new variant and inform future strategies in the ongoing battle against COVID-19.[6]

Vaccine Development Approaches: During the early stages of COVID-19 vaccine development, researchers quickly recognized the coronavirus spike protein (S protein) as a formidable candidate [7]. This choice was determined by its outstanding ability to induce a strong immune response from B and T lymphocytes, thus providing a promising approach to combat the virus. However, the search for an effective vaccine does not stop with the spike protein; Other viral proteins, especially the nucleocapsid (N) protein, have emerged as valuable contenders in the race to enhance immunity [8]. The appeal of the N protein lies in its ability to induce a robust T cell response, along with its genetic stability and reduced recombination sensitivity compared with the spike protein. To bring this scientific knowledge to life, various vaccine platforms were forged in 2020 [9]. These platforms include non-replicating viral vectors, nucleic acid technology, live attenuated viruses, and inactivated viruses. Notably, proven viral vector vaccine technologies, similar to those used to develop

Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

influenza vaccines, have not been widely adopted in the COVID-19 vaccine arena [10] .Instead, newer and more innovative techniques have emerged as pioneers, better suited to the unique pathogenesis of COVID-19.An attractive aspect of S protein vaccines is the use of the 2P mutation, which is strategically designed to stabilize the protein's pre-aggregation structure.This stabilization is necessary because it prevents spontaneous conversion of pre-aggregated spike proteins to their elongated form, thereby preserving the antigenic integrity of the protein (11).Therefore, the immune system is capable of recognizing and mounting a strong adaptive immune response against the virus before the spike protein has a chance to interact with host cells (12). In the evolving landscape of COVID-19 vaccine development, our review article aims to comprehensively explore the multifaceted strategies used to exploit the potential of SARS-CoV-2 proteins (13).We further investigated the complex interaction between spike protein and nucleocapsid protein, elucidating their distinct immunogenic roles. Additionally, we dissect the different vaccine platforms that emerged in 2020, assessing their strengths and limitations [14].As we navigate the complex terrain of COVID-19 vaccine development, our goal is to provide a comprehensive understanding of the innovative approaches shaping the fight against the pandemic. Through this exploration, we contribute to the broader scientific discourse and highlight promising strategies that hold the key to effective COVID-19 vaccination.

Immune Response Generated by Sars-Cov-2 Infection: Both the innate and adaptive immune systems are involved in the immunological response to SARS-CoV-2 infection [15].The innate immune system acts as the body's first line of defence against viruses, whereas the adaptive immune system uses B and T cells to manufacture targeted antibodies[16]. The innate immune response is suppressed by SARS-CoV-2, which makes it challenging for the body to combat infection. Eventually, though, the virus will be able to be eliminated by the adaptive immune system [17]. Antibodies that particularly target the virus' Spike protein, which is necessary for cell entry, are produced by B lymphocytes. T cells can directly destroy infected cells and aid in the activation of B cells. People with SARS-CoV-2 infection have more specific T cells, according to studies [18]. Although research into the intricate immune response of B and T cells to SARS-CoV-2 is ongoing, it is obvious that both play crucial roles in the battle against the virus [19].This knowledge aids in the creation of COVID-19 vaccines and therapies that are more successful.

Mrna Vaccines: A novel vaccination called the mRNA vaccine was created to provide defence against COVID-19[19]. mRNA vaccines are secure and efficient, and they could completely alter how we shield against infectious diseases. By injecting a small amount of RNA into the body, mRNA vaccines operate. This RNA contains the protein codes for the viral attachment proteins. Protein production starts when cells absorb RNA. The immune system of the body then develops antibodies against the protein after identifying it as alien. By doing this, the body is defended against viral infections. mRNA vaccines are quite secure. The majority of adverse effects are minor and go away in a couple of days. These side effects may include pain, redness, and swelling at the injection site, as well as fatigue, headache, muscle pain, chills, fever, and nausea. Serious allergic reactions are rare. mRNA vaccines have the potential to revolutionize the way we prevent infectious diseases. They are safe,

Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

effective and easy to manufacture. This makes them ideal for use in developing countries and during pandemics [20]

Mechanism of Action [21]: Vaccines work to activate the adaptive immune response by encouraging the body to create pathogen-specific antibodies. These antibodies specifically target antigens made by or found on infections. Recombinant viral vectors encoding the antigen as a safe viral carrier with the antigen transgene or attenuated or inactivated forms of the virus can be used to induce this reaction. mRNA vaccines, on the other hand, employ artificial, fragmented RNA that momentarily encodes viral antigens. By phagocytosis, dendritic cells take these mRNA extracts up. Dendritic cells use their own machinery (ribosomes) to read mRNA and make the viral antigens encoded by the mRNA.The mRNA fragments will decay a couple days after being ingested by the body. Vaccine mRNA droplets are taken up by dendritic cells significantly more quickly than by non-immune cells. These cells have the ability to absorb vaccination mRNA, synthesise, and surface-display antigen. The genomic DNA kept in the cell nucleus is unaffected by the mRNA fragments' translation in the cytoplasm. The adaptive immune system behaves normally when the host cell produces viral antigen. Antigen-degrading enzymes are known as proteasomes. The last antigen binds to MHC molecules, allowing them to go to the cell membrane where they can activate dendritic cells (Figure 1).After activation, dendritic cells move to lymph nodes and present the antigen to T and B lymphocytes, which causes the antigen to be recognised by antibodies.

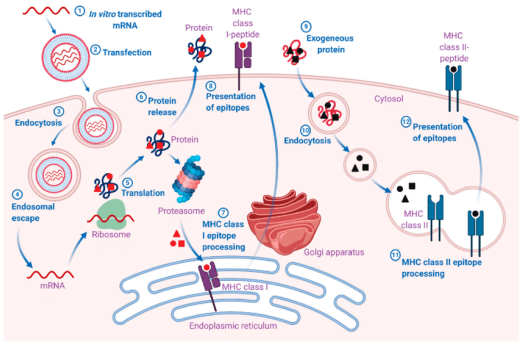

Figure 1. The mechanism of action by which immune response is generated by mRNA vaccine, adenoviral vaccines, and inactivated vaccines.

mRNA vaccines from companies like Pfizer-BioNTech and Moderna have emerged as cutting-edge weapons in the war against COVID-19. The SARS-CoV-2 viral spike protein, which is responsible for cell attachment, is encoded by synthetic mRNA in these vaccines. The mRNA is delivered into the body where it is transformed into viral proteins while being shielded by lipid nanoparticles. Immune cells and antibodies are produced after the immune system recognises this protein. The Pfizer-BioNTech and Moderna mRNA vaccines have demonstrated in clinical trials that they are very efficient in avoiding COVID-19 symptoms, hospitalisation, and death [23].The Pfizer vaccine has been shown to be 95 percent effective at preventing illness, and 87. five percent effective at preventing serious disease. The

Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

Moderna vaccine is 100% effective against severe symptoms and 94.5% effective against the disease. The minor and transient adverse effects of these vaccinations, which include injection site discomfort, weariness, headaches, muscle pain, chills, fever, and nausea, are often well tolerated. Although Pfizer's vaccine must be kept at extremely low temperatures during storage, research is being done to create formulations that can be kept at warmer temperatures [24]. Additionally, mRNA vaccinations trigger responses from both B and T cells. T cells contribute to the immune response, though its level of vigour can vary, while B cells create antibodies that target viruses. Importantly, these vaccines have shown antibodies that react similarly to infections acquired naturally, and studies are being conducted to determine their long-term efficacy [25].

Subunit Vaccines: Protein-based subunit vaccines work by triggering an immune response with the help of inert protein fragments that resemble the COVID-19 S protein [26].These vaccinations may be generated in enormous quantities and are secure and reliable. They are also successful at triggering cellular and humoral immune responses [27].The protein-based subunit COVID-19 vaccines NVX-CoV2373, EpiVacCorona, MVC COVID-19 vaccine, and Zifivax are some of the more promising ones [28].Different adjuvants are used in these vaccinations to boost immune response. A greater immune response is induced by the body when adjuvants are added to vaccines. In COVID-19 subunit vaccines, alum, beta-defensin, MF59, matrix-M, and CpG are the adjuvants that are most frequently employed [29]. Clinical studies demonstrate the safety and efficacy of protein-based subunit vaccinations in the prevention of COVID-19.Protein-based subunit vaccines are created by isolating and purifying the spike protein from SARS-CoV-2. The vaccine is then made using the spike protein [30]. The vaccination can be administered in a single dosage or in several doses. Mild and self-limiting adverse effects are most frequently seen with protein-based subunit vaccinations. The injection site may experience discomfort, redness, and swelling as a result of these adverse effects. Protein-based subunit vaccinations offer a secure and reliable way to stop COVID 19 [31].

Future Concerns and Considerations: As the SARS-CoV-2 virus continues to evolve, the emergence of new variants poses significant challenges in controlling the COVID-19 pandemic. These variants may be more transmissible and, in some cases, resistant to currently available vaccines and treatments. To address this problem, several strategies are being explored [32].One approach is to develop new vaccines that target multiple epitopes on the virus's spike protein, making them resistant to higher mutation [33].Additionally, future vaccines may include other highly immunogenic viral proteins, such as in the form of the nucleocapsid (N) protein, to provide broad protection than. Another strategy is to update existing vaccines to include the spike proteins of emerging variants, either by replacing older variants or by creating multivalent vaccines [34]. There have been reports of breakthrough infections in fully vaccinated people, but these cases were generally mild, that the vaccine remains effective in preventing severe illness and death. However, booster vaccinations may be needed to maintain long-term protection [35]. Some countries have adopted a heterologous vaccine strategy, combining different COVID-19 vaccines, showing positive results in inducing a strong immune response [36]. Additionally, viruses can evolve to use alternative

Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

receptors to enter cells, which adds complexity to vaccine development and evaluation. Understanding these underlying changes in receptors is essential to stopping the virus [37]. To evaluate vaccine effectiveness against variants, developing correlates of protection is important. This immune biomarker will accelerate the evaluation of vaccines against new variants and guide vaccination strategies [34].

2. CONCLUSION

The COVID-19 pandemic has posed a major challenge globally, leading to loss of life and widespread economic disruption. Vaccination has emerged as an important protective measure against the SARS-CoV-2 virus, offering hope in these difficult times. While COVID-19 vaccines have been shown to be highly effective in reducing severe illness, hospitalization and death, they are not without problems. This virus, part of the coronavirus family, continues to evolve, creating variants that could affect the effectiveness of vaccines. As we navigate this complex landscape, it is important to understand immune responses to vaccination and SARS-CoV-2 infection. Efforts to establish global herd immunity through natural infection or vaccination have begun. However, questions remain about the nature and duration of immunity following natural infection. The introduction of many different Covid-19 vaccines, based on many different platforms, is a remarkable scientific achievement. mRNA vaccines, such as Pfizer-BioNTech and Moderna, have proven highly effective, safe, and easy to produce. Viral vector vaccines, such as AstraZeneca and Johnson & Johnson, offer additional options with varying efficacy rates, but offer the advantage of easier storage and distribution. Inactivated vaccines have been shown to be safe and effective, although effectiveness may vary between different formulations. vaccines, which use protein fragments, have shown promise in inducing immune responses. The emergence of SARS-CoV-2 variants adds complexity to vaccine development and evaluation. Strategies such as updating vaccines to target emerging variants, implementing heterologous vaccine approaches, and developing correlative protections are essential to stay ahead of viral evolution withdraw. In this comprehensive review, we explored the complex immune responses induced by SARS-CoV-2 infection and vaccination, assessed the influence of emerging variants on vaccine efficacy, and consider future treatment strategies. Our goal is to contribute to the collective knowledge needed to successfully fight the ongoing war against COVID-19.As the pandemic continues, continued research and development of new vaccines and strategies is critical.This collaborative effort will ensure that we are better prepared to meet current and future challenges, ultimately ending this devastating global crisis.

3. REFERENCES

1. Baden LR, El Sahly HM, Essink B, Kotloff K, Frey S, Novak R, et al. Efficacy and safety of the mRNA-1273 SARS-CoV-2 vaccine. New England journal of medicine. 2021; 384(5):403-16.
2. Polack FP, Thomas SJ, Kitchin N, Absalon J, Gurtman A, Lockhart S, et al. Safety and efficacy of the BNT162b2 mRNA Covid-19 vaccine. New England journal of medicine. 2020 ;383(27):2603-15.

Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

3. Planas D, Bruel T, Grzelak L, Guivel-Benhassine F, Staropoli I, Porrot F, et al. Sensitivity of infectious SARS-CoV-2 B. 1.1. 7 and B. 1.351 variants to neutralizing antibodies. Nature medicine. 2021 ;27(5):917-24.
4. Cele S, Jackson L, Khoury DS, Khan K, Moyo-Gwete T, Tegally H, et al. Omicron extensively but incompletely escapes Pfizer BNT162b2 neutralization. Nature. 2022 ;602(7898):654-6.
5. Wang Z, Schmidt F, Weisblum Y, Muecksch F, Barnes CO, Finkin S, et al. mRNA vaccine-elicited antibodies to SARS-CoV-2 and circulating variants. Nature. 2021;592(7855):616-22.
6. Carabelli AM, Peacock TP, Thorne LG, Harvey WT, Hughes J, Barclay WS, et al. SARS-CoV-2 variant biology: immune escape, transmission and fitness. Nature Reviews Microbiology. 2023; 21(3):162-77.
7. Awadasseid A, Wu Y, Tanaka Y, Zhang W. Current advances in the development of SARS-CoV-2 vaccines. International journal of biological sciences. 2021;17(1):8.
8. ElBagoury M, Tolba MM, Nasser HA, Jabbar A, Elagouz AM, Aktham Y, et al. The find of COVID-19 vaccine: Challenges and opportunities. Journal of infection and public health. 2021;14(3):389-416.
9. Stander J, Mbewana S, Meyers AE. Plant-derived human vaccines: Recent developments. BioDrugs. 2022; 36(5):573-89.
10. Chavda VP, Soni S, Vora LK, Soni S, Khadela A, Ajabiya J. mRNA-based vaccines and therapeutics for COVID-19 and future pandemics. Vaccines. 2022 Dec;10(12):2150.
11. Holz E, Darwish M, Tesar DB, Shatz-Binder W. A Review of Protein-and Peptide-Based Chemical Conjugates: Past, Present, and Future. Pharmaceutics. 2023;15(2):600.
12. Gadanec LK, McSweeney KR, Qaradakhi T, Ali B, Zulli A, Apostolopoulos V. Can SARS-CoV-2 virus use multiple receptors to enter host cells? International journal of molecular sciences. 2021; 22(3):992.
13. Oran DP, Topol EJ. Prevalence of asymptomatic SARS-CoV-2 infection: a narrative review. Annals of internal medicine. 2020; 173(5):362-7.
14. Brady C, Tipton T, Longet S, Carroll MW. Pre-clinical models to define correlates of protection for SARS-CoV-2. Frontiers in Immunology. 2023; 14:1166664.
15. Balkhi MY. Mechanistic understanding of innate and adaptive immune responses in SARS-CoV-2 infection. Molecular Immunology. 2021; 135:268-75.
16. Catanzaro M, Fagiani F, Racchi M, Corsini E, Govoni S, Lanni C. Immune response in COVID-19: addressing a pharmacological challenge by targeting pathways triggered by SARS-CoV-2. Signal transduction and targeted therapy. 2020;5(1):84.
17. Pang NY, Pang AS, Chow VT, Wang DY. Understanding neutralising antibodies against SARS-CoV-2 and their implications in clinical practice. Military medical research. 2021;8(1):1-7.
18. Bertoletti A, Le Bert N, Qui M, Tan AT. SARS-CoV-2-specific T cells in infection and vaccination. Cellular & molecular immunology. 2021; 18(10):2307-12.
19. Hannan MA, Rahman MA, Rahman MS, Sohag AA, Dash R, Hossain KS, et al. Intermittent fasting, a possible priming tool for host defense against SARS-CoV-2 infection: Crosstalk among calorie restriction, autophagy and immune response. Immunology letters. 2020 ;226:38-45.

Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

20. Abbasi J. COVID-19 and mRNA vaccines—first large test for a new approach. Jama. 2020;324(12):1125-7.
21. Mistry P, Barmania F, Mellet J, Peta K, Strydom A, Viljoen IM, et al. SARS-CoV-2 variants, vaccines, and host immunity. Frontiers in immunology. 2022 ;12:809244.
22. Wadhwa A, Aljabbari A, Lokras A, Foged C, Thakur A. Opportunities and challenges in the delivery of mRNA-based vaccines. Pharmaceutics. 2020;12(2):102.
23. Pilishvili T, Fleming-Dutra KE, Farrar JL, Gierke R, Mohr NM, Talan DA, et al. Interim estimates of vaccine effectiveness of Pfizer-BioNTech and Moderna COVID-19 vaccines among health care personnel—33 US sites, January–March 2021. Morbidity and Mortality Weekly Report. 2021;70(20):753.
24. Fiolet T, Kherabi Y, MacDonald CJ, Ghosn J, Peiffer-Smadja N. Comparing COVID-19 vaccines for their characteristics, efficacy and effectiveness against SARS-CoV-2 and variants of concern: a narrative review. Clinical Microbiology and Infection. 2022;28(2):202-21.
25. Hellerstein M. What are the roles of antibodies versus a durable, high quality T-cell response in protective immunity against SARS-CoV-2?. Vaccine: X. 2020;6:100076.
26. Mascellino MT, Di Timoteo F, De Angelis M, Oliva A. Overview of the main anti-SARS-CoV-2 vaccines: mechanism of action, efficacy and safety. Infection and drug resistance. 2021:3459-76.
27. van Riel D, de Wit E. Next-generation vaccine platforms for COVID-19. Nature materials. 2020 ;19(8):810-2.
28. Marchese AM, Beyhaghi H, Orenstein WA. With established safe and effective use, protein vaccines offer another choice against COVID-19. Vaccine. 2022 ; 40(46): 6567–6569.
29. Mekonnen D, Mengist HM, Jin T. SARS-CoV-2 subunit vaccine adjuvants and their signaling pathways. Expert Review of Vaccines. 2022 ;21(1):69-81.
30. Wu Y, Huang X, Yuan L, Wang S, Zhang Y, Xiong H,et al. A recombinant spike protein subunit vaccine confers protective immunity against SARS-CoV-2 infection and transmission in hamsters. Science translational medicine. 2021;13(606):eabg1143.
31. Corbett KS, Edwards DK, Leist SR, Abiona OM, Boyoglu-Barnum S, Gillespie RA, et al. SARS-CoV-2 mRNA vaccine design enabled by prototype pathogen preparedness. Nature. 2020;586(7830):567-71.
32. Khandia R, Singhal S, Alqahtani T, Kamal MA, Nahed A, Nainu F, et al. Emergence of SARS-CoV-2 Omicron (B. 1.1. 529) variant, salient features, high global health concerns and strategies to counter it amid ongoing COVID-19 pandemic. Environmental research. 2022 ;209:112816.
33. Hastie KM, Li H, Bedinger D, Schendel SL, Dennison SM, Li K, et al. Defining variant-resistant epitopes targeted by SARS-CoV-2 antibodies: A global consortium study. Science. 2021;374(6566):472-8.
34. Chi WY, Li YD, Huang HC, Chan TE, Chow SY, Su JH, et al. COVID-19 vaccine update: Vaccine effectiveness, SARS-CoV-2 variants, boosters, adverse effects, and immune correlates of protection. Journal of biomedical science. 2022;29(1):1-27.

Journal of Community Pharmacy Practice
ISSN: 2799-1199
Vol: 03, No. 05, Aug – Sep 2023
http://journal.hmjournals.com/index.php/JCPP
DOI: https://doi.org/10.55529/jcpp.35.38.46

35. Rishi S, Gulzar B, Farhana A, Dewani S, Ashraf A. Omicron breakthrough infections in fully vaccinated individuals during omicron wave in Kashmir, India and current regional scenario. Journal of Positive School Psychology. 2022;6(3):5132-6.
36. Fang E, Liu X, Li M, Zhang Z, Song L, Zhu B, et al. Advances in COVID-19 mRNA vaccine development. Signal transduction and targeted therapy. 2022;7(1):94.
37. Kruse RL. Therapeutic strategies in an outbreak scenario to treat the novel coronavirus originating in Wuhan, China. F1000Research. 2020;9: 7.