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Predictors of Malaria Vaccine Hesitancy Among Caregivers in Bumula Subcounty, Bungoma County

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Abstract **Background:** Malaria is a disease that threatens health and economy of the world and is number nine among the diseases in contributing to high mortality and disability worldwide. Available WHO-recommended malaria control strategies are becoming less effective due to drug and insecticide resistance and parasite undetectability. In 2019, Mosquirix (RTS, S) vaccine was introduced to complement the existing package towards malaria prevention in children, making malaria a vaccine preventable disease (VPD). Vaccine hesitancy (VH) is a developing pattern in global health. **Broad Objective**: To determine the predictors of malaria vaccine hesitancy among caregivers in Bumula subcounty, Bungoma County, Kenya. **Methodology:** The cross-sectional study sampled 419 caregivers and their children eligible for four malaria vaccine doses by December 2022. Caregivers were interviewed face-to-face using a structured customized WHO-SAGE vaccine hesitancy questionnaire. Qualitative data was collected through 4 focus group discussions (FGDs) with 38 community health volunteers (CHVs) and key informant interviews (KIIs) with 10 key informants (KIs). Quantitative data was entered in SPSS version 28.0.1. Chi-square test was used at bivariate level and logistic regression at multivariate level. Significance level was set at 5%. Qualitative data was coded, categorized, summarized, and entered in WHO-SAGE BeSD qualitative data analysis template, where a framework was used to generate results. **Findings:** Out of 419 caregivers, 86.9% were female while 13.1% were male, mean age was 31.31 years and ranged from 17 to 80 years. Majority (71.8%) were married, and 89.5% Christian. Out of the 419 children, 52.5% were male and mean age was 29.32 months and ranged from 24 and 46 months. The uptake of first dose was 97.6%, which reduced to 96.2% for second dose, 86.6% for the third dose and finally 62.8% for the fourth dose. Vaccine hesitancy was at 37.2%, while vaccine acceptance was 62.8%. There were 13 significant independent variables from the chi-square bivariate analysis; religion ($\chi2$=13.274, df=3, P.=0.004) age of child ($\chi2$=6.739, df=2, P.=0.034), relationship between caregiver and child ($\chi2$=13.287, df=3, P.=0.004), previous decision not to get malaria vaccine for the child ($\chi2$=5.523, df=1, P.=0.019), feeling that information on malaria vaccine was being openly shared ($\chi2$=12.146, df=1, P.=0.00), trust on what the MoH says about malaria vaccine ($\chi2$=7.160, df=1, P.=0.007), source of verification of negative information on malaria vaccine ($\chi2$=15.368, df=3, P.=0.002), knowledge of any group or leaders, or individuals opposed to malaria vaccination ($\chi2$=9.291, df=1, P.=0.002), awareness of people in my community opposed to malaria vaccine due to religion ($\chi2$=8.224, df=1, P.=0.004) trust on malaria vaccine manufacturers to have good intentions for the child and other children in community($\chi2$=7.168, df=1, P.=0.007), having enough information about malaria vaccine and its safety ($\chi2$=6.344, df=1, P.=0.012), confidence level in the safety of malaria vaccine ($\chi2$=21.119, df=3, P.=0.000), trust in the country to manage risks associated with malaria vaccine side effects ($\chi2$=4.441, df=1, P.=0.035) and trust in the health system to deliver malaria vaccine to your community ($\chi2$=0.185, df=1, P.=0.667). At logistic regression analysis at multivariate level, 4 out of the 13 remained significant; Age of the child (AOR 0.634, 95% CI 0.418-0.962), information about malaria vaccine openly shared (AOR 4.085, 95% CI 1.671-9.987), source of verification of negative information about the malaria vaccine (AOR 1.573, 95% CI 1.120-2.207) and opposition to malaria vaccine linked to religion (AOR 0.581, 95% CI 0.352-0.958). The logistic regression model was statistically significant, $\chi2 = 37.076$, $p < .000$. The model explained 11.6% (Nagelkerke R2) of the variance in vaccine uptake and correctly classified 65.9% of cases. **Conclusions**: Uptake of the first and second doses met WHO's target coverage for vaccines, but uptake of the third and fourth doses do not. Malaria vaccine hesitancy is high, influenced by religion, confidence on the vaccine, open sharing of information and source of verification.

Keywords Malaria Vaccine, Vaccine Hesitancy, Behavioural and Social Determinants

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1. Introduction

Background

In 2020, there were about 241 million malaria cases and 627 000 malaria deaths globally. Malaria case incidence increased from 59 per 1000 population in 2015 to 56 per 1000 population in 2019, before rising to 81 per 1000 population in 2020. The rise was linked to COVID-19 pandemic which disrupted malaria control services. A decade ago, there were 251 million cases, hence there was progress in reduction except for the Covid-19 pandemic 24) [24].

Malaria is an important public health preventable disease in Kenya responsible for 13%-15% of outpatient cases. Its transmission and infection risks are influenced by altitude, rainfall patterns, and temperature, leading to huge difference in malaria prevalence seasonally and geographically. Approximately 70% of the Kenyan population is exposed to malaria, with 13 million and 19 million people in endemic and highland epidemic prone transmission areas, respectively. Malaria is a top cause of infant morbidity and mortality. Both children and pregnant women are at risk [11].

WHO-recommended core package of several tools is in use for malaria prevention, diagnosis, and treatment. These tools include protection from bites using Insecticide-Treated Mosquito Nets (ITNs), ridding the households of mosquitos by Indoor Residual Spraying with insecticides (IRS), preventing malaria in pregnancy using intermittent preventive treatment (IPTp) and timely diagnosis and treatment of confirmed cases using Artemisinin-based Combination Therapy (ACTs).

Recently, vaccination was identified as an additional tool to prevent malaria in children, making malaria a vaccine preventable disease (VPD). The Mosquirix (RTS, S) vaccine, which took 30 years to develop, has been clinically tried and is now in phased rollout [20]. Phase 3 clinical trials were done in 2009-2014 in a network of African research sites. Three of these sites are in Kenya and include Kombewa, Siaya and Kilifi. The trials involved more than 4,000 Kenyan children [15]. Children receiving four doses of RTS, S had reduced malaria and malaria-related complications compared to the control group [25]. Findings from the trial showed significant reduction of malaria in children, by 29%, including severe malaria and hospitalization [22].

Malaria vaccine is now in phased rollout in 3 countries in Africa (Ghana, Kenya, and Malawi). In Kenya, the rollout is in selected sites in 8 counties which had malaria burden of more than 20% (Siaya, Busia, Bungoma, Kakamega Homa Bay, Kisumu, Migori and Vihiga) in 2019. RTS, S which is given at 6,7,9 and 24 months was officially launched in September 2019 for routine use in Kenya [15].

Statement of the Problem

Malaria is a disease that threatens health and economy of the world. It is number nine among diseases in causing death and disability worldwide [2]. In 2020, there were about 241 million malaria cases and 627 000 malaria deaths globally. In Kenya, 70% of the population is exposed to malaria. WHO-recommended core package of several tools is in use for malaria prevention, diagnosis, and treatment. These tools include protection from bites using Insecticide-Treated Mosquito Nets (ITNs), ridding households of mosquitos by Indoor Residual Spraying with insecticides (IRS), preventing malaria in pregnancy using intermittent preventive treatment (IPTp) and timely diagnosis and treatment of confirmed cases using Artemisinin-based Combination Therapy (ACTs) [2].

In 2019, a new tool was introduced to complement the existing package towards malaria prevention in children. This was the RTS, S malaria vaccine that has shown promising results from the clinical trials, pilot, and ongoing phased rollout. Vaccine Hesitancy (VH) and acceptability studies indicate inhibitors and promoters of new vaccine uptake that may hinder the roll out of the new malaria vaccine. A study done in Ethiopia on willingness by caregivers to accept malaria vaccine for their children showed that the level of acceptance was 32.3%, where marital status (AOR = 1.243), knowledge (AOR = 3.120), and earlier encounter of childhood vaccination (AOR = 2.673) were significant predictors of acceptance of malaria vaccine [3].

A study done in Ghana, which is one of the three pilot countries, showed that full uptake was at 78%, which is below the WHO-recommended level of 90% [9].

Studies done by Achieng et al. in Kenya on acceptability of the vaccine before rolling out revealed that an average 88% of the population approved the malaria vaccine for their own child and community. The highest acceptance would be 98.9% in malaria-endemic region, and lowest at 23% in the seasonal transmission areas [2].

A study on perceptions of malaria vaccines before it was introduced in Kenya showed that uptake of malaria vaccine would be affected by culture, delivery of immunization services, level of education, existence of traditional methods to prevent malaria, gender, age, cohorts of caregivers and access. Most (94%) of the population with some schooling would accept the vaccine for a child, compared to 56% acceptance among those without schooling [22].

Vaccine hesitancy (VH) is challenge in global health that the new vaccines face. Covid-19 VH was reported across the world, even among health care workers [18]. Polio vaccination was rejected in Northern Nigeria because of erroneous judgment by the religious leaders. Communities in Ghana rejected mass deworming due to misinterpretation of its intentions. Malaria VH has been reported in Ethiopia, Rwanda, and Uganda [9].

The study therefore sought to establish the level of hesitancy for this malaria vaccine, and the associated predictors in Bumula Subcounty, Bungoma County.

Research Questions

1. What is the uptake level of the 4 doses of malaria vaccine?
2. What is the prevalence of malaria vaccine hesitancy?
3. What are the behavioural and social predictors of malaria vaccine uptake and hesitancy?

General Objective

To determine the predictors of malaria vaccine hesitancy among caregivers in Bumula subcounty, Bungoma County, Kenya.

Specific Objectives

1. To determine the level of uptake of the 4 doses of malaria vaccine.
2. To determine the prevalence of malaria vaccine hesitancy.
3. To determine the behavioural and social predictors of malaria vaccine uptake and hesitancy.

Significance of the Study

Available WHO-recommended control strategies against malaria are being faced with challenges due to drug and insecticide resistance and parasite undetectability, hence new and complementary tools such as malaria vaccine are timely to further reduce the disease burden. Kenya launched and introduced the malaria vaccine in phases in September 2019, to be an additional tool to control malaria, particularly among children.

The study provided information on uptake and hesitancy levels of the malaria vaccine, with associated sociodemographic, interpersonal, contextual, and organizational predictors.

This information obtained from of this study will be useful in developing strategies towards improving uptake to WHO-recommended levels in the pilot sites as well as when the vaccine will be rolled out across the country.

The study will be useful to Bungoma County and Bumula subcounty which is in the malaria lake-endemic region, as they will utilize the results of this study to improve uptake.

2. Methodology

Study design

This study utilized a cross-sectional design. Caregivers whose children were eligible for the four doses of the RTS, S vaccine as of December 2022 were recruited as participants. The participants were recruited, and data collection was done from 26th December 2022 to 20th January 2023. Prevalence of malaria vaccine hesitancy and associated predictors at the time of the study was determined. 38 CHVs and 10 KIs were also interviewed for qualitative data.

Study site

Bumula sub county is among the 10 sub counties in Bungoma County, which is in the malaria lake-endemic zone of Kenya. The subcounty is 345.2 km square, with a population density of 625 per km square. It has a population of about 220,000, with a total of 7 wards (*KNBS, 2019*). Males are about 105,000 while females are about 115,000. On average, each household has 4.8 members, which is higher than the national mean family size of 3.6 children. The population which lives below poverty line is 60% in the subcounty, compared to the national average of 53% (*KNSS*, 2021). The main economic activity is farming. The Bukusu tribe, which is a subset of the Luhya tribe, is the dominant group. Most of the population are Christians. Household heads are predominantly males, while females care for their children and conduct household chores. The mean age of marriage is 16 years for women and 18-27 for men. Bumula subcounty has 23 health facilities, with 18 public and 5 private facilities. The public facilities are one sub county hospital, five health centers, 12 dispensaries and 276 Community Units (CUs). The CHVs, who work in the 276 CUs are supervised by Community Health Extension workers. (CHEWs) and linked to the health facilities. The CHVs are trained to provide promotive, preventive, and basic treatment health services to children and the rest of the population, such as diarrhea, malaria, and pneumonia.

Study population

The caregivers of children who were eligible for all the four doses of the malaria vaccine between September 2019 and September 2022 were included in the study. The children whose caregivers were interviewed on their behalf, were 24 months to 46 months old by December 2022 since the fourth and final malaria vaccine dose is given at 24 months. Those younger than 24 months were too young to qualify for the fourth dose, while those older than 46 months were too old to have qualified for the first dose of malaria vaccine at 6 months when it was introduced in September 2019. The caregivers/children were identified from their attendance of the child welfare clinics (CWCs) clinics of the selected facilities.

Qualitative data were collected through 4 FGDs and KIIs. The FGDs were conducted with 38 CHVs from the 19 CHUs linked to 4 of the 7 sampled health facilities. KIIs were conducted with 10 KIs from SCHMT and the 7 health facilities. Subcounty Community health strategy focal person (SCCHSFP), subcounty malaria control coordinator (SCMCC) and subcounty public health nurse (SCPHN) from the subcounty health management team (SCHMT) were interviewed, and 7 health care staff each from the 7 sampled facilities were interviewed.

Inclusion criteria

Caregivers of children eligible for the four malaria vaccine doses between September 2019 and December 2022 attending the health facilities sampled were included.

Exclusion criteria

Caregivers of children who took part of the vaccines in another facility were excluded as it was hard to verify the uptake of the doses in the CWC register. Caregivers of children who were extremely sick during the interview day at

the facility were also excluded to enable them to attend to the child.

Sample Size

Cochrane's formula was used to determine the sample size of children whose caregivers were recruited into the study.

$$n = \frac{Z^2 pq}{e^2} \quad (1)$$

n is the sample size.

Z=1.96 is the Z-score at 95% confidence interval, assuming normal distribution table

P=0.5.

Q=0.5, which is the compliment of P, thus (1-P), and

e=0.05 is the sampling error. Thus, sample size comes to be, $n=1.96^2(0.5)(0.5)/(0.05)^2 \simeq 384$

A 10% allowance was made for non-response, and therefore a sample size of 423 children was targeted.

The 39 CHVs and 10 KIs were purposefully sampled based on their role in malaria vaccine rollout and their availability.

Sampling Methods

Clustered sampling was used to ensure the children were from each of the 7 wards. Each facility per ward was purposefully selected based on workload, the level of care and period of offering the malaria vaccine. The level of care classifies health facilities as level 2(dispensaries), level 3(health centres) and Level 4(hospitals) and was factored in to take care of possible variance in uptake due to the varied range of services in each level. The selected facilities should have been offering the vaccine from September 2019 when the vaccine was launched, to ensure that there were adequate numbers of children eligible for the four doses. The CWC workload, which is the number of children served by a health facility in each period, was used to calculate proportionate number of children to be sampled from each facility. The overall sampling ensured the children were representative of each of the three levels of care (level 2-4) and the wards which are heterogenous and allowed for comparison across levels and wards. Overall, seven facilities were sampled, one per ward. Proportionately, 1 subcounty hospital (SCH), 3 health centres (HCs) and 3 dispensaries were selected.

The 39 CHVs and 10 KIs were selected purposefully based on their role in malaria vaccine rollout and availability.

For the predictors, systematic sampling was utilized to select children proportionately from each health facility. Using the Child Welfare Clinic (CWC) registers at the 7 health facilities, a sampling frame was constructed. Children who are eligible for the 4 doses of the malaria vaccine were sampled. A sampling interval was decided for each sampling frame using the following formula.

$$K = \frac{N}{n} \quad (2)$$

where K is the sampling interval, N is the number of children in the sampling frame, and n is the sample size for the health facility. The sample per facility was computed proportionately from the target per facility. Simple random sampling was used to identify the first sample in each facility at the beginning of the day. Subsequent samples were determined by adding the sampling interval to the number of the first drawn sample until all samples required for the health facility are drawn. The caregivers of the selected children were requested to be interviewed after getting their consent. Nonrespondents were replaced by the next immediate eligible child on the CWC register.

Variables

The study collected data on dependent variable (vaccine uptake) and classified the respondents as either vaccine accepting (full uptake of all four doses) or vaccine hesitant (partial or no uptake of the doses). Data on possible sociodemographic, interpersonal, contextual, and organizational predictors was collected and analyzed for significance of association with the dependent variable.

Data collection

A structured questionnaire customized from the WHO-SAGE vaccine hesitancy matrix was administered to the caregivers to collect primary data on socio-demographic characteristics, individual, group, contextual and vaccine-specific influences on malaria vaccine hesitancy. The caregivers were interviewed face-to-face and were identified from the CWC register of the children eligible for the 4 doses of malaria vaccine and attending the facility on the day of data collection.

The questionnaire was structured into four sections. Section one covered socio-demographic variables such as age, religion, gender, level of education, employment, distance from facility and size of household. Section two covered individual and group influences due to personal perception or influences of the social/peer environment about the vaccine. Section three covered contextual influences such as historical, environmental, socio-cultural, health systemic or institutional, political, or economic factors. Section four covered vaccination specific issues such as safety, health facility factors, source of vaccine supply or reliability.

An interviewer guide customized from WHO-SAGE vaccine hesitancy matrix was used to guide the 4 FGDs and the key informant interviews (KIIs). The tools were piloted at Bumula Subcounty Hospital and relevant updates made.

CHVs and health facility vaccinators were trained and engaged to assist in administering the questionnaire face-to-face on the recruited caregivers. Two research assistants were recruited to support data collection and cleaning. The two research assistants were nurses and had experience in the MCH and were familiar with Bumula subcounty and the facilities. Prior to fieldwork, the research assistants and the data collectors were trained to ensure they were fully appraised of the research, data collection tools, informed consent process, ethical considerations when recruiting and engaging respondents, data quality, safety and confidentiality, honesty and integrity during data collection and logistics.

Data management and analysis

The filled hard copy interview questionnaires were securely and confidentially kept by the principal investigator. Data cleaning was done to check the completeness of the data. Quantitative Data was entered in SPSS version 28.0.1.

Descriptive and inferential statistics were applied for all variables. Chi-square test was used at bivariate level and logistic regression at multivariate level. Significance level was set at 5%. Qualitative data was coded, categorized, summarized, and entered in WHO-SAGE BeSD qualitative data analysis template, where a framework was used to generate results.

Ethical considerations

Informed consent was obtained from the respondents. The eligible participants identified from the CWC register were approached at the end of the CWC services and requested to participate as respondents after being briefed by the CWC health care worker. Those who accepted were ushered into a separate private room within the CWC or MCH or the health facility where they were given time to consent. Privacy was ensured through interviewing in a separate private room in the health facility. All the information from respondents was treated with the confidentiality it deserved. Respect and dignity were upheld while collecting data. The filled questionnaires were coded to ensure the respondents could not be identified in person. Names and other personal identifiers traceable to the respondent were not collected. As soon as questionnaires were filled, it was safely secured and only accessible to the interviewer and the investigators. Although the study did not benefit the participants directly, their responses will inform future interventions which will benefit the community at large. The study had no risks, and in case any had unexpectedly arisen, the interview with the affected respondent would have been terminated. All respondents were assured of the freedom to withdraw at any point in the interview, with no consequences to them. The data for the two participants who withdrew were discarded.

An approval was sought from the National Commission of Science, Technology, and Innovation (NACOSTI), and a research license number NACOSTI/P/23/22814 was issued. Ethical and scientific approval was sought from AMREF Ethics and Scientific Research Committee (ESRC), and approval letter number P1307/2022 was issued. Permission was sought from the office of the County Director of Health, Bungoma County, and authorization letter CG/BGM/CDH/RESRC/Vol.1 was issued. The authorization letter from the county was copied to Bumula Subcounty and health facilities where the research was done.

Study Limitations

This study was conducted in only 1 of the 8 sub counties where the malaria vaccine is being rolled out. Considering that the behavioral and social determinants could vary, the results may therefore not be generalizable to the whole population. The study was done in a limited period and with a small sample due to time and financial constraints. It is recommended that further research over a long period and with a bigger sample be done to ascertain the findings.

3. Results

Characteristics of Respondents

A total of 419 caregivers and their children, ten key informants and 38 FGD participants were recruited into the study.

Sociodemographic Characteristics of the Caregivers

A total of 419 caregivers and 38 key informants participated in the study. Majority (86.9%) of caregivers were female while 13.1% were male. The mean age of caregivers was 31.31 years (24, 35 years), and ranged from 17 to 80 years. 45.1% of the caregivers were 25-34 years, while 27.4% were below 24 years, and 27.4 were above 35 years. The majority (71.8%) of the caregivers were married, while 18.9% were single, 6.4% widowed and 2.9% divorced. Majority (89.5%) of the caregivers were Christian. 55.8% of the caregivers were not employed, while 28.9% had informal employment and 15.3% formally employed. 38.2% of the caregivers had primary education as their highest level of education, while 41% had secondary education, 3.8% had no formal education and 16.2% had tertiary education.

The mean number of members per family was 4.24, with a range of 2 to 14 members. Half (50%) of the families had 4-7 members, while 42.7% had below 3 members. Average monthly income of the caregiver is 9179.71(3000, 6000 Kenya shillings), with a range from 0 to 300,000 Kenya shillings. 50% of the caregivers had a salary of 5,000 and below, while 38.4% had salary of between 5001-10000.

Details of the distribution of the socio-demographic characteristics of caregivers are shown in ***Table 1*.**

Sociodemographic characteristics of the children

About half (52.5%) of the children were male while 47.5% were female. The mean age of the children was 29.32 months and ranged from 24 and 46 months. Most (71.8%) of the children were between 25-36 months, while 20.8% were below 2 years, and the rest (7.4%) were above 3 years.

Most (82.8%) of caregivers were biological parents, while 10.3% were grandparents and 5.7% relatives.

Details of the distribution of the socio-demographic characteristics of caregivers are shown in ***Table 2*** below.

Malaria Vaccine Uptake

Full uptake of the malaria vaccine was 62.8%, while partial uptake was at 34.8% (1 dose at 1.4%, 2 doses at 9.5% and 3 doses at 23.9%) and no uptake at 2.4%. Uptake of the first dose was 97.6%, which reduced to 96.2% for second dose, 86.6% for the third dose and finally 62.8% for the fourth dose. The uptake is as shown in Figure 1 below.

Overall vaccine hesitancy was at 37.2%, while vaccine acceptance was 62.8%, as shown in Figure 2 below. Individual dose hesitancy was 2.4%, 3.8%, 13.4% and 37.2% for 1st, 2nd, 3^{rd,} and 4th dose respectively.

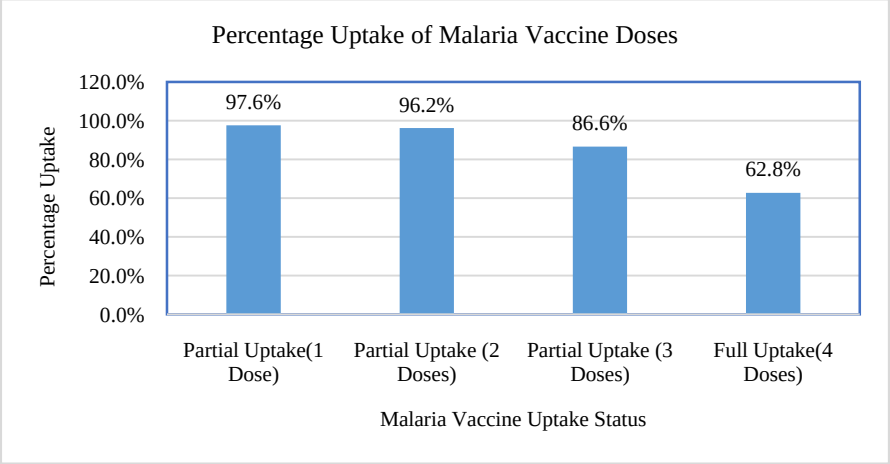

Figure 1. Malaria Vaccine Uptake

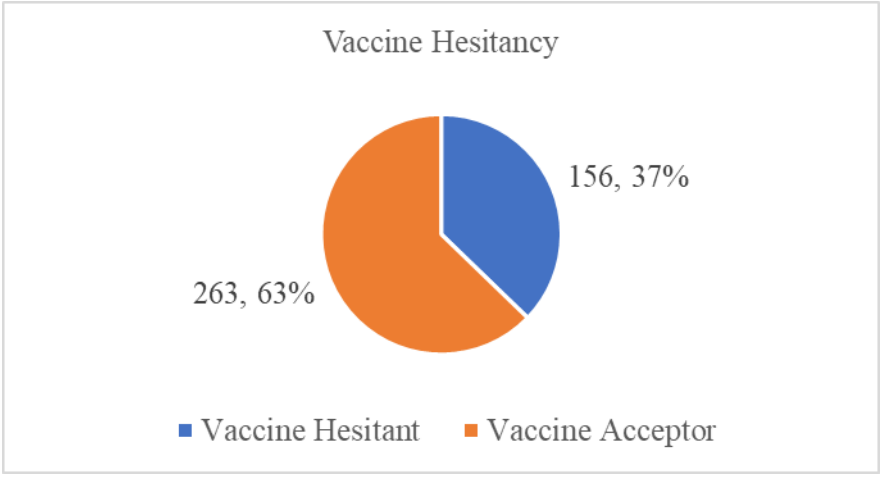

Figure 2. Malaria Vaccine Hesitancy Chart

Association between Vaccine Hesitancy and Caregiver Sociodemographic Variables

Male caregivers were likely to be vaccine hesitant compared with female caregivers, with 40% of the 55 male caregivers being vaccine hesitant compared to 36.8% of the 364 female caregivers. Despite this, gender was not significantly associated with vaccine hesitancy ($\chi2$=0.208, df=1, P.=0.649).

There was an increase in vaccine hesitancy with age, with 25-34 age category with 31.7%, which rose steadily to 48.1% for 55 and above age category. However, age of caregiver was not significantly associated with vaccine hesitancy ($\chi2$=5.518, df=4, P.=0.238).

The divorced and the widowed caregivers had about 50% vaccine hesitancy, compared to the single and the married whole hesitancy was lower at 32.9% and 36.9% respectively. Association between marital status and vaccine hesitancy was not significant ($\chi2$=2.861, df=3, P.=0.414).

Traditionalists had the highest vaccine hesitancy among the religions at 73.3%, followed closely by Muslims at 66.7%. Christians had vaccine hesitancy of 34.7%. Religion was significantly associated with vaccine hesitancy ($\chi2$=13.274, df=3, P.=0.004) with caregivers who are Christians more likely to accept the malaria vaccine compared to Muslims and traditionalists.

Caregivers with no formal education were more vaccine hesitant at 56.3%, which reduces to 38.8% VH for primary, 34.9% for secondary and 35.3% for tertiary level caregivers. Despite this decrease in vaccine hesitancy with increase in education, education of caregiver was not significantly associated with vaccine hesitancy ($\chi2$=3.166, df=3, P.=0.367).

Caregivers with no employment had the highest hesitancy at 40.2%, followed by those with formal employment at 37.5%. those with Informal employment had the lowest hesitancy at 31.4%. Employment status of the caregiver was not significantly associated with vaccine hesitancy ($\chi2$=2.625, df=2, P.=0.269).

Caregivers with highest income category of KES. 15,000 and above had the highest VH at 31.9%, compared to the other categories whose hesitancy decreased with decrease in income. Despite this, income was not significantly associated with vaccine hesitancy ($\chi2$=0.747, df=3, P.=0.862).

The bigger the family size, the higher the hesitancy, with families of below 3 members having 35.2% vaccine

hesitancy, 4-7 members 38.2% and 8 members and above 42.9% vaccine hesitancy. This association between family size and vaccine hesitancy was not significant ($\chi2$=0.783, df=2, P.=0.676).

In summary, out of the eight sociodemographic characteristics of the caregiver, only religion ($\chi2$=13.274, df=3, P.=0.004) was significantly associated with vaccine hesitancy, as summarized in ***Table 1*** below.

Table 1. Sociodemographic Characteristics of the Caregivers

Sociodemographic Variable of Caregiver		Vaccine Hesitancy					
		Vaccine Hesitant Not fully vaccinated at 24 months		Vaccine Acceptor Fully vaccinated 24 months		Total	Chi-Square
		n	%	n	%		
Gender of the Caregiver	Male	22	40.0%	33	60.0%	55	$\chi2$=0.208 df=1 P.=0.649
	Female	134	36.8%	230	63.2%	364	
Age of Caregiver	24 and below	49	42.6%	66	57.4%	115	$\chi2$=5.518 df=4 P.=0.238
	25-34	60	31.7%	129	68.3%	189	
	35-44	25	37.3%	42	62.7%	67	
	45-54	9	42.9%	12	57.1%	21	
	55 and above	13	48.1%	14	51.9%	27	
Marital Status of the Caregiver	Single	26	32.9%	53	67.1%	79	$\chi2$=2.861 df=3 P.=0.414
	Married	111	36.9%	190	63.1%	301	
	Widowed	13	48.1%	14	51.9%	27	
	Divorced	6	50.0%	6	50.0%	12	
Religion of caregiver	Christian	130	34.7%	245	65.3%	375	$\chi2$=13.274 df=3 P.=0.004
	Muslim	6	66.7%	3	33.3%	9	
	Traditionalist	11	73.3%	4	26.7%	15	
	Others	9	45.0%	11	55.0%	20	
Education Level of caregiver	None	9	56.3%	7	43.8%	16	$\chi2$=3.166 df=3 P.=0.367
	Primary	62	38.8%	98	61.3%	160	
	Secondary	61	34.9%	114	65.1%	175	
	Tertiary	24	35.3%	44	64.7%	68	
Employment Status of Caregiver	Not Employed	94	40.2%	140	59.8%	234	$\chi2$=2.625 df=2 P.=0.269
	Informal Employment	38	31.4%	83	68.6%	121	
	Formal Employment	24	37.5%	40	62.5%	64	
Income of caregiver	5000 and below	71	37.2%	120	62.8%	191	$\chi2$=0.747 df=3 P.=0.862
	5001-10000	62	38.5%	99	61.5%	161	
	10001-15000	8	40.0%	12	60.0%	20	
	15001 and above	15	31.9%	32	68.1%	47	
Family size	3 and below	63	35.2%	116	64.8%	179	$\chi2$=0.783 df=2 P.=0.676
	4-7	81	38.2%	131	61.8%	212	
	8 and above	12	42.9%	16	57.1%	28	

Association between Vaccine Hesitancy and Child Sociodemographic Variables

More (41.2% of the 199) female children eligible for malaria vaccine were vaccine hesitant compared to 33.6% of the 220 male children who were vaccine hesitant. However, gender of the children was not significantly associated with vaccine hesitancy ($\chi2$=2.562, df=1, P.=0.109).

Vaccine hesitancy increased with increase in age of the child, with 25.3% of children aged 24 months being vaccine hesitant compared to 40.2% for those aged 25-36 months and 41.9% for those aged 37 months and above. This association of age and vaccine hesitancy was significant ($\chi2$=6.739, df=2, P.=0.034).

Children whose caregivers were relatives had the highest vaccine hesitancy at 70.8%, while those whose caregivers were biological parents had the lowest vaccine hesitancy at 34.3%. Relationship between caregiver and child was significantly associated with vaccine hesitancy ($\chi2$=13.287, df=3, P.=0.004).

The association between vaccine hesitancy and sociodemographic characteristics of the children is ***Table 2*** below.

Table 2. Sociodemographic Variables of the Children

Sociodemographic variables of the children		Vaccine Hesitancy					
		Vaccine Hesitant Not fully vaccinated at 24 months		Vaccine Acceptor Fully vaccinated 24 months		Total	Chi-Square
		n	%	n	%		
Gender of the child	Male	74	33.6%	146	66.4%	220	$\chi2$=2.562 df=1 P.=0.109
	Female	82	41.2%	117	58.8%	199	
Age of Child(months)	24 and below	22	25.3%	65	74.7%	87	$\chi2$=6.739 df=2 P.=0.034
	25-36	121	40.2%	180	59.8%	301	
	37 and above	13	41.9%	18	58.1%	31	
Relationship between caregiver and child	Biological Parent	119	34.3%	228	65.7%	347	$\chi2$=13.287 df=3 P.=0.004
	Grandparent	18	41.9%	25	58.1%	43	
	Relative	17	70.8%	7	29.2%	24	
	Others	2	40.0%	3	60.0%	5	

Association between Vaccine Hesitancy and Health Facility Characteristics

The highest percentage of the caregivers who were vaccine hesitant were from South Bukusu and Kabula Wards at 47.4% and 46.8% respectively. The lowest percentage of vaccine hesitant caregivers were from West Bukusu and Kimaeti, at 22.9% and 29.25% respectively. Despite this disparity on VH across wards, ward was not significantly associated with vaccine hesitancy ($\chi2$=11.151, df=6, P.=0.084).

Level of care of health facility attended by the caregiver was not significantly associated with vaccine hesitancy ($\chi2$=0.086, df=2, P.=0.958) as vaccine hesitancy of the caregivers across levels ranged from 36.4% to 37.9%, a difference of only 1.5%.

The mean distance to the nearby health facility was 2.83 kilometres (1, 4 kilometres), with a range from 0 to 20 kilometres. Most (73%) of the caregivers were 3 kilometres or less from the health facility, while 21.5 % were 4-7 kilometres away. The longer the distance from the health facility, the higher the vaccine hesitancy, with 35.9% of the caregivers 3km and below being vaccine hesitant, compared to 40% of those 4-7km away, and 43.5% of those 8 km and above away from the health facility. Despite this, distance from the health facility of the caregiver was not significantly associated with vaccine hesitancy ($\chi2$=0.895, df=2, P.=0.639).

Table 3 below summarizes the health facility details and their relationship with vaccine hesitancy.

Table 3. Health Facility Variables

Health Facility Variables		Vaccine Hesitancy					
		Vaccine Hesitant Not fully vaccinated at 24 months		Vaccine Acceptor Fully vaccinated 24 months		Total	Chi-Square
		n	%	n	%		
Ward	Bumula	33	36.7%	57	63.3%	90	$\chi2$=11.151 df=6 P.=0.084
	Kabula	44	46.8%	50	53.2%	94	
	Khasoko	8	38.1%	13	61.9%	21	
	Kimaeti	28	29.2%	68	70.8%	96	
	Siboti	17	37.8%	28	62.2%	45	
	South Bukusu	18	47.4%	20	52.6%	38	
	West Bukusu	8	22.9%	27	77.1%	35	
Level of care of the health facility	Level 2	43	36.4%	75	63.6%	118	$\chi2$=0.086 df=2 P.=0.958
	Level 3	80	37.9%	131	62.1%	211	
	Level 4	33	36.7%	57	63.3%	90	
Distance to the health facility in Kilometers	3 and below	110	35.9%	196	64.1%	306	$\chi2$=0.895 df=2 P.=0.639
	4-7	36	40.0%	54	60.0%	90	
	8 and above	10	43.5%	13	56.5%	23	

Association between Vaccine Hesitancy and Interpersonal Variables

Few (17.4%) of the respondents had ever decided to deny malaria vaccine to their child. Out of the 73 caregivers who had ever decided to refuse a malaria vaccine for their child, 49.3% were vaccine hesitant compared to 34.7% of the 346 who have never refused a malaria vaccine. Previous decision to refuse malaria vaccine was significantly associated with malaria vaccine hesitancy ($\chi2$=5.523, df=1, P.=0.019), with those caregivers with a history more vaccine hesitant compared to those who had no history of refusing the vaccine.

Most (60.4%) caregivers believed it is possible to have too many vaccines. Less (36%) caregivers who believed there were too many vaccines were malaria vaccine hesitant compared to 39.2% of those who thought the vaccines were many. This association between malaria vaccine hesitancy and believe in too many vaccines was not significant ($\chi2$=0.436, df=1, P.=0.509).

Caregivers aware of bad reaction following malaria vaccination were more (44.6%) vaccine hesitant compared the caregivers not aware of bad reaction following malaria vaccination at 34.5% VH. Despite this, the association between awareness of bad reaction and malaria VH was not significant ($\chi2$=0.3.593, df=1, P.=0.058).

About 46.5% knew a child in the community who had not been vaccinated and had severe malaria. Knowledge of child in community with severe malaria and not vaccinated did not influence malaria vaccine hesitancy, with those aware or not at 37% vaccine hesitancy, hence the association was not significant ($\chi2$=0.007, df=1, P.=0.936).

Whereas 67.5% believed that the vaccine was the best option to prevent malaria, 32.5% thought otherwise. More (39.7%) caregivers who believed in other means of preventing malaria vaccine other than using the malaria vaccine were more hesitant to take malaria vaccine compared to 36% vaccine hesitancy of those who believed in malaria vaccine as the best alternative. The association between belief in alternatives to malaria vaccine and vaccine hesitancy was not significant ($\chi2$=0.528, df=1, P.=0.468).

Majority (93.8%) of the caregivers believe information on the vaccine is openly shared. The difference in vaccine hesitancy between those who believe information is openly shared and those who do not, at 35.1% and 69.2% respectively. This association between belief in open sharing of information about malaria vaccine and vaccine hesitancy is significant ($\chi2$=12.146, df=1, P.=0.00).

Majority (98.3%) of the caregivers trust the information about the vaccine from the MOH. There is a huge disparity of vaccine hesitancy between those who trust the MOH and those who do not, at 36.4% and 85.7% respectively. The association between trust in MOH and vaccine hesitancy is significant ($\chi2$=7.160, df=1, P.=0.007).

Association between the 7 interpersonal characteristics of the caregiver and vaccine hesitancy is summarized in ***Table 4*** below.

Table 4. Interpersonal Variables

Interpersonal Variables		Vaccine Hesitancy					
		Vaccine Hesitant (Not fully vaccinated at 24 months)		Vaccine Acceptor (Fully vaccinated 24 months)		Total	Chi-Square
		n	%	n	%		
Ever decided not to get Malaria Vaccine for my child	No	120	34.7%	226	65.3%	346	$\chi2$=5.523 df=1 P.=0.019
	Yes	36	49.3%	37	50.7%	73	
Consider it is possible to have too many vaccines	No	65	39.2%	101	60.8%	166	$\chi2$=0.436 df=1 P.=0.509
	Yes	91	36.0%	162	64.0%	253	
Aware of any bad reactions in children who have had malaria vaccine	No	106	34.5%	201	65.5%	307	$\chi2$=0.3.593 df=1 P.=0.058
	Yes	50	44.6%	62	55.4%	112	
Know a child who had serious malaria because of being not being vaccinated.	No	83	37.1%	141	62.9%	224	$\chi2$=0.007 df=1 P.=0.936
	Yes	73	37.4%	122	62.6%	195	
Believe that there are other better ways to prevent malaria other than giving the children the vaccine.	No	102	36.0%	181	64.0%	283	$\chi2$=0.528 df=1 P.=0.468
	Yes	54	39.7%	82	60.3%	136	
Feel that information on malaria vaccine is being openly shared.	No	18	69.2%	8	30.8%	26	$\chi2$=12.146 df=1 P.=0.00
	Yes	138	35.1%	255	64.9%	393	
Trust what the MoH says about malaria vaccine.	No	6	85.7%	1	14.3%	7	$\chi2$=7.160 df=1 P.=0.007
	Yes	150	36.4%	262	63.6%	412	

Association between Vaccine Hesitancy and Contextual Variables

Most (44.4%) of the respondents received malaria vaccine information from community meetings, while 21.5% received through Radio/TV. Caregivers who sourced information from social media and other sources had the highest vaccine hesitancy at 41.5% and 48.8% respectively, while those who sourced from information and communication (IEC) materials from ministry of health (MOH) had the lowest VH at 32.8%. Association between source of information about malaria vaccine and malaria vaccine hesitancy was not significant ($\chi2$=3.597, df=4, P.=0.463).

Majority (81.9%) counter-checked negative information on the malaria vaccine with health care workers. There was a big difference in vaccine hesitancy across the various sources of verification of negative information on malaria vaccine, with the highest vaccine hesitancy of 67.6% among caregivers verifying information from friends or relatives, and lowest vaccine hesitancy of 33.8% among caregivers verifying from health care workers. Vaccine hesitancy and source of verification are significantly associated ($\chi2$=15.368, df=3, P.=0.002).

Knowledge of leaders or individuals who were opposed to the vaccine greatly influenced malaria vaccine hesitancy, with 53.7% VH among caregivers aware of leaders opposed to the vaccine compared to 34.1% VH among caregivers who were not aware of individuals or leaders opposed to the vaccine. The association between vaccine hesitancy and awareness of opposition to the vaccine by individuals or leaders was significant ($\chi2$=9.291, df=1, P.=0.002).

Knowledge of opposition to the malaria vaccine due to religion influenced vaccine hesitancy, with 50% VH among caregivers aware of opposition due to religion, compared to 33.6% VH among caregivers not aware of opposition due to religion. Relationship between religion and malaria vaccine hesitancy was significant ($\chi2$=8.224, df=1, P.=0.004).

Whereas Vaccine hesitancy among those aware and those not aware of opposition to malaria vaccine due to culture was 45.8% and 35.1% respectively, the association was not significant ($\chi2$=3.239, df=1, P.=0.072).

Recall of any vaccine-associated health problems in the past slightly influenced malaria vaccine hesitancy, with 44.1% VH among caregivers who recalled compared to 35.9% VH among caregivers who could not recall. This association between recall of past vaccine problem and vaccine hesitancy was not significant ($\chi2$=1.647, df=1, P.=0.199).

While majority (92.6%) of the caregivers trust the government's decision to introduce the vaccine, 51.6% of the caregivers who did not trust the government were VH, compared to 36.1% VH among the caregivers who trusted the government. This association between trust in government and vaccine hesitancy was not significant ($\chi2$=2.963, df=1, P.=0.085).

While 92.8% of the caregivers believe the manufacture has good intentions, 60% of those who do not believe are vaccine hesitant compared to 35.5% VH among those who believe in the manufacture. This association between believe in manufacture's intention and vaccine hesitancy is not significant ($\chi2$=7.168, df=1, P.=0.007).

Malaria vaccine hesitancy among caregivers who thought the vaccine should be compulsory was 35.4%, compared to 44.5% VH among those who thought the vaccine should not be compulsory. This association was not significant ($\chi2$=2.240, df=1, P.=0.135).

The 92.4% of the caregivers who considered travel time to get malaria vaccine important were less (35.9%) VH compared to 53.1% VH among those who found travel time to get the vaccine not important. This association between consideration of travel time for vaccine as important and vaccine hesitancy was not significant ($\chi2$=3.745, df=1, P.=0.053).

The association between the 10 contextual variables of the caregiver and vaccine hesitancy is summarized in ***Table 5*** below.

Table 5. Contextual Variables

Contextual Variables		Vaccine Hesitancy					
		Vaccine Hesitant Not fully vaccinated at 24 months		Vaccine Acceptor Fully vaccinated 24 months		Total	Chi-Square
		n	%	n	%		
Most popular source of information on malaria vaccine that you and your community come across.	Social Media	17	41.5%	24	58.5%	41	$\chi2$=3.597 df=4 P.=0.463
	Radio/TV	34	37.8%	56	62.2%	90	
	IEC Materials from MoH	20	32.8%	41	67.2%	61	
	Community Meetings	65	34.9%	121	65.1%	186	
	Others	20	48.8%	21	51.2%	41	
Who to turn to for verification when you come across negative information on malaria vaccine.	Friends / Relatives	23	67.6%	11	32.4%	34	$\chi2$=15.368 df=3 P.=0.002
	Internet	12	40.0%	18	60.0%	30	
	Health Workers	116	33.8%	227	66.2%	343	
	Others	5	41.7%	7	58.3%	12	

Contextual Variables		Vaccine Hesitancy					
		Vaccine Hesitant Not fully vaccinated at 24 months		Vaccine Acceptor Fully vaccinated 24 months		Total	Chi-Square
		n	%	n	%		
Know of any group or leaders, or individuals opposed to malaria vaccination.	No	120	34.1%	232	65.9%	352	χ2=9.291 df=1 P.=0.002
	Yes	36	53.7%	31	46.3%	67	
Recall any vaccine-associated health problems in the past that may make me not get the malaria vaccine for my child	No	126	35.9%	225	64.1%	351	χ2=1.647 df=1 P.=0.199
	Yes	30	44.1%	38	55.9%	68	
Aware of people in my community opposed to malaria vaccine due to religion	No	110	33.6%	217	66.4%	327	χ2=8.224 df=1 P.=0.004
	Yes	46	50.0%	46	50.0%	92	
Aware of people in community opposed to malaria vaccine due to culture	No	118	35.1%	218	64.9%	336	χ2=3.239 df=1 P.=0.072
	Yes	38	45.8%	45	54.2%	83	
Trust government made the right decision on to introduce malaria vaccine.	No	16	51.6%	15	48.4%	31	χ2=2.963 df=1 P.=0.085
	Yes	140	36.1%	248	63.9%	388	
Think malaria vaccine should be compulsory.	No	38	44.2%	48	55.8%	86	χ2=2.240 df=1 P.=0.135
	Yes	118	35.4%	215	64.6%	333	
Consider travel time to get malaria vaccine for my child important enough.	No	17	53.1%	15	46.9%	32	χ2=3.745 df=1 P.=0.053
	Yes	139	35.9%	248	64.1%	387	
Think malaria vaccine manufacturers have good intentions for their child and other children in community	No	18	60.0%	12	40.0%	30	χ2=7.168 df=1 P.=0.007
	Yes	138	35.5%	251	64.5%	389	

Association between Vaccine Hesitancy and Vaccine Related Characteristics

Most (80.7%) of the respondents felt they had enough information about the malaria vaccine. There was a stark difference in VH between those who felt they had little information about the malaria vaccine compared to those who felt they had information, at 49.4% and 34.3% VH respectively. There was significant association between vaccine hesitancy and feeling of having enough information about malaria vaccine by the caregiver ($\chi2=6.344$, df=1, P.=0.012).

The more confident a caregiver was on the safety of the malaria vaccine, the lesser the vaccine hesitancy. Those who were not confident were 100% VH, while those very confident were 34.4% VH. Confidence in malaria vaccine was significantly associated with malaria vaccine hesitancy ($\chi2=21.119$, df=3, P.=0.000).

Majority (92.8%) had convenient access to the health facility. There was less (36.2%) VH among caregivers who thought the malaria vaccination health facility was accessible and conveniently located compared to 50% VH among those who thought the health facility was far and not convenient. However, the association was not significant ($\chi2=2.254$, df=1, P.=0.133).

While 97.9% found the vaccination process welcoming, 44.4% of those who did not find the process welcoming were vaccine hesitant, which was slightly more than 37.1% VH among those who found the vaccination process welcoming. The association between vaccine hesitancy and caregiver perception of welcoming process was not significant ($\chi2=0.205$, df=1, P.=0.651).

Out of the 93.3% caregivers who were confident the vaccine would be available when they needed, 36.1% were vaccine hesitant, compared to a higher vaccine hesitancy of 53.6% among caregivers who were not confident of the availability of the vaccine. Confidence in availability of vaccine when needed was not significantly associated with vaccine hesitancy ($\chi2=3.428$, df=1, P.=0.064).

Vaccine hesitancy was 35.9% among the caregivers who found the schedule convenient, compared to vaccine hesitancy of 47.1% among the caregivers who found the schedule inconvenient. The association between convenience of vaccine schedule and vaccine hesitancy was not significant ($\chi2=2.400$, df=1, P.=0.121).

Majority (92.6%) of the caregivers felt the country can manage risks associated with the vaccine, and 35.8% of this majority were vaccine hesitant compared to a higher vaccine hesitancy of 54.8% among caregivers who thought the country cannot manage risks associated with the vaccine. Trust in the country to manage risks was significantly

associated with malaria vaccine hesitancy ($\chi2$=4.441, df=1, P.=0.035).

Vaccine hesitancy among the caregivers who trust the health system to deliver the vaccine was lower at 36.2% compared to 62.5% VH among those who did not trust the system. Trust in the health system to deliver the vaccine was significantly associated with malaria vaccine hesitancy ($\chi2$=4.545, df=1, P.=0.033).

Majority (90.2%) had no concerns about the vaccine, and this had little effect on the vaccine hesitancy. Concerns about malaria vaccine and vaccine hesitancy were not significantly associated ($\chi2$=0.185, df=1, P.=0.667).

Association between the 9 vaccine related variables and vaccine hesitancy is summarized in ***Table 6*** below.

Table 6. Vaccine Related Determinants

Vaccine related determinants		Vaccine Hesitancy					
		Vaccine Hesitant Not fully vaccinated at 24 months		Vaccine Acceptor Fully vaccinated 24 months		Total	Chi-Square
		n	%	n	%		
Feel you have enough information about malaria vaccine and its safety.	No	40	49.4%	41	50.6%	81	$\chi2$=6.344 df=1 P.=0.012
	Yes	116	34.3%	222	65.7%	338	
Confidence level in the safety of malaria vaccine.	Very Confident	72	34.4%	137	65.6%	209	$\chi2$=21.119 df=3 P.=0.000
	Confident	52	35.6%	94	64.4%	146	
	Somehow Confident	20	38.5%	32	61.5%	52	
	Not Confident	12	100.0%	0	0.0%	12	
Think the malaria vaccination health facility is accessible and conveniently located.	No	15	50.0%	15	50.0%	30	$\chi2$=2.254 df=1 P.=0.133
	Yes	141	36.2%	248	63.8%	389	
Think malaria vaccination process at health facility welcoming	No	4	44.4%	5	55.6%	9	$\chi2$=0.205 df=1 P.=0.651
	Yes	152	37.1%	258	62.9%	410	
Confident that the health facility will have the malaria vaccine you need when you need them.	No	15	53.6%	13	46.4%	28	$\chi2$=3.428 df=1 P.=0.064
	Yes	141	36.1%	250	63.9%	391	
Think the recommended malaria vaccine schedule is convenient	No	24	47.1%	27	52.9%	51	$\chi2$=2.400 df=1 P.=0.121
	Yes	132	35.9%	236	64.1%	368	
Feel your country can manage risks associated with malaria vaccine side effects.	No	17	54.8%	14	45.2%	31	$\chi2$=4.441 df=1 P.=0.035
	Yes	139	35.8%	249	64.2%	388	
Trust the health system to deliver malaria vaccine to your community.	No	10	62.5%	6	37.5%	16	$\chi2$=4.545 df=1 P.=0.033
	Yes	146	36.2%	257	63.8%	403	
Any concerns about malaria vaccine.	No	142	37.6%	236	62.4%	378	$\chi2$=0.185 df=1 P.=0.667
	Yes	14	34.1%	27	65.9%	41	

Association between Vaccine Hesitancy and Independent Variables at Multivariate Level

All the 13 significant independent variables from the Chi-square analysis at bivariate analysis were used to conduct logistic regression analysis at multivariate level, where 4 out of the 13 remained significant; Age of the child (AOR 0.634, 95% CI 0.418-0.962), information about malaria vaccine openly shared (AOR 4.085, 95% CI 1.671-9.987), source of verification of negative information about the malaria vaccine (AOR 1.573, 95% CI 1.120-2.207) and opposition to malaria vaccine linked to religion (AOR 0.581, 95% CI 0.352-0.958).

The logistic regression model was statistically significant, $\chi2$ = 37.076, p < .000. The model explained 11.6% (Nagelkerke R2) of the variance in vaccine uptake and correctly classified 65.9% of cases. Age of the child and awareness of opposition linked to religion are negatively associated with the vaccine hesitancy, while believe that information is openly shared and the source of verification of negative information are positively associated with vaccine hesitancy. Those who believed information on malaria vaccine was secret were 4.085 times more likely to be vaccine hesitant compared to those who believed the information was openly shared. Those who sourced the information from the social media more likely to be vaccine hesitant, and those sourcing information from MOH less hesitant.

Table 7. Significant Variables at Multivariate Analysis

	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I. for EXP(B)	
							Lower	Upper
Age of child	-.455	.212	4.596	1	.032	.634	.418	.962
Information on the vaccine openly shared	1.407	.456	9.520	1	.002	4.085	1.671	9.987
Source of verification of negative information about the vaccine	.453	.173	6.853	1	.009	1.573	1.120	2.207
Opposition to the vaccine linked to religion	-.543	.255	4.522	1	.033	.581	.352	.958
Constant	-.990	.577	2.946	1	.086	.372		

Qualitative Results

A total of 48 respondents participated as key informants (KIs). Most (79.17%) of the KIs were at community level doing sensitization, mobilization, and defaulter tracing, while 14.58% were at health facility level offering vaccination services, and 6.25% were at subcounty level in charge of coordination and logistics.

Table 8. Characteristics of Respondents for Qualitative Data

Station of Key Informant	Frequency	Percentage
Subcounty	3	6.25%
Health Facility	7	14.58%
Community	38	79.17%
Role of key informant in malaria vaccine	Frequency	Percentage
Coordination and Logistics	10	20.83%
Service provider (Vaccinator)	7	14.58%
Sensitization and Mobilization	45	93.75%
Defaulter tracing	38	79.17%

General description of the uptake of malaria vaccine

The key informants were asked to give a general description of ease of penetration and progress of uptake of the malaria vaccine since it was introduced in September 2019 up to now.

The uptake of malaria vaccine was described by majority of the key informants as having a slow start. The rollout was not easy at the beginning. However, the uptake has improved and there is increasing demand, positive attitude towards the vaccine and trust in its efficacy and safety.

"…After the big launch of the vaccine at the subcounty level, the excitement died immediately as the community shied away from the vaccine. Many questioned the choice of their subcounty, and felt they were being experimented on. As community mobilizers, we had to put more effort to allay fears and convince the community to embrace the vaccine. With time, the few who had taken the vaccine became evidence that the vaccine was safe, and therefore more and more families brought their children for the vaccine. Now, we are only handling a few people who not sure about the vaccine, but the majority have embraced the vaccine, and add to our efforts in the community…"

FGD Bumula, CHV, Bumula Subcounty Hospital

A few key informants said the uptake had a rush at the start, which then dropped, and finally grew exponentially.

"…When the vaccine was launch at national level, and a few selected sub counties conducted the first vaccination, families from the nearby sub counties also brough their children, leading to immunization of more children than the target. This overwhelmed the staff at health facilities offering the immunization. Immediately this was noticed, screening was done to ensure the children were within the target area. From here, numbers dropped, and slowly normalized, before exponentially growing…"

KII Bumula, Subcounty Community Focal Person, Bumula Subcounty

The key informants also described the uptake of the first two doses to be consistent, while the third and fourth uptake is erratic.

Promoters of uptake of malaria vaccine

The key informants were asked for socio demographic, behavioural and social promoters of malaria vaccine uptake from their experience implementing the rollout of the vaccine.

According to the key informants, the high uptake of the first two doses was due to many factors, including convenient schedule with the other vaccines in the KEPI schedule, the vaccine being offered for free, effective public mobilization and education through the community strategy(CHVs), accessibility of the vaccine as it was offered in all the health facilities, availability of the vaccine, and the high morbidity and mortality of the children due to malaria that made the caregivers count on the new intervention.

"…The caregivers consider the first two doses as important, and they are timed at crucial months when the child is vulnerable and is still a priority to the mother and visits the health facility regularly for other services. The caregiver does not need to make a trip just for the malaria vaccine, but for other CWC services.…"

KII Bumula, Health Worker, Kabula Health Centre

"…Due to many cases of sickness and death of young children due to malaria, mothers count on the malaria vaccine to protect their child, hence the high uptake. mothers also have their children take the vaccine because they fear that if the child becomes sick or dies

of malaria, they will feel guilty that they did not do all it takes to protect the child, including having the child take malaria vaccine…"

FGD Bumula, CHV, Kimaeti Health Centre

Inhibitors of uptake of malaria vaccine

The key informants were asked to share socio demographic, behavioural and social inhibitors of malaria vaccine uptake from their experience implementing the rollout of the vaccine.

The opposition due to culture and religion was due to misconception on the malaria vaccine being a source of curses, that God is the only healer, that it is a way of reducing population by making the children less fertile or sterile, that vaccines do not work, malaria vaccine is under experiment, the vaccine is selectively implemented in selected regions and not others, there is political motivation, and manufacturers are from outside the country, hence safety and purpose is not clear.

The low uptake of the third and fourth dose was due to their scheduling which was considered by caregivers as spread over a long period of time, perception that the doses are too many and the first two are sufficient, lack of reminders to the caregivers, adverse events following immunization (AEFI) experienced in the first two doses, and vaccine unavailable outside the pilot subcounty.

"…Some caregivers frequently move in and out of the subcounty and county. If the new destination does not offer the malaria vaccine, the uptake ends there. When we do follow-up and we find the caregiver and child far from the subcounty, there is nothing we can do…."

FGD Bumula, CHV, Khasoko Health Centre

The caregivers were asked if they had any concerns about the vaccine.

Some of the AEFIs related to malaria vaccine listed by the respondents include cholic, loss of appetite, headache, localized inflammation, fever, nausea and vomiting, unconsciousness, diarrhea, rashes, irritation, and convulsion, while death after vaccination and lameness in nearby county was due to other vaccines. The fourth vaccine was mentioned to be scheduled at the time the mother is likely to be having a pregnancy or another baby, and therefore the child would no longer receive much attention. Some of the residents of the subcounty where the vaccine is offered frequently move out of the subcounty, especially when the baby is old enough, to look for opportunities. Were the vaccine is not offered in the new location, they fail to continue with the doses, and when they come back, they are off the schedule.

"…Most of the other vaccines are 2 or 3. Malaria vaccines are 4, which I think is too many. After the injection with the vaccine, my child became almost fully sick, and this made me reconsider vaccines every time I take the child to the health facility. Most facilities do not give us medication for treating this sickness after vaccination, and we are left to struggle with the child for about three days…."

One-on-one interview, Caregiver, Khasoko Health Centre

Suggestions to improve uptake of malaria vaccine.

Several suggestions were given by the key informants on how the uptake can be improved. The majority suggested that the health facilities should stock medication to address AEFIs. The immunization program needs to consider reducing the number of doses and rescheduling the fourth dose from 24 months to an earlier time and changing route of administration from injection to oral. CHVs suggested that they need to do more intensive mobilization, more door-to-door campaigns, training CHVs to immunize, motivation of CHVs and caregivers through incentives and linking the program with other essential services would improve uptake, use provincial administration to enforce uptake.

"…Despite mobilization and sensitization through the community health units, the CHVs do not carry any authority. If the provincial administration is incorporated, the community will take the vaccine seriously, and will easily comply. Including the village elders, subchiefs, chiefs and county commissioners' office will improve the uptake…"

FGD Bumula, CHV, Miluki Dispensary

"…Caregivers and CHVs lack motivation. If a motivation for CHVs and Caregivers is provided for, I think the uptake will improve. The motivation does not have to be money. For example, the caregiver can be given medical cover, or the CHV given a certificate. …"

FGD Bumula, CHV, Lunakwe Dispensary

Caregivers who had concerns gave many suggestions to improve uptake, which included change from injection to oral dose, have medication to address side effects, implement in all areas to avoid fear of feeling being experimented on, implement for the whole population, not just children under 2 years, confirm efficacy, as there are still malaria cases even among the vaccinated, conduct more research and improve it and reduce the number of doses.

"…The health facility should have medication issued to us to reduce sickness after vaccination. The doses can also be reduced to two instead of 4 and given at 6 and 7 months. If it is also possible, more and more vaccines including this malaria vaccine can be oral…."

One-on-one interview, Caregiver, Machwele Dispensary

Some of the caregivers who had ever decided to deny malaria vaccine to their child gave varied reasons, including adverse events following immunization(AEFI), too many doses and therefore only allowed a few doses to be taken, child was sick when dose was due, fear of new ideas and therefore opted to wait and see, feel it is still an experiment and risk of infection of healthy child with compromised immunity, distance to health facility with malaria vaccine services, and child still got malaria after initial dose hence not sure of efficacy. Some of the AEFIs mentioned include

cholic, loss of appetite, headache, localized inflammation, fever, nausea and vomiting, unconsciousness, diarrhea, rashes, irritation, and convulsion. While majority of the caregivers believed the malaria vaccine was the best option, those who did not thought treated mosquito nets, fumigation of households, clearing of bushes where mosquitoes hide, draining of stagnant water were mosquitos breed, preventive drugs such as SP for pregnant mothers, mosquito repellents and use herbs for washing the child were better than the vaccine.

> *"…I have been using the treated mosquito net given to me when I was pregnant, and another one given when the child was born. I prefer the nets than the 4 injections.…"*
>
> One-on-one interview, Caregiver, Machwele Dispensary

4. Discussion

Uptake of the first and second dose met the WHO target of 90%, while uptake of third and fourth dose did not. Reduced uptake of subsequent doses of the vaccine is similar to that observed in Ghana, where uptake of the three doses was 94.1% for RTS,S 1; 90.6% for RTS,S 2; and 78.1% for RTS,S 3 [22].

This reduction in uptake of subsequent doses of the vaccine has also been observed in other vaccines in in Ghana [1], Cameroun [8], Senegal [13], Togo [1], Nigeria [7] and Congo [5].

A study done in Togo in 2016 showed complete immunization coverage was 72.3% (95% CI 69.7–74.8), which is higher than 68.2% in this study [1], but still below WHO recommendation. A cross-sectional study in Nigeria in 2016 revealed 58 % of children were fully immunized, which is lower than 68.2% found in this study, and still below WHO and national level targets [7].

The uptake from this study of 62.8% is lower than what Achieng et al. found in Kenya in a study on acceptability of the vaccine before rolling out predicted, where an average of 88% of the population approved the malaria vaccine for their own child and community, ranging from 98.9% in malaria-endemic region, to 23% in the seasonal transmission areas [2]. Another study done in Ethiopia on willingness to accept malaria vaccine among caregivers of under-5 children in Southwest Ethiopian predicted a low uptake of 32.3% among caregivers, which is lower than the 62.8% in this study [3].

This study identified some of the challenges with uptake of malaria vaccine similar to the challenges faced, and lessons learned, during the planning and early implementation of the RTS,S/AS01$_E$ vaccine in three out of the six regions that implemented the programme in Ghana [9].

A study in Cameroon on vaccine coverage and determinants of incomplete vaccination in children aged 12-23 months in, Cameroon revealed that longer distance from the vaccination centers was marginally significant [8], and another study in Togo found that children whose parents had to walk half an hour to one hour to reach a healthcare center were 57% (aOR = 1.57, 95% CI 1.15–2.13) more likely to have an incomplete immunization coverage than those whose parents had to walk less than half an hour [5]. This study contradicted these two studies, as distance from the health facility of the caregiver was not significantly associated with vaccine hesitancy ($\chi2$=0.895, df=2, P.=0.639) [8]. Despite the insignificance of the association, the longer the distance from the health facility, the higher the vaccine hesitancy, with 35.9% of the caregivers 3km and below being vaccine hesitant, compared to 40% of those 4-7km away, and 43.5% of those 8 km and above away from the health facility.

Despite decrease in vaccine hesitancy with increase in education, education of caregiver was not significantly associated with vaccine hesitancy ($\chi2$=3.166, df=3, P.=0.367). This result contradicts findings from a study in Congo were children of mothers with secondary or higher education (AOR: 1.32; 95%CI: 1.00, 1.81) had significantly higher odds of being fully immunized compared to their counterparts whose mothers were less educated [19]. Another study on determinants of complete immunization among Senegalese children aged 12-23 months found that caregivers who attended at least secondary education level was a predictor of full childhood immunization (AOR 1.8 95% CI 1.20-2.48) [13]. Additionally, studies by Tabiri et al., and Ngeno et al and Acharya et al. found out that a higher educated parent was associated with higher odds of complete uptake both in the univariate analysis and the multivariate analysis (AOR: 4.72, 95% CI 1.27–17.55) [16].

Feeling that information about malaria vaccine was shared openly was significantly associated with vaccine hesitancy (AOR 4.085, 95% CI 1.671-9.987), which is similar to findings from a study in Nigeria on immunization coverage and its determinants among children, were access to immunization information (aOR = 1.8, 95% CI = 1.1-2.5) and mothers having good knowledge of immunization (aOR = 2.4, 95% CI = 1.6-3.8) were significant determinants of full immunization [7].

Income was not significant predictor of vaccine hesitancy in this study ($\chi2$=0.747, df=3, P.=0.862), which contradicts findings from a study done on incomplete immunization among children aged 12-23 months in Togo, were the likelihood of incomplete immunization in children decreased with the increase in household's income (aOR = 0.73, 95% CI 0.58-0.93) [5]. Another study on individual and community level determinants of child immunization in the Democratic Republic of Congo found out that children from the richest wealth quintile had significantly higher odds of being fully immunized compared to their counterparts whose mothers were relatively poorer (AOR: 1.96; 95% CI: 1.18-3.27) [19].

Whereas marital status, was not significantly associated with vaccine hesitancy in this study, findings from a study done by Asmare et al in Ethiopia showed that marital status (AOR = 1.243; 95% CI 1.021–3.897) was significantly

associated with willingness to accept a malaria vaccine for their children [3]. Additionally, the study found knowledge (AOR = 3.120; 95% CI 1.689–5.027), and previous experience with childhood vaccination (AOR = 2.673; 95% CI 1.759–4.101) significantly associated with willingness to accept a malaria vaccine for their children, while this study found knowledge((χ2=3.166, df=3, P.=0.367) and previous experience with vaccines ((χ2=1.647, df=1, P.=0.199) not significant.

5. Conclusions

Uptake of the individual doses varies, with first and second dose meeting the WHO target of 90%, while uptake of third and fourth dose did not. Full uptake is below recommended target, and vaccine hesitancy is therefore high. Despite the uptake having a slow start and high hesitancy at the beginning, there has been improvement of uptake and decrease in hesitancy over time, even though it is yet to meet WHO recommended levels. Despite promising results in reducing malaria burden, malaria vaccine uptake faces an uphill task with the behavioral and social drivers of uptake. Social and behavioral determinants of vaccine hesitancy include age of the child, information about malaria vaccine openly shared, source of verification of negative information about the malaria vaccine and opposition to malaria vaccine linked to religion.

6. Recommendations

Due to the 3rd and 4th dose not meeting WHO target, action from all stakeholders is required to improve the uptake in preparation for scale-up to other sub counties and the rest of the country. The county and immunization program need to implement suggestions shared by the respondents. Health promotion need to be done, targeting and through religious institutions.

Mobilization, outreach, and follow-up targeting the older children eligible for 3rd and 4th vaccine need to be strengthened. There is need for a longer, more intensive, and sustained delivery of contextually appropriate sensitization prior to implementation of a programme such as MVIP.

More research needs to be undertaken within same location and other areas where the vaccine is being implemented to get more insights on the predictors of vaccine hesitancy.

There is a lot of work needed to improve uptake of vaccines to WHO-recommended levels. With Covid-19 uptake having faced similar challenges even among health care workers, the socio-demographic predictors of vaccine uptake need to be studied more to enable interventions that address them.

Due to the time and scope limitations of this study, it is recommended that further research over a long period and with a bigger sample be done to ascertain the findings.

A channel for verifying negative information needs to be established, such as a toll-free line. Promotional activities should be done through the religious institutions and leaders. More open sharing of information about malaria vaccine should be done through all channels of communication.

More scientific research needs to be done to ascertain whether the fourth vaccine can be either removed or moved to a lower age.

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