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Analysis of Improvements to the Chickenpox Vaccine and the Development of New Vaccines

Ping Feng, Danni Gu, Yanfei Wang
People's Pharmacy Chain Co., Ltd., Changsha, 41000, Hunan, China
Corresponding author: 1931515591@qq.com
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Abstract The improvement of the chickenpox vaccine and the development of new vaccines are of significant importance in preventing and controlling the spread of chickenpox. Chickenpox is a highly contagious disease, especially among children, and it can pose risks of complications and hospitalization. Enhancing the chickenpox vaccine can increase its protective efficacy and reduce the occurrence of adverse reactions. The development of new vaccines can meet the needs of specific populations and provide preventive measures on a global scale. Improvements in the chickenpox vaccine can enhance its protective efficacy and the duration of immunity. By refining the vaccine's formulation and production processes, the duration of immune protection can be prolonged, reducing the frequency of vaccination, and improving the vaccine's practicality and convenience. Furthermore, vaccine improvements can reduce the incidence of adverse reactions and side effects, increasing vaccine safety and acceptance. The development of new vaccines is crucial for addressing specific populations. Currently available chickenpox vaccines are generally suitable for children and adults, but they may not be suitable or effective for pregnant women, immunocompromised patients, and individuals with weakened immunity. Therefore, the development of new vaccines tailored to specific populations is necessary. This review briefly outlines the improvement of the chickenpox vaccine and the development of new vaccines, aiming to provide the public with a better understanding of chickenpox vaccines. This, in turn, can lead to improved prevention and control of chickenpox transmission, reducing the impact of chickenpox on individuals and society.
Keywords Improvement of Chickenpox vaccine; International cooperation and collaborative efforts; Safety assessment and monitoring; Development of new vaccines; Promotion and popularization of vaccine immunization

Chickenpox, also known as herpes zoster, is an acute infectious disease caused by the varicella-zoster virus. It is primarily transmitted through airborne droplets, with the virus entering the bodies of others through the respiratory system when an infected individual coughs, sneezes, or has close contact with others. Additionally, the varicella-zoster virus can also spread through direct contact with the skin lesions of the patient. Once infected with chickenpox, the body generates specific immune responses, but this does not imply complete immunity because the virus can lie dormant in nerve tissues, leading to the development of herpes zoster in the future. Chickenpox is a widely contagious disease, especially common among children. Patients typically experience fever, itchy rashes, and varying degrees of discomfort. While most chickenpox patients recover on their own, there is a risk of severe complications, such as skin infections, pneumonia, encephalitis, and herpes zoster. Furthermore, chickenpox can have a more severe impact on specific populations, such as pregnant women, individuals with compromised immune systems, and newborns.

The introduction and widespread vaccination of the chickenpox vaccine can significantly reduce the incidence of chickenpox and the risk of complications. The vaccine works by activating the immune system in the human body, causing it to produce specific antibodies to combat the varicella-zoster virus. These antibodies can identify and neutralize the virus, thereby preventing further virus replication and infection of other cells. Through vaccination with the chickenpox vaccine, individuals can acquire long-term immune protection, reducing the occurrence and transmission of chickenpox. The importance of the chickenpox vaccine is not only evident at the individual level but also holds significant implications for public health. Widespread chickenpox vaccination can achieve herd immunity, meaning that by vaccinating a large portion of the population, most people gain immunity, reducing the speed and scope of virus transmission. This, in turn, protects those who cannot be vaccinated, such as individuals with compromised immune systems and infants who are too young to receive the vaccine. Additionally, the widespread vaccination of the chickenpox vaccine can alleviate the burden on the healthcare system, lowering hospitalization rates and medical costs associated with chickenpox.

The introduction and improvement of the chickenpox vaccine play a crucial role in addressing the issue of chickenpox. Through widespread vaccine administration, it is possible to reduce the incidence of chickenpox and the risk of complications, protecting individuals from the harm caused by chickenpox and achieving herd immunity, thereby reducing the spread and speed of virus transmission. Therefore, further research and improvement of the chickenpox vaccine are important tasks in current medical science to address the chickenpox problem and enhance public health. This review, by briefly introducing the improvement of the chickenpox vaccine and the development of new vaccines, aims to better address the vaccination needs of diverse populations and enhance vaccination strategies and promotion efforts. It can also provide more choices and enhance comprehensive prevention and control capabilities in chickenpox prevention and control, meeting the diverse needs of various populations, which is of significant importance in enhancing comprehensive prevention and control capabilities.

1 Current Status of Chickenpox Vaccination

1.1 Immunogenicity and vaccination strategies for Chickenpox vaccines

Existing chickenpox vaccines have demonstrated good immunogenicity in preventing chickenpox infection through clinical trials and widespread application. Chickenpox vaccines work by activating the body's immune system, inducing the production of specific antibodies to combat the varicella-zoster virus. These antibodies can swiftly recognize and neutralize the virus, preventing further virus replication and the infection of other cells. Individuals who receive the chickenpox vaccine can obtain long-term immune protection. Research data indicates that after vaccination with the chickenpox vaccine, over 95% of individuals can achieve immunity when exposed to the varicella-zoster virus. This means that even when vaccinated individuals have close contact with chickenpox patients, the likelihood of chickenpox infection is low. Even if a few vaccinated individuals contract chickenpox, the course of the disease is much milder, and symptoms are more relieved (Gershon et al., 2021; Liu , 2023).

The immunogenicity of the chickenpox vaccine also contributes to the prevention of severe complications related to chickenpox. Chickenpox infection can lead to complications such as skin infections, pneumonia, encephalitis, and herpes zoster. Vaccination with the chickenpox vaccine can mitigate the risk of infection and decrease the incidence of complications. Research indicates that after chickenpox vaccination, hospitalization rates and medical expenses related to chickenpox are significantly reduced, providing significant benefits to individuals and society. For the vaccination strategy of the chickenpox vaccine, it typically involves a two-dose regimen. The first vaccine dose is usually administered at 12 to 15 months of age, while the second dose is given at 4 to 6 years old. This vaccination strategy can provide better immunogenicity and enhance individual immune protection. Administering the second dose of the vaccine can further reinforce and prolong the immune effect, ensuring long-lasting immunity for individuals. For children and adults who have not received the chickenpox vaccine, vaccination is still an option to obtain immunity. The optimal time for chickenpox vaccination is before an individual becomes infected with the varicella-zoster virus to fully utilize the vaccine's immunogenicity. In specific situations, such as when an individual's immune system is compromised or there are specific medical indications, healthcare professionals may recommend alternative vaccination strategies, such as early vaccination or booster doses (Figure 1) (Duan et al., 2022).

Although the chickenpox vaccine is highly effective in providing immune protection, it is not suitable for everyone. For example, pregnant women, individuals with compromised immune systems, and those allergic to vaccine components should consult a doctor and make a vaccination decision based on the doctor's advice. Doctors will consider factors such as the patient's age, health status, and immunization history to develop the most appropriate vaccination plan, ensuring safety and effectiveness. Receiving the chickenpox vaccine does not guarantee complete immunity to chickenpox. A very small number of vaccine recipients may still contract chickenpox after vaccination, but the symptoms are typically milder, and the duration of the illness is shorter. This condition is known as "vaccine-related chickenpox," but the risk of illness is still much lower than in unvaccinated individuals. Furthermore, vaccination with the chickenpox vaccine can reduce the spread of chickenpox, protecting those who have not been vaccinated, especially individuals with weakened immune systems (Wang and Liu, 2021).

Figure 1 Vaccination of Chickenpox Vaccine for eligible children

1.2 Safety and side effects of existing vaccines

Existing chickenpox vaccines are generally safe and effective for most individuals. Side effects are usually mild and short-lived, such as redness and swelling at the injection site, and fever. Severe allergic reactions and the occurrence of vaccine-related chickenpox are very rare. Before receiving the chickenpox vaccine, individuals should inform their doctors about their allergy history and health condition so that the doctor can assess the suitability of vaccination and take necessary preventive measures. Pregnant women should avoid receiving the chickenpox vaccine and should consult a doctor if they come into contact with the varicella-zoster virus. Doctors will develop the most appropriate vaccination plan for each individual to ensure safety and effectiveness. Existing chickenpox vaccines have been proven to be safe and effective in clinical trials and widespread use. Most vaccine recipients experience only mild side effects, such as redness and swelling at the injection site, fever, pain, or discomfort. These side effects typically resolve on their own within a few days after vaccination and do not require special treatment.

While the side effects of the chickenpox vaccine are generally mild and short-lived, a very small number of vaccine recipients may experience severe allergic reactions. Allergic reactions may include symptoms such as shortness of breath, facial swelling, rashes, hives, and more. If vaccine recipients experience these severe side effects, they should seek medical assistance immediately. Individuals who receive the chickenpox vaccine may experience vaccine-related chickenpox after vaccination. This condition is known as "vaccine-related chickenpox," and the symptoms are usually mild and of short duration. While the incidence of vaccine-related chickenpox is low but it cannot be entirely avoided.. Nevertheless, vaccination with the chickenpox vaccine can still reduce the spread of chickenpox, protecting those who have not been vaccinated.

Before receiving the chickenpox vaccine, individuals should inform their doctors about their personal allergy history and health condition. This allows the doctor to assess the suitability of the chickenpox vaccine and take necessary preventive measures. For those with pre-existing immune system disorders, undergoing immunosuppressive treatment, or having other specific medical conditions, doctors may recommend special vaccination strategies or selective vaccination. Pregnant women should avoid receiving the chickenpox vaccine during pregnancy. Although the safety of the chickenpox vaccine in pregnant women is not fully established, according to related research, pregnant women should not receive the vaccine. If pregnant women come into contact with the varicella-zoster virus, they should consult a doctor immediately to determine whether additional measures are needed to protect their own and their baby's health (Yoshikawa et al., 2016) (Figure 2).

Figure 2 Chickenpox Vaccine reagents

2 Methods to Improve Existing Chickenpox Vaccines

2.1 Impact of factors like dose, vaccination schedule, and timing on immune effectiveness

Changes in factors such as dose, vaccination schedule, and timing can influence the immune effectiveness of the chickenpox vaccine. However, many other factors require further research and evaluation to ensure the optimal immune effectiveness of the vaccine. By understanding the impact of these factors, experts can further improve the chickenpox vaccine to provide more effective and safe immune protection, reducing the incidence of chickenpox and vaccine side effects. The optimal age for chickenpox vaccination remains a debated issue. Early vaccination may offer better immune protection but may also increase the risk of reduced vaccine effectiveness. Some studies suggest that vaccination in infants under one year of age may not be as effective because their immune systems are not fully developed. Therefore, current recommendations are to administer the first dose of the chickenpox vaccine between 12 and 15 months of age, followed by the second dose at 4~6 years of age.

Individuals' immune status may also affect the immune effectiveness of the chickenpox vaccine. For example, individuals with compromised immune systems may not derive strong immune protection from the vaccine. Therefore, when assessing vaccine immune effectiveness, the recipient's immune status, such as immunodeficiency diseases or immunosuppressive treatments, needs to be considered. The varicella-zoster virus exhibits some variability, which could impact the immune effectiveness of the vaccine. Researchers need to continually monitor variations in virus strains and make corresponding adjustments to the vaccine to ensure its immune protection effectiveness against different strains. Differences in immune effectiveness between children and adults: Immune effectiveness of the chickenpox vaccine may differ between children and adults. Some studies suggest that adults may experience lower immune protection after receiving the chickenpox vaccine. This could be due to weaker immune responses in adults or prior exposure to the chickenpox virus. Therefore, researchers need to further study the vaccination effectiveness in different age groups to determine the optimal immune strategy (Kanra et al., 2000).

2.2 Protective effects and limitations of BCG vaccine

Combination schedules involve administering multiple vaccines simultaneously in one vaccination plan to enhance immune protection. For example, in the chickenpox vaccine schedule, co-administration with the measles, mumps, and rubella (MMR) vaccine can be considered. Studies indicate that co-administering the chickenpox vaccine with the MMR vaccine can provide similar immune protection effectiveness without increasing the risk of adverse reactions. Furthermore, combination vaccination can reduce the number of required vaccinations and enhance vaccination convenience. Co-administration refers to vaccinating with different vaccines at different time points to improve immune protection. For example, in the chickenpox vaccine schedule, co-administration with other vaccines like pertussis or influenza can be considered. Research shows that co-administration can maintain immune effectiveness while reducing the number of vaccinations, improving vaccination rates, and without increasing the risk of adverse reactions. Additionally, co-administration can save time and costs and help establish more comprehensive immune protection.

Combination schedules or co-administration can enhance immune effectiveness by providing more comprehensive and longer-lasting immune protection, as different vaccines can elicit different immune responses when activating the immune system. Moreover, some studies suggest that combination schedules or co-administration can promote the formation of immune memory, enabling the immune system to respond more effectively to future infections. However, the safety and immune effectiveness of combination schedules or co-administration need careful evaluation. Researchers need to consider interactions between vaccines, optimize doses, and timing to ensure optimal immune effectiveness. Furthermore, for specific populations such as individuals with immunodeficiency diseases or undergoing immunosuppressive treatments, more research and evaluation may be required regarding the safety and effectiveness of combination schedules or co-administration. Combination schedules or co-administration, as strategies to enhance immunity, can improve immune protection effectiveness against specific diseases. Nevertheless, further research and evaluation are needed to determine the best combination schedules or co-administration strategies and ensure their safety and maximum immune effectiveness. This will contribute to providing more effective and comprehensive immune protection, reducing disease transmission and incidence, and better safeguarding public health (Baxter et al., 2013).

3 Enhancing the Safety of Chickenpox Vaccines

3.1 Studying vaccine's side effects and finding methods to reduce them

To enhance the safety of chickenpox vaccines, researchers need to conduct in-depth studies on the side effects of existing vaccines and explore methods to reduce these side effects. Here are additional approaches to studying vaccine side effects and minimizing them: Establishment of adverse event monitoring and reporting systems: Establishing a comprehensive adverse event monitoring and reporting system is crucial for researching chickenpox vaccine side effects. This system should include timely monitoring and reporting mechanisms to promptly detect and address adverse events. Additionally, the system should encourage healthcare institutions and vaccine recipients to proactively report adverse events to provide more comprehensive data and information.

Researchers can reduce the occurrence of side effects by optimizing the vaccine's dosage and vaccination schedule. This may involve adjusting factors such as vaccine dosage, timing between doses, and the number of doses administered. Rational design of vaccine dosage and vaccination schedules can minimize the occurrence of adverse reactions. Researchers can also reduce side effects by improving the vaccine's formulation. This may include adjusting the proportions of components in the vaccine, optimizing the choice of adjuvants, and refining the vaccine manufacturing process. Improving the vaccine formulation can enhance both safety and immune effectiveness. Management of side effects in high-risk populations: For high-risk populations such as individuals with immunodeficiency disorders or those with a predisposition to allergies, researchers need to develop specific strategies for managing vaccine side effects. This may involve taking preventive measures such as administering antiallergy medications or adjusting the vaccination schedule to minimize the occurrence and impact of side effects (Hong et al., 2023).

3.2 Research on vaccine safety and effectiveness in different populations

It is crucial to conduct research on the safety and effectiveness of the chickenpox vaccine in different populations. Chickenpox primarily affects children, so it is essential to study the safety and effectiveness of the vaccine in this age group. This can include evaluating vaccine efficacy in children of different age groups to determine the optimal timing and dosage of vaccination. Additionally, it is necessary to monitor and research potential side effects in the pediatric population to provide safety evidence. Although chickenpox typically occurs in childhood, adults can also become infected with the varicella-zoster virus. Therefore, research on the safety and effectiveness of the vaccine in the adult population is equally important. This can involve assessing the immune response and side effects in adults following vaccination to determine the vaccine's safety and efficacy in the adult population.

Safety and effectiveness studies of the chickenpox vaccine in pregnant women are an area that requires special attention. Since the chickenpox vaccine is a live vaccine, its use in pregnant women carries certain risks. Researchers can evaluate the safety and effectiveness of chickenpox vaccination in pregnant women through retrospective studies and cohort studies, among other methods, to guide vaccination strategies for expectant mothers. Research on the safety and effectiveness of the chickenpox vaccine in immunocompromised populations is also of great importance. This includes studying the immune response and side effects of the vaccine in immunocompromised patients, organ transplant recipients, and individuals undergoing immunosuppressive therapy. High-risk populations, such as individuals with underlying health conditions or potential risks like those with allergies or chronic diseases, also require research into the safety and effectiveness of the chickenpox vaccine. This helps ensure the safety and efficacy of chickenpox vaccination in these populations (Caple, 2006; Perella et al., 2016).

4 Development of New Chickenpox Vaccines

4.1 Exploring the potential of recombinant protein or virus-like particle (VLP) based on vaccine's development

Chickenpox is a highly contagious disease caused by the varicella-zoster virus, primarily transmitted through respiratory droplets. Traditional chickenpox vaccines use live attenuated viruses for immunization, which, while effective, come with certain safety concerns. Therefore, researchers have begun exploring the potential of developing vaccines based on recombinant proteins or virus-like particles (VLPs) to enhance vaccine safety and immunogenicity. Recombinant protein-based vaccine development is a novel approach that eliminates the use of live viruses. By selecting specific protein genes of the varicella-zoster virus and inserting them into host cells for expression, resulting in the artificial synthesis of varicella-zoster virus proteins. This approach avoids the use of live viruses, thereby reducing the risk of vaccine side effects and infection. Furthermore, recombinant protein vaccines can be purified using techniques such as affinity chromatography and chromatin immunoprecipitation, improving vaccine purity and stability. Additionally, by selecting appropriate expression vectors and host cells, large-scale production can be achieved, enhancing vaccine availability.

Virus-Like Particles (VLPs) are particles formed through the self-assembly of recombinant proteins in an expression system, While resembling the shape and structure of real viruses, they lack the genetic material of the virus.. Researchers can optimize the production yield and purity of VLPs by selecting suitable expression vectors and host cells. VLPs activate the immune system while avoiding the risk of infection associated with live viruses. Furthermore, VLPs can achieve vaccine multivalency and enhanced immunogenicity by modifying the structure and composition of their surface proteins. Studies indicate that VLP-based vaccines have the potential to prevent chickenpox effectively, eliciting robust immune responses and providing long-term protection. These vaccine development methods based on recombinant proteins or virus-like particles offer numerous advantages. Firstly, they can significantly reduce the risk of side effects and infection associated with vaccines by avoiding the use of live viruses. Secondly, these vaccines can be produced on a large scale by selecting appropriate expression vectors and host cells, thereby enhancing their availability. Additionally, the purity and stability of vaccines can also be improved through the application of purification techniques. While vaccine development methods based on recombinant proteins or virus-like particles show tremendous promise in the field of chickenpox vaccines, they still face some challenges.

Vaccine's development methods based on recombinant proteins or virus-like particles have made significant advancements in the field of medical science. These methods can offer safer and more effective vaccine options while also helping to reduce the risk of infection during the vaccine production process. Recombinant protein-based vaccine development involves introducing specific protein genes from the target pathogen into host cells and utilizing the host cell's mechanisms to express and generate the target protein. This approach avoids the use of live viruses, thereby reducing the risk of vaccine-related side effects and potential infections. After purification and stabilization, recombinant protein vaccines can stimulate the immune system to produce specific antibodies, providing protection against the target pathogen. Virus-like particle-based vaccine development, on the other hand, leverages the self-assembly of recombinant proteins in the expression system to form particle structures similar to real viruses but without the viral genetic material. This approach activates the immune system while avoiding the risk of viral infections. Virus-like particle vaccines can induce robust immune responses and offer long-lasting protection. Despite the considerable potential of vaccine development methods based on recombinant proteins or virus-like particles, they still face some challenges. For instance, the purity and stability of vaccines are crucial, as any impurities or instability could affect vaccine safety and effectiveness. Additionally, the vaccine production process requires appropriate technical and equipment support to ensure consistency and quality.

4.2 Analyzing the application of new vaccine delivery systems, such as nanoparticles or gene delivery techniques

New vaccine delivery systems such as nanoparticles and gene delivery techniques have significant potential in vaccine development. They can enhance vaccine immunogenicity and effectiveness, boosting immune responses. However, the application of these new technologies requires further research and validation to ensure their safety and effectiveness. As science continues to advance, these new vaccine delivery systems are expected to contribute to more breakthroughs and innovations in vaccine development and immunoprotection. Nanoparticles are tiny particles typically ranging in size from 1 to 100 nanometers. Due to their small size and unique physical and chemical properties, nanoparticles can serve as carriers in vaccine delivery systems. First, nanoparticles can provide a larger surface area relative to their size, increasing the contact area between the vaccine and the immune system, thus enhancing immunogenicity. Second, nanoparticles can modulate the uptake and antigen presentation of immune cells by altering their surface properties and structure, thereby activating and enhancing immune responses. Additionally, nanoparticles can protect antigens from degradation and inactivation, prolonging vaccine persistence and stability.

Gene delivery techniques involve the introduction of target genes into host cells to express and produce target proteins. In vaccine delivery systems, gene delivery techniques can be used to transfer genes encoding pathogen antigens, leading to antigen production within host cells. This approach avoids the use of live viruses or protein preparations in vaccines, thus reducing the risks of infection and side effects. Gene delivery techniques can efficiently introduce and express target genes by selecting suitable vectors and delivery methods. Furthermore, gene delivery techniques can be used to modulate the intensity and type of immune response, allowing for personalized immune protection.

The application of nanoparticles and gene delivery techniques in vaccine delivery systems offers several advantages. Firstly, they can enhance vaccine immunogenicity and effectiveness, thus boosting immune responses. Secondly, these delivery systems can achieve prolonged and specific immune protection by controlling antigen release and presentation. Additionally, nanoparticles and gene delivery techniques can enhance vaccine stability and production efficiency through proper design and optimization. However, their application of these technologies in vaccine delivery systems also presents some challenges. For example, the preparation and characterization of nanoparticles require complex technical and equipment support, along with comprehensive assessments of their biocompatibility and safety. Gene delivery techniques need to address issues related to the efficient delivery and expression of genes, as well as potential risks associated with gene immunogenicity (Liese et al., 2013).

5 Summary and Outlook

Improvements in chickenpox vaccines and the development of new vaccines are of paramount importance for preventing and controlling the spread of chickenpox. Chickenpox is a highly contagious disease, particularly risky for children, as it may lead to complications and hospitalization. Therefore, enhancing chickenpox vaccines and researching new vaccines are crucial for reducing the incidence of the disease and mitigating its impact on individuals and society. Improvements in chickenpox vaccines can enhance their efficacy in protection. While existing chickenpox vaccines have proven highly effective in preventing chickenpox infection, their protective efficacy may wane over time. Hence, by improving vaccine formulations and manufacturing processes, it is possible to enhance their immunogenicity and effectiveness, extending the duration of immune protection. This can reduce the frequency of vaccine administration, improving vaccine practicality and convenience.

Enhancements in chickenpox vaccines can also reduce the incidence of adverse reactions and side effects. Although chickenpox vaccines are widely accepted and considered safe, a small percentage of individuals may experience adverse reactions, such as pain, swelling at the injection site, or post-vaccination fever. By improving vaccine formulations and manufacturing processes, it is possible to reduce the occurrence of adverse reactions and side effects, enhancing vaccine safety and acceptability. The development of new vaccines is crucial to meet the needs of specific populations. Current chickenpox vaccines are generally suitable for children and adults, but they may not be suitable or effective for certain special populations, such as pregnant women, immunocompromised patients, and individuals with weakened immune systems. Therefore, the development of new vaccines tailored to these special populations is highly necessary. This can provide broader protection, reduce the risk of chickenpox infection in these populations, and decrease the occurrence of complications (LaRussa et al., 1996).

To ensure the provision of safe and effective chickenpox vaccines, international cooperation and joint efforts are indispensable. Chickenpox is a global disease, and countries face similar challenges and demands. Only through strengthened international cooperation, the sharing of experiences and resources can we better address the improvement and development of chickenpox vaccines. Countries can enhance cooperation in vaccine research and development. By jointly conducting research projects, exchanging scientific achievements, and sharing technical expertise, innovation and optimization of chickenpox vaccines can be promoted. Furthermore, international cooperation can strengthen collaboration in vaccine clinical trials, ensuring vaccine safety and efficacy by establishing uniform vaccine standards and regulatory mechanisms. Through international collaboration, countries can collectively engage in advocacy and educational activities, raising public awareness and understanding of chickenpox vaccines, dispelling misconceptions and concerns about vaccines, and promoting the widespread adoption and dissemination of vaccines. This can increase vaccination rates globally, reducing the transmission of chickenpox and the occurrence of complications.

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Conflict of Interest Disclosure

The authors affirm that this research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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