

Comparative Cost-Effectiveness of Typhoid Vaccination and Treatment in Rural vs. Urban Ugandan Healthcare Settings

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ABSTRACT

Typhoid fever remains a major public health challenge in Uganda, particularly in communities where sanitation, water quality, and healthcare access are inadequate. Despite the availability of effective vaccines and antibiotics, disparities in healthcare infrastructure and resource allocation between rural and urban areas continue to influence disease outcomes and economic burdens. This review examines the comparative cost-effectiveness of typhoid vaccination versus treatment in rural and urban Ugandan healthcare settings. It explores the economic implications of preventive immunization programs relative to the costs associated with diagnosis, hospitalization, and antimicrobial therapy. The review highlights how variations in healthcare infrastructure, disease burden, and access to vaccination services affect overall cost-efficiency. Findings suggest that vaccination is a more cost-effective and sustainable intervention, especially in rural areas with limited access to timely treatment. Policy recommendations emphasize integrating typhoid vaccination into Uganda's Expanded Programme on Immunization (EPI) and strengthening health systems to reduce disease incidence and associated economic losses.

Keywords: Typhoid fever, cost-effectiveness, vaccination, treatment, rural health, urban health, Uganda.

INTRODUCTION

Typhoid fever, a serious systemic infection caused by *Salmonella enterica* serovar Typhi, continues to represent a major public health challenge in Uganda, despite the disease being both preventable and treatable. The persistence of typhoid in the country is closely linked to inadequate access to safe drinking water, poor sanitation, and limited healthcare infrastructure, particularly in rural and densely populated urban areas [1]. Transmission occurs primarily through the ingestion of food or water contaminated with fecal matter from infected individuals, creating a cycle of infection that is difficult to break in environments with substandard hygiene practices. According to reports from the World Health Organization (WHO) and Uganda's Ministry of Health, children and young adults remain disproportionately affected, with urban centers such as Kampala and Mbale frequently experiencing outbreaks, while rural areas continue to report endemic disease [2]. This disparity underscores the intersection of social, economic, and infrastructural factors in disease distribution, highlighting how poverty, overcrowding, and lack of public sanitation systems exacerbate vulnerability to typhoid.

The impact of typhoid fever extends beyond the immediate health consequences to encompass substantial economic and social burdens. Infected individuals often experience prolonged fever, abdominal pain, weakness, and other gastrointestinal complications, which reduce productivity, disrupt schooling, and, in severe cases, lead to death. Households, particularly those with low incomes, face catastrophic medical expenses from hospitalization, laboratory testing, and antibiotic treatments. [3] Compounding these challenges is the rising prevalence of antimicrobial-resistant *S. Typhi* strains, which not only increase treatment complexity and hospital stay duration but also escalate overall healthcare costs. These realities have led to growing interest in preventive strategies such as vaccination,

which could offer a cost-effective alternative to reliance solely on curative care, particularly in resource-constrained settings [4].

Uganda has achieved notable public health progress through long-standing immunization programs targeting diseases like measles, polio, and tuberculosis, yet typhoid vaccination has not been fully incorporated into the national schedule due to competing priorities, vaccine supply limitations, and cost constraints. The advent of typhoid conjugate vaccines (TCVs), which provide longer-lasting immunity and are suitable for children under two years, has renewed interest in assessing the feasibility and economic value of widespread vaccination [5]. However, healthcare infrastructure differences between urban and rural settings influence the effectiveness and cost-efficiency of vaccination programs. Urban areas benefit from relatively better access to diagnostic facilities, healthcare services, and cold-chain systems, yet residents face higher exposure to contaminated food and water due to poor waste management and overcrowding. Conversely, rural populations encounter limited healthcare facilities, long travel distances to medical centers, and inadequate laboratory support, which challenges timely diagnosis and treatment [6].

Given these complexities, evaluating the comparative cost-effectiveness of typhoid vaccination versus treatment is critical for informing health policy and optimizing resource allocation. While vaccination promises to reduce disease incidence and long-term economic burden, limited empirical data exist on its cost-effectiveness across Uganda's diverse healthcare settings. A context-specific analysis is therefore essential to guide strategic planning, improve population health outcomes, and reduce the multifaceted impact of typhoid fever in both rural and urban communities [7]. The primary aim of this study is to assess the economic implications of typhoid prevention and treatment in Uganda, with particular attention to both rural and urban healthcare settings. Specifically, the study seeks to evaluate the direct and indirect costs associated with typhoid vaccination and treatment, compare their cost-effectiveness in terms of healthcare expenditure, reduction in disease incidence, and quality-adjusted life years (QALYs) saved, and examine how variations in healthcare infrastructure, accessibility, and population density influence cost-efficiency. Additionally, the study intends to provide evidence-based policy recommendations for integrating typhoid vaccination into Uganda's national immunization program. Central research questions include identifying the comparative costs of vaccination versus treatment, determining which intervention offers greater cost-effectiveness in preventing typhoid-related morbidity and mortality, and exploring how rural-urban disparities shape intervention efficiency. The significance of this study lies in its potential to inform resource allocation, strengthen equitable health interventions, and support sustainable disease prevention strategies. By highlighting the economic advantages of preventive vaccination, the research also contributes to mitigating antimicrobial resistance, advancing Uganda's national health priorities, and providing insights applicable to other low-income countries facing similar public health challenges.

Epidemiological Overview of Typhoid in Uganda

Typhoid fever remains a significant public health concern in Uganda, with a burden that varies considerably across regions due to environmental, socioeconomic, and infrastructural disparities. Urban centers, particularly Kampala, have experienced large-scale outbreaks, including the notable 2015 epidemic that affected over 10,000 individuals, highlighting the vulnerability of densely populated areas with inadequate sanitation and water management systems [8]. Rural districts, especially in the Eastern and Northern regions, also report persistently high endemic levels of typhoid, largely attributed to limited access to safe drinking water, poor sanitation, and reliance on unprotected water sources for domestic use. Epidemiological estimates suggest that Uganda experiences between 200 and 800 typhoid cases per 100,000 population annually; however, underreporting due to limited surveillance and diagnostic capacity likely underestimates the true burden. Compounding the challenge, antimicrobial resistance (AMR) has emerged as a critical concern, with increasing resistance observed against first-line antibiotics such as chloramphenicol, ampicillin, and trimethoprim-sulfamethoxazole, thereby complicating treatment and increasing healthcare costs [9]. These factors underscore the importance of preventive strategies, including improved sanitation, hygiene practices, and vaccination, as cost-effective approaches to reducing the typhoid burden in Uganda.

Healthcare Infrastructure and Access Disparities

Healthcare infrastructure and access in Uganda exhibit significant disparities between urban and rural areas, reflecting differences in resources, capacity, and service delivery. Urban healthcare systems, as seen in cities such as Kampala, Entebbe, and Mbarara, generally benefit from better-equipped hospitals and clinics, with improved diagnostic tools, laboratory capacity, and supply chains for essential medicines, including antibiotics [10]. Access to private healthcare facilities and pharmacies further enhances treatment availability, although often at higher financial costs, which can limit utilization among lower-income urban populations. Despite these advantages, urban centers face challenges arising from high patient volumes, rapid slum proliferation, and intermittent water contamination, which strain public health services and increase vulnerability to infectious diseases. Vaccination coverage in urban areas is typically higher due to well-organized public health outreach programs and reliable cold chain systems. In contrast, rural healthcare infrastructure is characterized by limited human resources, inadequate

diagnostic capacity, and high transportation costs, often forcing residents to rely on community health workers or informal drug vendors. Logistical barriers, such as poor road networks, cold chain maintenance challenges, and limited health education, reduce vaccination uptake and contribute to delayed diagnosis, inappropriate antibiotic use, and higher disease-related costs in rural communities [11].

Economic Evaluation Framework

Cost-effectiveness analysis (CEA) offers a structured and rigorous method for comparing the relative costs and health outcomes of alternative interventions, providing crucial insights for decision-makers in resource-limited settings. In the context of typhoid control, CEA can be applied to evaluate the economic efficiency of vaccination programs versus treatment-based approaches [12]. Vaccination entails multiple cost components, including the procurement of vaccines, their safe distribution and cold-chain storage, training of healthcare personnel, and community engagement and mobilization to achieve adequate coverage. Conversely, treatment-based strategies incur expenses related to medical consultations, laboratory diagnostics such as Widal tests and blood cultures, antibiotics, hospitalization, and management of severe complications, including intestinal perforation and other typhoid-related morbidities. A comprehensive economic evaluation also accounts for indirect costs, such as lost productivity due to illness or caregiving responsibilities, as well as intangible costs, including reductions in quality of life and psychosocial burdens on patients and families. By systematically integrating these direct, indirect, and intangible costs with health outcomes, CEA provides policymakers with evidence to prioritize interventions that maximize health benefits while ensuring efficient allocation of limited healthcare resources [13].

Comparative Cost-Effectiveness Analysis

The introduction of the WHO-prequalified typhoid conjugate vaccine (TCV) has marked a significant advancement in typhoid prevention, offering long-term protection of up to five years and suitability for children as young as six months. Evidence from sub-Saharan Africa demonstrates that TCV vaccination programs are highly cost-effective, with cost-effectiveness ratios ranging between US\$150 and US\$400 per disability-adjusted life year (DALY) averted [14], depending on coverage rates and healthcare infrastructure. In Uganda, the integration of TCV into existing immunization programs further reduces delivery costs, enabling substantial long-term savings for both households and the healthcare system. By preventing outbreaks, vaccination not only diminishes direct medical costs but also reduces indirect economic burdens such as lost productivity and emergency care expenses. While rural vaccination programs may incur higher initial costs due to logistical challenges, their potential return on investment is considerable, particularly given limited access to timely treatment in remote areas [15]. Conversely, treatment of typhoid, though essential, is becoming progressively less cost-effective due to rising antimicrobial resistance. Mild cases typically cost US\$15–25 to manage, while severe hospitalizations can exceed US\$100 per patient, with additional transport and productivity losses further escalating the economic impact.

Table 1: Rural vs. Urban Comparison

Parameter	Rural Uganda	Urban Uganda
Healthcare access	Limited, delayed	Readily available
Vaccine coverage	Low–moderate	Moderate–high
Treatment cost per case	Higher due to transport and delays	Lower due to proximity
AMR prevalence	Moderate	High
Overall cost-effectiveness (vaccination)	High (greater impact per dollar spent)	Moderate
Overall cost-effectiveness (treatment)	Low	Moderate

These comparisons indicate that while both regions benefit from vaccination, rural settings achieve greater economic and health gains per dollar spent on preventive measures, given the higher barriers to effective treatment.

Policy and Programmatic Implications

To maximize the effectiveness of typhoid control strategies, Uganda must adopt a comprehensive and integrated approach that combines immunization, surveillance, infrastructure improvements, and evidence-based policymaking. A key priority is the national integration of the typhoid conjugate vaccine (TCV) into the Expanded Program on Immunization (EPI), with particular emphasis on districts identified as high-risk due to recurrent outbreaks or poor sanitation [16]. Complementing this, targeted outreach programs are essential to ensure equitable access to vaccination, especially for populations in remote and underserved areas, where health services are limited and typhoid incidence remains high. Strengthening disease surveillance systems, including monitoring antimicrobial resistance (AMR), is critical to inform timely and effective treatment protocols and prevent the emergence of drug-resistant typhoid strains. Investments in water, sanitation, and hygiene (WASH) infrastructure are equally important to address the root causes of transmission and reduce the overall disease burden. Finally, continuous economic modeling and data collection should guide policy decisions, allowing health authorities to evaluate the

cost-effectiveness of interventions and prioritize resource allocation across different regions, ensuring that typhoid control strategies remain both sustainable and impactful [17].

Challenges and Research Gaps

Despite ongoing efforts to control typhoid fever in Uganda, several challenges continue to hinder effective prevention, treatment, and economic evaluation of interventions, particularly in rural districts. One major challenge is the limited availability of economic data on the direct and indirect costs of typhoid, including treatment expenses, lost productivity, and household financial burdens [18]. This lack of comprehensive data is compounded by underreporting of cases and incomplete surveillance systems, which limit the ability to accurately assess disease burden and plan targeted interventions. Vaccine hesitancy and widespread misinformation further constrain uptake of typhoid vaccination programs, reducing their potential impact at the community level. Additionally, inconsistent donor funding and procurement challenges result in irregular vaccine supply and distribution, creating gaps in coverage and reducing program effectiveness. Another critical limitation is the relatively low health economic research capacity in Uganda, which restricts the performance of detailed cost-benefit and cost-effectiveness analyses necessary for evidence-based policy decisions [19]. To address these gaps, further research should prioritize longitudinal studies that evaluate community-level vaccination and treatment costs while incorporating environmental, behavioral, and socio-demographic risk factors to inform sustainable, context-specific interventions.

CONCLUSION

This review demonstrates that typhoid vaccination is a more cost-effective and sustainable intervention compared to treatment-based strategies in Uganda, particularly in rural areas where access to timely healthcare is limited. While urban populations benefit from closer proximity to healthcare facilities and moderately higher vaccination coverage, rural communities experience greater economic and health gains per dollar spent on preventive measures due to higher treatment costs, logistical barriers, and delayed care. Integrating the typhoid conjugate vaccine (TCV) into Uganda's Expanded Program on Immunization (EPI) could significantly reduce disease incidence, household expenditures, and the broader economic burden associated with typhoid fever. However, persistent challenges including underreporting, vaccine hesitancy, uneven donor support, and limited health economic research capacity underscore the need for context-specific strategies, strengthened surveillance, and continuous economic evaluation. Ultimately, prioritizing preventive vaccination, coupled with improved water, sanitation, and healthcare infrastructure, offers the most effective pathway to reducing typhoid-related morbidity, mortality, and economic losses in both rural and urban Ugandan settings.

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