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Impact of Malaria Vaccination Coverage on Uncomplicated and Severe Malaria Cases Among Children Under Five Years in Central Region, Ghana

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Abstract:

- ***Background:***

Malaria remains a leading cause of morbidity and mortality among children under five in sub-Saharan Africa, including Ghana. Despite significant efforts to control the disease through interventions such as insecticide-treated nets (ITNs) and indoor residual spraying (IRS), malaria continues to pose a public health challenge. The introduction of the RTS,S/AS01 malaria vaccine in 2019 aimed to complement existing interventions. However, its impact on uncomplicated and severe malaria cases among children under five in Ghana's Central Region remains poorly understood. This study assesses the impact of malaria vaccination coverage on malaria cases and explores implementation challenges associated with the Malaria Vaccine Implementation Program (MVIP).

- ***Methods:***

A retrospective longitudinal study design was employed, analyzing routine health data from the District Health Information Management System 2 (DHIMS-II) from January 2016 to December 2022. Interrupted Time Series (ITS) analysis was used to evaluate the impact of the RTS,S vaccine on uncomplicated and severe malaria cases. Qualitative interviews with healthcare workers and caregivers provided insights into implementation challenges.

- ***Results:***

The study found a complex relationship between vaccination coverage and malaria cases, with significant declines in uncomplicated malaria in some districts (e.g., Agona East, Assin Fosu, Cape Coast) but increases in others (e.g., Asikuma-Odoben-Brakwa). Qualitative data highlighted challenges such as cold chain deficiencies, financial constraints, cultural barriers, and logistical issues.

- ***Conclusion:***

The effectiveness of malaria vaccination varied across districts, underscoring the need for localized strategies to address context-specific barriers. Strengthening cold chain infrastructure, improving community engagement, and addressing logistical challenges are essential to optimize vaccine impact.

Keywords: *Malaria, RTS,S Vaccine, Children Under Five, Central Region, Ghana, Interrupted Time Series, Vaccination Coverage, Implementation Challenges.*

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I. INTRODUCTION

Malaria remains one of the most significant public health challenges in sub-Saharan Africa, particularly among children under five years of age. According to the World Health Organization (WHO), there were an estimated 241 million malaria cases globally in 2020, resulting in 627,000 deaths, with 95% of these deaths occurring in sub-Saharan Africa (WHO, 2021). Ghana, a malaria-endemic country, continues to bear a disproportionate burden of the disease. In 2019, malaria accounted for approximately 40% of all outpatient visits and 30% of all hospital admissions in Ghana (GHS, 2019). The Central Region of Ghana, with its high malaria transmission rates, recorded 11,744 malaria admissions in 2019, making it one of the regions most affected by the disease (GHS, 2019).

Despite significant efforts to control malaria through interventions such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), and effective case management, the disease persists due to factors such as drug resistance, climatic conditions, and socio-economic disparities. The RTS,S/AS01 malaria vaccine, introduced in Ghana in 2019, represents a promising tool to reduce malaria morbidity and mortality. However, its impact on uncomplicated and severe malaria cases among children under five in the Central Region remains poorly understood. This study aims to assess the impact of malaria vaccination coverage on malaria cases in this vulnerable population and explore implementation challenges associated with the Malaria Vaccine Implementation Program (MVIP).

II. METHODS

➢ *Study Design*

A retrospective longitudinal study design was employed, analyzing routine health data from the District Health Information Management System 2 (DHIMS-II) from January 2016 to December 2022. The study used an Interrupted Time Series (ITS) analysis to evaluate the impact of the RTS,S vaccine on uncomplicated and severe malaria cases. ITS is a quasi-experimental design that allows for the assessment of the impact of an intervention (in this case, the introduction of the RTS,S vaccine) by comparing trends before and after the intervention.

➢ *Study Setting*

The study was conducted in the Central Region of Ghana, which comprises 22 districts with varying malaria transmission patterns. The region has a population of approximately 2.9 million, with a significant proportion of children under five. The Central Region is characterized by a tropical climate, with seasonal rains that create breeding grounds for malaria-transmitting mosquitoes.

➢ *Data Collection*

Data on uncomplicated and severe malaria cases among children under five were extracted from DHIMS-II. The data included monthly counts of malaria cases from January 2016 to December 2022. Qualitative data were collected through semi-structured interviews with healthcare workers and caregivers involved in the MVIP. The interviews explored implementation challenges, including logistical, financial, and cultural barriers.

➢ *Data Analysis*

Quantitative data were analyzed using ITS models to assess changes in malaria cases before and after the introduction of the RTS,S vaccine. Poisson regression and quantile regression were used to estimate the impact of vaccination coverage. Qualitative data were analyzed thematically to identify key implementation challenges.

III. RESULTS

A. Quantitative Findings

The study analyzed data from 22 districts in the Central Region of Ghana, covering the period from January 2016 to December 2022. The introduction of the RTS,S malaria vaccine in May 2019 served as the intervention point for the Interrupted Time Series (ITS) analysis. The results revealed a complex and heterogeneous impact of vaccination coverage on uncomplicated and severe malaria cases across districts.

➢ *Overall Regional Trends:*

At the regional level, there was a modest decline in uncomplicated malaria cases post-vaccination, but this reduction was not statistically significant ($p=0.273$). The median number of cases decreased from 13,028.5 before vaccination to 12,436.5 after vaccination, representing a 4.5% reduction. However, the confidence interval (CI: -1,625.8 to 465.8) indicated considerable variability across districts.

➢ *District-Level Variations:*

- *Agona East District:*

This district recorded a significant decline of 169 uncomplicated malaria cases post-vaccination ($p<0.001$, CI: -233.3 to -104.7). The immediate impact of the vaccine was evident, with a 24% reduction in cases during the first month ($p=0.049$). However, the sustained impact was less pronounced, with a 4% increase in cases after the first month ($p=0.029$).

- *Assin Fosu District:*

A reduction of 123 uncomplicated malaria cases was observed ($p<0.001$, CI: -177.7 to -68.3). The vaccine showed an immediate but transient impact, with a 46% increase in cases in the first month ($p=0.003$), followed by a 5% decline in subsequent months ($p=0.006$).

- *Cape Coast District:*

This district experienced a sustained reduction in malaria cases, with a 25% decline in the first month ($p=0.020$) and a 13% reduction in subsequent months ($p<0.001$). The median number of cases decreased from 574 to 381 post-vaccination.

- *Asikuma-Odoben-Brakwa District:*

Contrary to expectations, this district saw a 57% increase in uncomplicated malaria cases in the first month post-vaccination ($p=0.004$), followed by a 5% increase in

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subsequent months (p=0.001). This suggests potential challenges in vaccine implementation or coverage in this district.

➢ *Severe Malaria Cases:*

The impact of vaccination on severe malaria cases was less pronounced. While some districts showed modest reductions, the overall regional trend was not statistically significant. For example, in Agona East, severe malaria cases decreased by 12% (p=0.045), but in Asikuma-Odoben-Brakwa, cases increased by 8% (p=0.032).

B. Qualitative Findings

The qualitative interviews with healthcare workers and caregivers revealed several implementation challenges that likely influenced the variability in vaccine impact:

➢ *Cold Chain Deficiencies:*

Many health facilities lacked adequate cold chain infrastructure, such as vaccine fridges, leading to vaccine spoilage and stockouts. One healthcare worker noted, *"Sometimes, we receive vaccines, but we have no way to store them properly. This affects our ability to vaccinate children consistently."*

➢ *Financial Constraints:*

Limited funding for the MVIP hindered vaccine distribution and awareness campaigns. A district health director stated, *"We often run out of funds for outreach programs, which limits our ability to reach remote communities."*

➢ *Cultural Barriers:*

Misconceptions about the vaccine and cultural resistance were significant barriers. A caregiver shared, *"Some people believe the vaccine is harmful or unnecessary because malaria is seen as a normal part of life."*

➢ *Logistical Challenges:*

Transporting vaccines to remote areas was a major challenge, particularly during the rainy season. A community health nurse explained, *"The roads are often impassable, and we struggle to deliver vaccines on time."*

➢ *Community Engagement:*

While some districts had strong community engagement programs, others lacked effective strategies to promote vaccine uptake. A healthcare worker emphasized, *"When communities are involved and understand the benefits, vaccination rates improve significantly."*

IV. DISCUSSION

The findings of this study highlight the complex and context-dependent impact of the RTS,S malaria vaccine in Ghana's Central Region. While the vaccine demonstrated significant reductions in uncomplicated malaria cases in some districts, its effectiveness varied widely, with some districts experiencing increases in cases. These results underscore the importance of addressing implementation challenges to optimize vaccine impact.

A. District-Level Variability

The variability in vaccine impact across districts can be attributed to several factors:

➢ *Cold Chain Infrastructure:*

Districts with robust cold chain systems, such as Agona East and Cape Coast, showed significant reductions in malaria cases. In contrast, districts with cold chain deficiencies, such as Asikuma-Odoben-Brakwa, experienced increases in cases. This aligns with previous studies emphasizing the critical role of cold chain systems in vaccine effectiveness (Conteh et al., 2021).

➢ *Community Engagement:*

Districts with strong community engagement programs reported higher vaccination coverage and better outcomes. For example, in Cape Coast, community leaders played a pivotal role in promoting vaccine uptake, leading to sustained reductions in malaria cases. This finding is consistent with the Health Belief Model (HBM), which highlights the importance of perceived benefits and community cues to action in health interventions (Glanz et al., 2008).

➢ *Logistical and Financial Barriers:*

Logistical challenges, such as poor road infrastructure and limited funding, hindered vaccine delivery in remote areas. These barriers were particularly pronounced in districts like Asikuma-Odoben-Brakwa, where vaccine stockouts and delays were common. Similar challenges have been reported in other low-resource settings, underscoring the need for targeted investments in vaccine logistics (Gosling & von Seidlein, 2016).

B. Implications for Policy and Practice

The study has several implications for malaria control policies and vaccination programs:

➢ *Strengthening Cold Chain Systems:*

Investments in cold chain infrastructure are essential to ensure vaccine efficacy. This includes providing vaccine fridges, training healthcare workers, and establishing monitoring systems to prevent stockouts.

➢ *Enhancing Community Engagement:*

Culturally sensitive community engagement programs can address misconceptions and promote vaccine uptake. Strategies such as involving local leaders, using local languages, and conducting awareness campaigns have proven effective in other settings (Tabiri et al., 2021).

➢ *Addressing Logistical Challenges:*

Improving transportation networks and allocating sufficient funding for vaccine distribution are critical to reaching remote communities. Mobile clinics and outreach programs can help bridge gaps in healthcare access.

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➢ *Adaptive, Localized Strategies:*

The variability in vaccine impact across districts highlights the need for adaptive, context-specific strategies. District-level process evaluations can identify local barriers and inform tailored interventions.

C. Comparison with Existing Literature

The findings of this study align with and expand upon existing literature on malaria vaccination. For example:

- The modest efficacy of the RTS,S vaccine (39% against uncomplicated malaria and 29% against severe malaria) has been well-documented in clinical trials (Olotu et al., 2016). However, real-world effectiveness is often lower due to implementation challenges, as observed in this study.
- The importance of cold chain systems and community engagement has been emphasized in previous studies (Conteh et al., 2021; Gosling & von Seidlein, 2016). This study provides additional evidence of their critical role in vaccine effectiveness.
- The variability in vaccine impact across districts is consistent with findings from other regions, highlighting the need for localized strategies (Tabiri et al., 2021).

V. CONCLUSION

The RTS,S malaria vaccine has the potential to reduce malaria morbidity among children under five in Ghana's Central Region. However, its impact varies significantly across districts, highlighting the need for context-specific strategies. Addressing cold chain deficiencies, financial constraints, and cultural barriers is essential to maximize the vaccine's effectiveness. Future research should explore the long-term impact of the vaccine and the role of other malaria control interventions in reducing transmission.

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