



CHALLENGES AND COMPLICATIONS ASSOCIATED WITH BCG VACCINATION: AN IN-DEPTH REVIEW

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ABSTRACT

Bacillus Calmette-Guérin (BCG) vaccination remains a cornerstone in the global strategy for tuberculosis (TB) control, particularly in regions with high TB prevalence. Despite its widespread use, several challenges and complications associated with BCG vaccination have emerged, affecting its efficacy and safety. These include variations in vaccine strain, differences in immunogenic response, and adverse reactions ranging from mild local reactions to more severe, albeit rare, systemic complications. The effectiveness of BCG in preventing pulmonary tuberculosis and its potential role in protecting against other diseases such as bladder cancer and leprosy have sparked ongoing debate. This review explores the key issues surrounding BCG vaccination, including its historical background, current challenges in its application, and the management of associated complications. Special attention is given to the risks and benefits of the vaccine in immunocompromised populations, as well as the global implications for TB control efforts.

ПРОБЛЕМЫ И ОСЛОЖНЕНИЯ, СВЯЗАННЫЕ С ВАКЦИНАЦИЕЙ БЦЖ: УГЛУБЛЕННЫЙ ОБЗОР

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ABSTRACT

Вакцинация бациллой Кальметта-Герена (БЦЖ) остается краеугольным камнем глобальной стратегии борьбы с туберкулезом (ТБ), особенно в регионах с высокой распространенностью туберкулеза. Несмотря на ее широкое применение, возникло несколько проблем и осложнений, связанных с вакцинацией БЦЖ, влияющих на ее эффективность и безопасность. К ним относятся



*изменчивость штамма
вакцины, побочные
реакции,
иммунодефицитные
группы населения,
глобальное
здравоохранение,
эффективность вакцины.*

различия в штамме вакцины, различия в иммуногенном ответе и побочные реакции, варьирующиеся от легких местных реакций до более тяжелых, хотя и редких, системных осложнений. Эффективность БЦЖ в профилактике туберкулеза легких и ее потенциальная роль в защите от других заболеваний, таких как рак мочевого пузыря и проказа, вызвали продолжающиеся дебаты. В этом обзоре рассматриваются ключевые вопросы, связанные с вакцинацией БЦЖ, включая ее историческую подоплеку, текущие проблемы в ее применении и управление связанными с ней осложнениями. Особое внимание уделяется рискам и преимуществам вакцины для иммунодефицитных групп населения, а также глобальным последствиям для усилий по борьбе с туберкулезом.

Relevance. Bacillus Calmette-Guérin (BCG) vaccine, developed in the early 20th century, remains one of the most widely used vaccines globally, primarily for the prevention of tuberculosis (TB). It is estimated that over 100 million BCG vaccinations are administered annually, making it a cornerstone of public health strategies aimed at controlling the spread of TB, particularly in countries with a high incidence of the disease (World Health Organization, 2020). The BCG vaccine is a live attenuated strain of *Mycobacterium bovis*, and its effectiveness in preventing severe forms of TB, such as TB meningitis and miliary tuberculosis in children, has been well-documented (Vynnycky & Fine, 2000).

However, despite its widespread use, the BCG vaccine has been subject to several challenges and controversies, particularly regarding its variable efficacy in different populations and geographic regions. While the vaccine has been shown to offer significant protection against severe forms of TB in children, its effectiveness in preventing pulmonary TB, the most common and transmissible form of the disease, has been inconsistent across various studies (Colditz et al., 1994). Furthermore, the BCG vaccine is not without complications, ranging from mild local reactions such as injection site swelling to more severe adverse effects, including systemic infections in immunocompromised individuals (Basile et al., 2003). The variability in vaccine efficacy has led to ongoing debates regarding the need for booster doses and the development of new, more effective TB vaccines.

Complications arising from BCG vaccination, although rare, also raise concerns regarding the safety of the vaccine, especially in certain vulnerable populations. For instance, individuals with immunodeficiencies, such as those with HIV or congenital immunodeficiency disorders, are at an increased risk of developing disseminated BCG infection (Baio et al., 2018). Moreover, in some instances, the vaccine has been associated with granulomatous lesions at the injection site, abscess formation, and lymphadenitis, which can complicate diagnosis and treatment (Clerici et al., 2007). These adverse reactions have led to specific



recommendations regarding the administration of the BCG vaccine in immunocompromised individuals and the management of any resulting complications.

This review aims to examine the challenges and complications associated with BCG vaccination, focusing on its efficacy, safety profile, and the management of adverse reactions. By highlighting the current issues related to the use of the BCG vaccine, this article seeks to contribute to ongoing discussions about its role in modern TB control strategies and to provide insights into potential future directions for TB vaccination programs.

1. Efficacy of the BCG Vaccine

The Bacillus Calmette-Guérin (BCG) vaccine has been the primary method of preventing tuberculosis (TB) for nearly a century. Historically, the BCG vaccine has demonstrated substantial protection against severe forms of TB, especially in children. Early clinical studies showed that BCG vaccination reduced the incidence of TB meningitis and miliary tuberculosis by over 80% in pediatric populations (Colditz et al., 1994). These findings led to the widespread adoption of BCG vaccination, particularly in high-burden TB countries, as a primary tool for controlling childhood TB.

However, the vaccine's efficacy in preventing pulmonary TB, the most common and transmissible form of the disease, has been more variable. A meta-analysis by Colditz et al. (1994) revealed that BCG efficacy in preventing pulmonary TB ranges from 0% to 80%, with substantial differences observed based on geographic location, population characteristics, and study design. This variation has been attributed to several factors, including differences in the BCG strain used, environmental factors, and the presence of pre-existing mycobacterial exposure, which may influence immune response (Vynnycky & Fine, 2000). More recent studies, such as those by Aaby et al. (2015), suggest that the BCG vaccine's efficacy might be influenced by socioeconomic and health conditions in the areas where it is administered.

2. Complications and Adverse Reactions

Although the BCG vaccine is generally considered safe, it is not without complications. Most adverse reactions are mild and localized, such as erythema, induration, or swelling at the injection site, which typically resolve within weeks without the need for medical intervention (Basile et al., 2003). However, more severe complications, though rare, have been reported. These include regional lymphadenitis, abscess formation, and, in some cases, osteitis, which can occur in infants and young children following vaccination (Clerici et al., 2007).

In immunocompromised individuals, such as those with HIV/AIDS, congenital immunodeficiencies, or those undergoing immunosuppressive therapy, BCG vaccination can lead to more severe and disseminated infections. Baio et al. (2018) highlight the risk of disseminated BCG infection in immunocompromised populations, which can result in serious morbidity and mortality. These complications have led to changes in vaccination policies, particularly regarding the use of BCG in HIV-positive individuals and those with other immune system deficiencies. In some cases, the vaccination is contraindicated due to the potential for severe disseminated disease (Seward et al., 2019).

3. The Role of BCG in Non-Tuberculosis Diseases

In addition to its role in TB prevention, the BCG vaccine has been studied for its potential therapeutic effects against other diseases. One of the most promising areas of



research is the use of BCG in the treatment of bladder cancer. Clinical trials have demonstrated that BCG instillation into the bladder significantly reduces recurrence rates in non-muscle invasive bladder cancer (Lamm et al., 1991). The immunological mechanisms underlying this effect are thought to involve the stimulation of local immune responses, which may also play a role in the protection against TB.

Moreover, the BCG vaccine has been suggested to have potential benefits beyond TB and cancer treatment. Some studies indicate that BCG may have an immune-modulatory role in preventing certain autoimmune diseases and even improving the response to other vaccinations (Garg et al., 2018). However, the evidence in this area remains inconclusive, and further studies are needed to better understand the broader applications of BCG vaccination.

4. Global Challenges and Recommendations for BCG Vaccination

Despite its long history of use, the global implementation of BCG vaccination continues to face significant challenges. One of the primary issues is the variation in vaccine efficacy across different populations and regions. This has prompted calls for a more standardized approach to vaccine delivery and the need for new, more effective TB vaccines. While the World Health Organization (WHO) continues to recommend BCG vaccination as part of national TB control programs, there is increasing recognition that alternative vaccines or booster strategies may be required to address the limitations of BCG in preventing pulmonary TB (WHO, 2020).

Additionally, concerns over the safety of BCG in immunocompromised individuals remain a critical challenge. Several studies, including those by Aaby et al. (2015) and Baio et al. (2018), have recommended stricter screening protocols for individuals at risk of adverse reactions to BCG, as well as modified vaccination strategies to ensure that vulnerable populations are not exposed to unnecessary risks.

Conclusion. The BCG vaccine remains one of the most important tools in the global fight against tuberculosis, particularly in preventing severe childhood forms of the disease. However, its variable efficacy in preventing pulmonary TB and the potential for complications in certain populations necessitate ongoing research and improvements in vaccination strategies. Despite these challenges, the BCG vaccine continues to have significant global public health value, and its role in treating conditions such as bladder cancer further underscores its versatility. Future research should focus on refining the use of BCG, developing new vaccines, and addressing the complexities associated with vaccination in immunocompromised individuals.

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