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Economic and Health System Impacts of Typhoid Control Strategies in Uganda: Vaccination Versus Antibiotic Treatment

Kamanzi Ntakirutimana G.

School of Natural and Applied Sciences Kampala International University Uganda

ABSTRACT

Typhoid fever remains a significant public health challenge in Uganda, where inadequate sanitation, urbanization, and limited access to clean water contribute to frequent outbreaks. Antibiotic treatment has long been the mainstay of managing the disease, but rising antibiotic resistance complicates effective treatment, leading to higher healthcare costs and treatment failures. Vaccination, particularly with the typhoid conjugate vaccine (TCV), offers a promising alternative to reduce the disease burden and prevent outbreaks. However, challenges such as vaccine hesitancy, logistical difficulties, and high initial costs hinder large-scale implementation. This review examines the economic and health system impacts of antibiotic treatment versus vaccination strategies for typhoid fever control in Uganda. It explores the limitations of current antibiotic therapies, the potential cost-effectiveness of vaccination programs, and the feasibility of scaling up immunization efforts. The review also discusses how integrated strategies, combining both antibiotics and vaccines, could optimize outcomes and reduce the strain on Uganda's healthcare system. Recommendations include strengthening vaccination efforts, monitoring antibiotic use, expanding public awareness, enhancing surveillance, and leveraging international partnerships to improve the effectiveness and sustainability of typhoid fever control in Uganda.

Keywords: Typhoid fever, Uganda, antibiotic resistance, typhoid conjugate vaccine.

INTRODUCTION

Typhoid fever, caused by the bacterium *Salmonella enterica* serovar Typhi, is a major public health concern in many low- and middle-income countries, including Uganda. This bacterial infection is primarily transmitted through the ingestion of contaminated food or water, often due to inadequate sanitation and poor hygiene practices. Globally, typhoid fever accounts for an estimated 9.9 million cases and over 110,000 deaths annually, with the burden disproportionately affecting sub-Saharan Africa and South Asia. In Uganda, the disease remains endemic, with periodic outbreaks contributing to significant morbidity, mortality, and economic strain on households and the healthcare system [1]. The control and management of typhoid fever in Uganda necessitate a multifaceted approach, combining treatment and prevention strategies to mitigate its impact.

The high prevalence of typhoid fever in Uganda can be attributed to several socioeconomic and environmental factors. Rapid urbanization without adequate infrastructure development has led to the proliferation of informal settlements characterized by overcrowding, poor sanitation, and limited access to clean water. These conditions create an ideal environment for the transmission of *Salmonella Typhi.* Additionally, public awareness about typhoid fever and its transmission dynamics remains low, further exacerbating the spread of the disease. Seasonal variations in rainfall also play a role, with typhoid outbreaks often peaking during periods of heavy rainfall when flooding contaminates water sources [2]. Management of typhoid fever has traditionally relied on antibiotic therapy, which effectively reduces disease severity and prevents complications when administered promptly. However, the rise of antibiotic resistance has emerged as a critical challenge. Strains of *Salmonella Typhi* resistant to first-line antibiotics such as chloramphenicol, ampicillin, and trimethoprim-sulfamethoxazole have become increasingly prevalent, necessitating the use of more expensive and less accessible second-line drugs. The situation is further compounded by the inappropriate use of antibiotics, including self-

medication and incomplete adherence to prescribed treatment regimens, which accelerates the development of resistance.

Vaccination represents a promising preventive strategy to complement antibiotic treatment. Two main types of typhoid vaccines are currently available: the Vi polysaccharide vaccine and the typhoid conjugate vaccine (TCV). The latter has shown greater efficacy, particularly in young children, and offers the potential for longer-lasting immunity. In 2018, the World Health Organization (WHO) recommended TCVs for use in endemic countries, emphasizing their role in reducing the incidence of typhoid fever and curbing the spread of antibiotic-resistant strains [3]. Despite these advancements, the adoption of vaccination programs in Uganda has faced logistical, financial, and cultural barriers. Typhoid fever imposes a dual burden on Uganda, manifesting as both a public health crisis and an economic challenge. The recurrent outbreaks not only strain healthcare resources but also disrupt livelihoods, particularly for affected households. The cost of treatment, including medical expenses and indirect costs such as lost income, disproportionately affects low-income populations [4]. Additionally, the increasing prevalence of antibiotic-resistant *Salmonella Typhi* strains undermines the effectiveness of traditional treatment approaches, posing a significant threat to public health security. While vaccination offers a viable alternative to reduce the incidence and severity of typhoid fever, its implementation on a national scale has been limited. Factors such as high initial costs, logistical challenges in vaccine distribution, and vaccine hesitancy among the population hinder the widespread adoption of this preventive measure. Furthermore, the absence of comprehensive data on the long-term economic and health system benefits of vaccination compared to antibiotic treatment complicates decision-making for policymakers. This review aims to evaluate the economic and health system impacts of antibiotic treatment and vaccination for typhoid fever in Uganda. It assesses the effectiveness and limitations of current antibiotic treatment strategies, focusing on trends in antibiotic resistance and their implications for typhoid fever management [5]. The review also evaluates the feasibility and long-term benefits of vaccination programs, identifying logistical, financial, and cultural challenges that need to be addressed for effective interventions. The review also proposes evidence-based recommendations for integrated management strategies, exploring how antibiotics and vaccines can be used synergistically to optimize outcomes for individuals and communities. This review focuses on the context of Uganda, a country where typhoid fever remains a significant public health issue. It draws upon available data from epidemiological studies, health system analyses, and economic evaluations to provide a nuanced understanding of the challenges and opportunities associated with managing typhoid fever. By highlighting the interplay between treatment and prevention strategies, the review aims to inform policymakers, healthcare providers, and stakeholders about the most effective approaches to addressing this pressing health challenge. The findings of this review have important implications for public health policy and practice in Uganda. By elucidating the comparative benefits and limitations of antibiotics and vaccination, the study provides a framework for evidence-based decision-making [6]. The insights gained can guide the allocation of resources, inform the design of vaccination campaigns, and support efforts to strengthen the healthcare system's capacity to manage typhoid fever. Moreover, addressing the economic burden of the disease aligns with broader goals of poverty reduction and sustainable development, contributing to the well-being of vulnerable populations and the resilience of communities. Typhoid fever remains a persistent challenge in Uganda, requiring a multifaceted approach to mitigate its impact. This review underscores the importance of balancing immediate treatment needs with long-term prevention strategies to achieve sustainable improvements in public health outcomes. Through a comprehensive evaluation of antibiotics and vaccination, this study aims to contribute to the ongoing efforts to control typhoid fever and enhance the resilience of Uganda's healthcare system [7].

Healthcare Resource Allocation

Typhoid fever management requires a balanced approach to healthcare resource allocation. Antibiotic treatment, which requires hospital beds, skilled medical personnel, diagnostic tools, and a consistent supply of antibiotics, can overwhelm already stretched healthcare systems in low-resource settings. The emergence of multidrug-resistant and extensively drug-resistant typhoid strains has led to a reliance on second- and third-line antibiotics, which are often more expensive, require longer treatment courses, and are less readily available in endemic regions [8]. This increases the economic burden on healthcare providers and patients, as treatment failures and prolonged illnesses necessitate repeated healthcare visits and extended hospitalization. Recurrent outbreaks of typhoid fever strain healthcare infrastructure, hindering the management of other critical healthcare needs. Overburdened facilities may also experience a decline in care quality, compounding the public health challenge. Vaccination programs are a cornerstone of proactive healthcare management, reducing the incidence of typhoid fever and the demand for hospital-based care. Typhoid conjugate vaccines (TCVs) have been shown to be highly cost-effective, especially in typhoid-

endemic regions. Initial investment in vaccine procurement and distribution infrastructure leads to long-term savings by reducing the incidence of typhoid fever, hospitalizations, and the use of costly antibiotics. Integration of vaccination programs into existing immunization schedules maximizes resource utilization, improves vaccine coverage rates, and reduces logistical and financial burdens of standalone vaccination campaigns [9].

Antibiotic Resistance

Antibiotic resistance is a growing global health crisis, with bacteria becoming resistant to commonly used antibiotics like ampicillin, chloramphenicol, and ciprofloxacin. This increases the cost and complexity of treatment, leading to longer hospital stays and higher mortality rates. The emergence and spread of antibiotic-resistant bacteria pose a severe threat to global health security, driven by misuse and overuse of antibiotics in human medicine, agriculture, and veterinary practices, as well as inadequate infection control measures [10]. The global interconnectedness of trade and travel facilitates the rapid spread of resistant strains, making localized outbreaks a worldwide concern. Addressing this issue requires urgent investments in alternative strategies, such as the development of new antibiotics, improved diagnostic tools, and enhanced global surveillance systems. Vaccination is a pivotal strategy in combating antibiotic resistance indirectly. Typhoid conjugate vaccines (TCVs) reduce the incidence of typhoid fever, a condition often treated with antibiotics, by lowering the disease burden and decreasing the selective pressure that drives resistance. Immunization campaigns can help control outbreaks caused by resistant strains, providing a cost-effective and sustainable alternative to reliance on antibiotics. Expanding vaccine coverage in high-burden regions can significantly curb the spread of resistant pathogens and protect the efficacy of existing antibiotics. Antibiotic resistance is a multifaceted challenge requiring a global, coordinated response. Efforts must focus on promoting judicious use of antibiotics, strengthening vaccination programs, investing in research for novel therapies, public education, and policy enforcement [11].

Productivity Losses and Societal Costs

Typhoid cases can lead to productivity losses and societal costs, particularly for those in subsistence farming or informal labor. The economic impact of illness is direct, as severe cases often involve extended recovery periods, affecting individuals' ability to work and meet basic needs. Household burdens can be high, especially for low-income households, which can lead to poverty and chronic health conditions. Vaccination is a proactive approach that reduces productivity losses by preventing typhoid infections, reducing absenteeism from work and school, and sustaining household income [12]. High vaccine coverage can lead to herd immunity, protecting even unvaccinated individuals by reducing the overall prevalence of the disease. This amplifies the societal benefits, minimizing the risk of outbreaks and reducing the collective healthcare burden on communities and health systems. Equity impacts can be mitigated by targeting vaccination programs to vulnerable populations, such as those in low-income areas or regions with limited access to clean water and sanitation. These programs reduce disparities in typhoid incidence and ensure that marginalized groups benefit from disease prevention measures, promoting social and economic inclusion.

Feasibility and Scalability of Vaccination Programs

Vaccination programs are crucial for public health, preventing the spread of infectious diseases, reducing mortality, and improving societal productivity. However, their feasibility and scalability depend on several factors. Initial investments in vaccine procurement, infrastructure setup, training, and distribution can lead to long-term economic savings. Preventing illnesses reduces healthcare expenditures and minimizes indirect costs [13]. Effective programs often leverage a mix of government budgets, international aid, and private sector partnerships to ensure sustainability. Robust infrastructure is essential for safe and effective vaccine delivery. Cold chain systems, trained personnel, and community engagement can improve program uptake and address logistical challenges in remote areas. Strong policy frameworks and governmental commitment are crucial for scaling vaccination programs. Legislative backing, funding and resource allocation, and collaboration with global health bodies like WHO and UNICEF enhance resource-sharing and align with international standards. Addressing social and cultural factors like vaccine hesitancy, awareness campaigns, and monitoring and feedback can help achieve high vaccination coverage. Targeted educational campaigns, awareness campaigns, and monitoring can counter vaccine hesitancy and build public trust [3]. The feasibility and scalability of vaccination programs depend on integrating financial planning, robust infrastructure, supportive policies, and community engagement. Investing in sustainable immunization strategies is essential for long-term health and economic benefits. Governments, global organizations, and local communities must collaborate to address barriers and ensure equitable vaccine access.

Evidence-Based Recommendations

These evidence-based recommendations aim to enhance typhoid control and prevention efforts, particularly in regions like Uganda where the burden

of the disease remains high. Here's an expanded explanation of each recommendation:

Strengthen Vaccination Programs: Typhoid fever, caused by *Salmonella Typhi*, continues to pose significant health risks in low-resource settings, including Uganda. The introduction and scaling up of typhoid conjugate vaccines (TCVs) can be a game-changer in reducing the burden of the disease. TCVs are effective in preventing typhoid in both children and adults, especially in areas with high disease prevalence. Integrating TCVs into Uganda's routine immunization schedules will ensure widespread coverage and help establish herd immunity. Ensuring that the vaccine is accessible in all regions, especially underserved rural areas, can dramatically reduce typhoid incidence and its associated complications [14].

Monitor Antibiotic Use: Antibiotic resistance (AMR) is a growing concern in the treatment of typhoid fever, with the emergence of multidrug-resistant *Salmonella Typhi* strains. To combat this, it's crucial to implement robust antibiotic stewardship programs across Uganda's healthcare system. These programs would regulate and monitor the use of antibiotics, ensuring that they are prescribed appropriately and only when necessary. By reducing unnecessary prescriptions and ensuring the correct use of antibiotics, Uganda can slow the development of resistance, thus preserving the efficacy of existing antibiotics for treating typhoid and other bacterial infections.

Expand Public Awareness: Public awareness campaigns are essential for increasing the uptake of vaccination programs and encouraging communities to adopt preventive behaviors. In Uganda, educating the population on the benefits of vaccination—such as reducing the incidence of severe illness, hospitalizations, and deaths—can build trust in immunization efforts [15]. Public health campaigns should also highlight the importance of sanitation and hygiene in preventing typhoid, as these factors contribute to the transmission of the disease. Schools, health centers, and community leaders can play vital roles in spreading awareness and debunking myths that may hinder vaccination efforts.

Enhance Surveillance Systems: Surveillance systems are essential to track disease trends, assess the effectiveness of interventions, and identify emerging hotspots. Strengthening disease surveillance in Uganda, especially in areas with a high burden of typhoid, will enable the country to collect real-time data on incidence rates and vaccine coverage [16]. This data can be used to adapt and refine vaccination campaigns, prioritize high-risk areas, and monitor trends in antibiotic resistance. Enhanced surveillance will also contribute to better preparedness in addressing potential outbreaks and ensure that resources are allocated efficiently.

Leverage International Partnerships: Global health organizations like the World Health Organization (WHO) [3], GAVI (the Vaccine Alliance), and other international donors and technical partners can provide crucial support to Uganda in implementing large-scale vaccination programs. These partnerships can help secure funding, provide technical assistance for vaccine distribution and cold chain management, and share best practices for program implementation. By collaborating with international organizations, Uganda can access the expertise and resources necessary to enhance its typhoid prevention efforts and scale up vaccination programs to reach underserved populations.

CONCLUSION

The control of typhoid fever in Uganda requires a comprehensive and integrated approach that addresses both immediate treatment and long-term prevention. The growing challenge of antibiotic resistance has significantly complicated the management of typhoid fever, necessitating more robust and sustainable solutions. Antibiotic treatment, while effective in the short term, is becoming increasingly expensive and less effective due to the rise of resistant strains of *Salmonella Typhi*. This underscores the urgent need for innovative strategies that reduce the reliance on antibiotics and promote sustainable disease control. Vaccination, particularly with typhoid conjugate vaccines (TCVs), presents a promising alternative. The introduction of TCVs could substantially decrease the incidence of typhoid fever, reduce the burden on healthcare systems, and help curb the spread of antibiotic-resistant strains. However, the successful implementation of vaccination programs in Uganda faces challenges, including logistical hurdles, vaccine hesitancy, and financial constraints. Overcoming these barriers will require strategic investments in healthcare infrastructure, robust surveillance systems, and public education campaigns that emphasize the benefits of vaccination and improved sanitation. The economic burden of typhoid fever in Uganda is significant, with productivity losses and societal costs adding to the strain on households and healthcare systems. Vaccination offers a cost-effective solution by reducing disease incidence, preventing hospitalizations, and ultimately lowering treatment costs. By investing in vaccination programs, Uganda can not only improve public health outcomes but also achieve long-term economic benefits by reducing the direct and indirect costs associated with the disease. To optimize the impact of typhoid control strategies, it is essential to adopt a dual approach that combines both vaccination and prudent antibiotic use. Strengthening antibiotic stewardship programs will

help mitigate the risk of further resistance and preserve the effectiveness of existing treatments. Additionally, continuous monitoring, data collection, and international collaboration are vital to ensure that interventions are responsive and adaptive to changing disease dynamics. Ultimately, a comprehensive strategy that integrates prevention, treatment, and public health initiatives can significantly reduce the burden of typhoid fever in Uganda. With a coordinated effort from government, healthcare providers, international partners, and local communities, it is possible to reduce the incidence of typhoid fever, improve health outcomes, and enhance the overall resilience of Uganda's healthcare system.

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