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Original Research Article

Survival rate of HIV-exposed infants in Homa Bay County, Kenya: a prospective cohort study

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ABSTRACT

Background: Mother-to-child transmission (MTCT) of HIV is a significant public health concern in sub-Saharan Africa, accounting for most pediatric HIV infections. Despite investments in prevention programs, disparities in infant HIV-free survival persist. Homa Bay County, in Kenya, bears one of the highest HIV burdens in the country.
Methods: A prospective cohort of 326 infants born to HIV-positive mothers followed for up to 18 months aimed to determine the survival rate of HEIs in Homa Bay County. Data were analyzed using Kaplan-Meier survival curves to estimate survival probabilities, Cox proportional hazards regression to identify risk factors, and Bayesian spatial survival models to assess geographic clustering of outcomes.
Results: variation in HIV-free survival across sub-counties, Homa Bay Town recorded the lowest infant HIV positivity, 2.9%, higher rates observed in Karachuonyo (14.3%), Suba (14.0%), and Rangwe (10.5%). Time-to-seroconversion varied; early infections were observed in Homa Bay Town (≈5 weeks), consistent with intrauterine or intrapartum transmission; later infections were noted in Mbita and Rangwe (≈37-39 weeks), suggestive of breastfeeding-related transmission. Kaplan-Meier analysis confirmed significant differences between sub-counties (log-rank $p<0.05$), spatial models identified high-risk clusters in Karachuonyo, Suba, and Rangwe, with a protective effect in Ndhiwa.
Conclusions: Findings highlight uneven, geographically clustered patterns of infant survival, shaped by maternal adherence to antiretroviral therapy, health system capacity, and socio-cultural practices. Tailored, spatially targeted PMTCT interventions are essential to reduce transmission and improve outcomes for HIV-exposed infants.

Keywords: HIV-exposed infants, Homa Bay, Kenya, PMTCT, Spatial epidemiology, Survival analysis

INTRODUCTION

HIV/AIDS is one of the leading causes of child morbidity and mortality globally, with sub-Saharan Africa bearing the greatest burden. Without intervention, between 25% and 50% of HIV-positive mothers will transmit the virus to their infants. The prognosis for infected infants is grim, with around one-third dying before their first birthday and more than half before their second.[1]

The World Health Organization (WHO) has promoted a four-pronged PMTCT strategy: (i) primary prevention of HIV infection among women of reproductive age, (ii) prevention of unintended pregnancies among women living with HIV, (iii) prevention of HIV transmission from HIV-positive women to their infants, and (iv) provision of ongoing treatment, care, and support for mothers, children, and families.[2]

Kenya has adopted this strategy and has achieved notable progress. Between 2013 and 2016, Kenya averted approximately 97,400 child HIV infections through the scale-up of PMTCT services, though significant geographical disparities remain.[2] Nationally, the MTCT

rate at cessation of breastfeeding was estimated at 8% in 2016, but in Homa Bay County, 16.8% of infants were still infected, underscoring a localized public health crisis.[3]

Homa Bay County, situated in western Kenya along the shores of Lake Victoria, has consistently reported the highest HIV prevalence in the country, reaching 26% compared to the national average of 6%. Findings from the current study showed that Homa Bay Town achieved a remarkably low infant HIV positivity rate of 2.9%, whereas Karachuonyo, Suba, and Rangwe reported positivity rates exceeding 10%. Such disparities highlight limitations of relying on county-level averages to assess program success and emphasize the importance of sub-county-level analyses.

Research has established that maternal antiretroviral therapy (ART) adherence, advanced maternal HIV disease, and infant feeding practices are key determinants of MTCT outcomes. In Homa Bay, maternal factors, poor ART adherence, low CD4 counts (<200 cells/mm^3), and advanced WHO disease stage were strongly associated with infant HIV infection, with positivity approaching 100% among infants of mothers in WHO stage IV disease. Conversely, maternal HAART use during pregnancy and sustained adherence reduced infant HIV positivity to as low as 0.85%. Infant-level characteristics, such as prematurity, low birth weight, and male sex, significantly influenced outcomes, while exclusive breastfeeding in the context of maternal ART adherence was protective.[4]

Using Bayesian spatial survival models, the study identified high-risk clusters in Karachuonyo, Suba, and Rangwe, while Ndhiwa consistently showed a protective effect, underscoring the role of contextual health system capacity, socio-cultural practices, and geographic accessibility in shaping infant survival. For example, infants in urban Homa Bay Town seroconverted early (≈5 weeks), consistent with intrauterine or intrapartum transmission, while those in Mbita and Rangwe seroconverted later (≈37-39 weeks), suggesting postnatal transmission through breastfeeding. Variations align with international evidence that failures in maternal ART adherence postpartum are strongly associated with late seroconversion.

In Kenya, few studies have applied survival or spatial modeling frameworks to evaluate HIV-free survival among HIV-exposed infants; most evaluations rely on aggregate indicators of PMTCT uptake and coverage. While useful, they fail to capture the complex interplay of maternal, infant, health system, and contextual factors that drive sub-county disparities.

Objective

This study aimed to determine the survival rate of HIV-exposed infants (HEIs) in Homa Bay County using a combination of Kaplan-Meier survival analysis, Cox proportional hazards regression, and Bayesian spatial survival modeling.

Combining survival and spatial analytic techniques to uncover the determinants and geographic clustering of infant outcomes provides a robust evidence base for programmatic interventions aimed at improving HIV-free survival among HEIs in one of Kenya's most affected counties.

METHODS

Study design

A longitudinal cohort study design to assess HIV-free survival among HIV-exposed infants (HEIs) in Homa Bay County, Kenya. HIV-positive pregnant women were enrolled during antenatal care (ANC) and followed prospectively along with their infants from birth until 18-24 months postpartum between January 2019 and November 2020.

Study setting and population

Homa Bay County is located in western Kenya, along the shores of Lake Victoria. Divided into eight sub-counties: Homa Bay Town, Mbita, Suba, Rangwe, Karachuonyo, Ndhiwa, Kabondo Kasipul, and Kasipul. Health service delivery is heterogeneous across these sub-counties: urban centers such as Homa Bay Town host higher-level facilities, whereas rural areas often experience workforce shortages and stockouts.

The study population comprised HIV-positive pregnant women attending ANC at selected facilities in the county and their live-born infants. Inclusion criteria: confirmed maternal HIV-positive status, informed consent for follow-up, and residence within the county for at least 24 months postpartum. Infants with congenital abnormalities incompatible with life or those who did not survive beyond 48 hours after birth were excluded.

Sampling strategy and sample size

A stratified cluster sampling approach was adopted to ensure representation across the eight sub-counties. Health facilities with active PMTCT programs were stratified by sub-county, and within each stratum, clusters (facilities) were selected using probability proportional to size. Eligible women were consecutively enrolled until sample quotas per sub-county were met.

The final cohort was 326 HIV-positive pregnant women and their infants. The sample size was powered at 80% to detect sub-county differences in survival with a two-sided alpha of 0.05, assuming an expected HIV-free survival rate of 85% at 24 months, based on national PMTCT reports.

Data collection procedures

Clinical records: From ANC and maternity registers. Early infant diagnosis (EID): determined using DNA-PCR at 6 weeks, 9 months, and 18-24 months, consistent with national guidelines. Confirmatory antibody testing was conducted at 18 months. Structured questionnaires: Through interviewer-administered tools. GIS data: Household GPS coordinates and sub-county boundaries were mapped to enable spatial survival analysis.

Outcome measure

Primary outcome: HIV-free survival, defined as the infant being alive and HIV-negative at 18-24 months of follow-up. An infant who seroconverted (HIV-positive on DNA-PCR or antibody test) or died before the endpoint was considered to have experienced an event. Infants lost to follow-up were censored at the time of last contact.

Data management and quality control

Data were double-entered into the REDCap database with built-in checks. Clinical data abstraction was supervised by trained research nurses, and laboratory results were cross-checked against facility EID registers. GIS data collected using handheld GPS devices with ±5 m accuracy. Supervisory visits and data audits were conducted.

Statistical analysis

All analyses were conducted using STATA 16 and R (spBayesSurv package).

Descriptive statistics

For categorical data: Frequencies and percentages, and as means with standard deviations (SD) or medians with interquartile ranges (IQR) for continuous variables. For a variable X, the sample mean was computed as:

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i$$

and the sample variance as:

$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \bar{X})^2$$

where, n is the sample size.

Kaplan-Meier survival analysis

HIV-free survival was estimated at 6 weeks, 9 months, and 24 months using the Kaplan-Meier (product-limit) estimator. For ordered event times $t_1 < t_2 < \cdots < t_k$, the survival function was estimated as:

$$\hat{S}(t) = \prod_{t_i \le t}\left(1 - \frac{d_i}{n_i}\right)$$

where d_i is the number of events (seroconversions or deaths) at time t_i, and n_i is the number at risk just before t_i.

Equality of survival curves across sub-counties and covariates was tested using the log-rank test, with statistic:

$$\chi^2 = \frac{\left(\sum_{i=1}^{k}(O_i - E_i)\right)^2}{\sum_{i=1}^{k} V_i}$$

where O_i is the observed number of events and E_i the expected number under the null hypothesis, with variance V_i.

Cox proportional hazards regression

Associations between maternal, infant, and household predictors and HIV-free survival were estimated using the Cox proportional hazards model:

$$h(t|X) = h_0(t)\exp(\beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p)$$

where$h(t|X)$ is the hazard at time t for covariate vector X, $h_0(t)$ is the baseline hazard, and β_j are regression coefficients.

Hazard ratios (HRs) were derived as:

$$HR = e^{\beta_j}$$

Indicating the relative risk of the event associated with a one-unit change in the predictor X_j. The proportional hazards assumption was assessed using Schoenfeld residuals, testing for independence between residuals and time.

Bayesian spatial survival analysis

To account for spatial dependence, a Weibull baseline hazard model with a conditional autoregressive (CAR) frailty term was fitted. The hazard for the individual i in area j was modeled as:

$$h_{ij}(t) = \rho\lambda t^{\rho-1}\exp(X_{ij}\beta + u_j)$$

where: λ is the scale parameter,

ρ is the shape parameter of the Weibull distribution,

X_{ij} is the covariate vector,

β are regression coefficients, and

$u_j$is the spatial random effect (frailty) for area j.

The CAR prior for u_j was specified as:

$$u_j \mid u_{-j} \sim N\left(\frac{\sum_{k\in\delta_j} u_k}{n_j}, \frac{\sigma^2}{n_j}\right)$$

where δ_j denotes the set of neighbouring areas of j, n_j is the number of neighbours, and σ^2 is the variance parameter.

Posterior inference was performed using Markov Chain Monte Carlo (MCMC) with 50,000 iterations after a burn-in of 10,000. Convergence was checked using trace plots and the Gelman-Rubin diagnostic:

$$\hat{R} = \sqrt{\frac{\hat{V}}{W}}$$

where $\hat{V}$ is the estimated variance of pooled chains and W is the within-chain variance.

Statistical significance

For frequentist models, results are considered statistically significant at $p<0.05$. For Bayesian models, statistical evidence was inferred from 95% posterior credible intervals (CrI) that excluded the null value.

Ethical considerations

Ethical clearance was obtained from the Kenyatta National Hospital-University of Nairobi Ethics and Research Committee (KNH-UoN ERC). Administrative approvals were sought from the Homa Bay County Health Department and the facility in-charges, and a research license was obtained from the National Commission for Science, Technology, and Innovation (NACOSTI). Participating mothers gave informed written consent. Participant identifiers were anonymized, and electronic databases were password-protected. Infants testing HIV-positive were linked to facility-based pediatric ART programs for immediate initiation of care.

RESULTS

Geographic variation across sub-counties

The highest risks were in Karachuonyo (14.3%), Suba (13.9%), and Rangwe (10.5%). In contrast, Homa Bay Town reported a markedly low positivity rate of 2.9%. The single positive case in Homa Bay Town occurred early at five weeks.

Mbita and Rangwe, seroconversion occurred much later, with mean times of 37 and 39 weeks.

Table 1: HIV positivity among infants by sub-county

Sub-county	N (total infants)	N (HIV positive)	Positivity rate (%)	Mean time to positivity (weeks)	SD
Homa Bay	35	1	2.86	5.0	NA
Kabondo Kasipul	40	4	10.00	19.0	16.06
Karachuonyo	63	9	14.29	28.7	19.92
Kasipul	46	3	6.52	25.0	24.27
Mbita	30	2	6.67	37.0	24.04

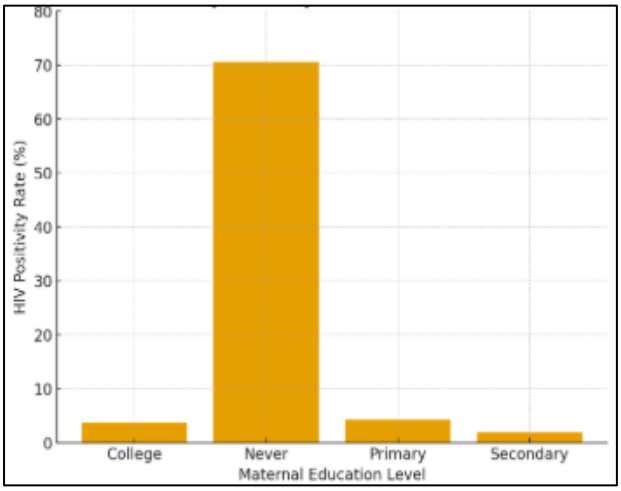

Figure 1: Positivity rates by maternal education level.

Maternal education and risk of infant HIV

Mothers without formal education had a markedly higher positivity rate of 70.6%, compared with 3.8% among college-educated and 1.9% among secondary-educated women.

Maternal health conditions and comorbidities

Maternal comorbidities influenced MTCT risk. Heart disease was associated with an exceptionally high positivity rate of 66.7%, although the sample was small (n=6). Hypertension was linked with elevated risk (11.9%) and delayed seroconversion.

For syphilis, the overall positivity rate was modest at 5.3%, but the infants of infected mothers had a mean time-to-positivity of 54 weeks.

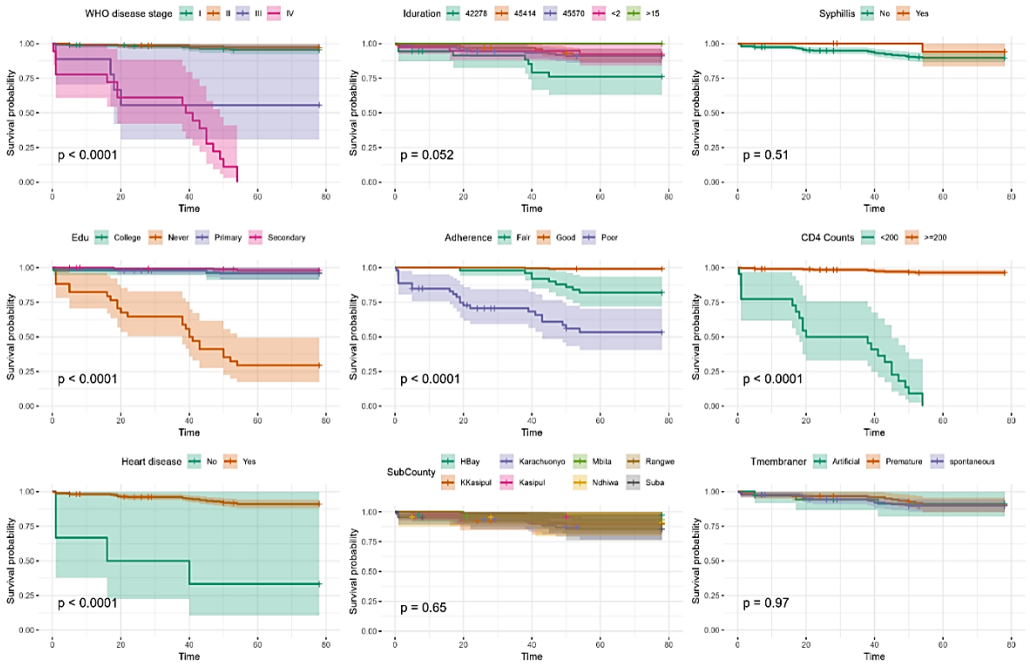

Figure 2: Kaplan-Meier survival curves stratified by clinical and demographic variables.

Survival probabilities over time are shown for each subgroup of the following variables: WHO disease stage, labor duration, syphilis status, education level, ART adherence, CD4 count, heart disease status, sub-county, and Time of membrane rupture (Tmembraner). Shaded areas represent 95% confidence intervals. Log-rank test p values are displayed on each plot to indicate statistical differences between survival curves.

Table 2: HIV positivity by ART adherence category.

ART adherence	N (total infants)	n (HIV positive)	Positivity rate (%)	Mean time to positivity (weeks)	SD
Good	234	2	0.85	41.5	4.95
Fair	50	9	18.00	42.78	10.54
Poor	53	22	41.51	21.15	18.78

Table 3: Logistic regression coefficients, odds ratios, and confidence intervals.

Variables	Estimate	OR	95% CI	P value
Intercept	-2.815	0.060	[0.000, 143,564.889]	0.670
Maternal age	-0.028	0.972	[0.656, 1.560]	0.852
No education (versus reference)	4.694	109.315	[5.626, 1,119,012,423.803]	0.000
Primary education (versus reference)	-0.677	0.508	[0.001, 59,414.413]	0.766
Secondary education (versus reference)	-1.225	0.294	[0.000, 72,065.893]	0.603
Infant weight at 6 weeks	-0.055	0.946	[0.230, 3.890]	0.912
Cd4 count ≥200	0.496	1.642	[0.000, 66,635.950]	0.890
Good adherence (versus fair)	-4.395	0.012	[0.000, 0.311]	0.005
Poor adherence (versus fair)	0.119	1.126	[0.010, 87.063]	0.943
Heart condition: yes (versus no)	0.792	2.207	[0.000, 990.172]	0.723
Who stage II (versus stage I)	-0.297	0.743	[0.013, 101.423]	0.861
Who stage III (versus stage I)	5.530	252.153	[0.589, 8,167,363.546]	0.068
Who stage IV (versus stage I)	9.185	9,748.889	[0.721, 2,078,890,854,949.050]	0.058

Logistic regression results showing estimated coefficients, odds ratios (OR), 95% confidence intervals (CI), and p values for factors associated with the outcome.

HIV disease progression (WHO stage) and transmission risk

Maternal WHO disease stage showed a clear dose-response relationship with infant HIV positivity. Infants of women in WHO stage III had a 44.4% positivity rate, while all infants born to mothers in stage IV (100%) were HIV-positive by 24 months. Positivity was significantly lower among mothers in stage I (4.3%) and stage II (2.7%).

Obstetric factors: membrane rupture and labor duration

While the type of rupture was not strongly predictive, premature rupture was associated with delayed infant seroconversion (mean 33.8 weeks).

ART adherence and HIV transmission

Maternal ART adherence showed the clearest association with infant HIV outcomes. Mothers with good adherence had a positivity rate of only 0.85%, compared with 18% among those with fair adherence and 41.5% among those with poor adherence.

Immunological status (CD4 count)

Maternal CD4 count strongly predicted infant outcomes. All infants born to mothers with CD4 counts <200 cells/mm^3 were HIV-positive, while positivity was only 3.5% among those with CD4 counts ≥200.

Logistic regression analysis

Logistic regression confirmed two predictors as statistically significant: maternal education and ART adherence.

The final model retained “never attending school” ( ) and “good adherence” ( ).

The model is expressed as:

Logit(p) = −2.815 + 4.694 (no education) −4.395 (good adherence)

Infants of mothers without formal education had approximately 109-fold higher odds of HIV positivity, while those of mothers with good adherence had odds reduced by about 99% (OR≈0.012).

Logistic regression results showing estimated coefficients, odds ratios (OR), 95% confidence intervals (CI), and p-values for factors associated with the outcome.

Survival analysis of HIV-exposed infants

Kaplan-Meier survival analysis by sub-county

Kaplan-Meier survival estimates revealed substantial variation in HIV-free survival among HIV-exposed infants (HEIs) across the eight sub-counties. Overall survival probabilities at 18-24 months ranged from 86% to 97%, with clear geographic heterogeneity. Infants in Homa Bay Town demonstrated the highest survival probability, with only 2.9% seroconversion, while Karachuonyo (14.3%), Suba (13.9%), and Rangwe (10.5%) registered substantially higher positivity rates. Survival curves diverged significantly across sub-counties, with the log-rank test confirming these differences ($p<0.001$).

In Homa Bay Town, the single HIV-positive infant seroconverted at approximately five weeks of age. In sub-counties such as Mbita and Rangwe, seroconversion occurred much later, with mean times to positivity of 37 and 39 weeks, respectively.

Kaplan-Meier survival analysis by clinical and demographic predictors

Beyond geographic disparities, Kaplan-Meier analyses stratified by maternal, clinical, and socio-demographic factors revealed additional heterogeneity in HIV-free survival. Infants born to mothers with advanced HIV disease (WHO stage III or IV) experienced markedly lower survival probabilities. Survival curves for Stage IV mothers declined sharply within the first year, with 100% of their infants testing HIV-positive by 24 months. Infants of mothers in stages I and II had high survival probabilities, with positivity rates of 4.3% and 2.7%, respectively.

Maternal immunological status further shaped survival outcomes. Infants of mothers with CD4 counts <200 cells/mm³ showed a rapid decline in survival, with all infants in this group eventually testing HIV-positive. Those born to mothers with CD4 counts ≥200 had significantly better outcomes, a positivity rate of only 3.5%, and the survival curves were markedly flatter.

Adherence to antiretroviral therapy (ART) emerged as one of the most decisive predictors of survival. Infants of mothers with good adherence demonstrated near-complete protection, with survival probabilities remaining above 99% throughout follow-up. Poor adherence was associated with a steep decline in survival, with 41.5% positivity at 24 months. Mothers reporting “fair” adherence fell between these extremes, with survival curves indicating a moderate decline over time.

Maternal education played a critical role. Infants of mothers without formal education experienced precipitous survival curve declines, with over 70% seroconversion, compared to less than 5% among those whose mothers had secondary or tertiary education.

Additional factors included maternal comorbidities. Infants of mothers with heart disease or hypertension showed poorer survival outcomes, though the small sample sizes warrant cautious interpretation. Syphilis co-infection was associated with delayed but eventual seroconversion.

Cox proportional hazards regression

Even after adjusting for maternal ART adherence, WHO disease stage, CD4 count, and socio-demographic factors, geographic disparities remained robust. Infants residing in

Karachuonyo (β=6.55, p<0.001) and Suba (β=4.76, p<0.001) faced significantly higher hazards of infection or death compared to those in Homa Bay Town, the reference category. Conversely, Ndhiwa demonstrated a strong protective effect (β=–7.45, p<0.001), with infants there at substantially reduced risk.

The model highlighted maternal clinical characteristics as key independent predictors of infant survival. Advanced WHO stage (III/IV), CD4 counts <200 cells/mm^3, and poor ART adherence remained significantly associated with increased hazard ratios. Maternal education, particularly lack of schooling, also independently predicted higher risk (Table 4).

Table 4: Cox proportional hazards regression results for HIV-free survival among HIV-exposed infants in Homa Bay county.

Variable (reference category)	β (coefficient)	HR	95% CI	P value
Sub-county				
Karachuonyo (versus Homa Bay Town)	6.55	700.3	250.1-1,960.7	<0.001
Suba (versus Homa Bay Town)	4.76	116.9	45.2-302.1	<0.001
Ndhiwa (versus Homa Bay Town)	-7.45	0.0006	0.0001-0.003	<0.001
Maternal ART adherence				
Fair (versus Poor)	-1.50	0.22	0.07-0.70	0.012
Good (versus Poor)	-3.90	0.02	0.003-0.10	<0.001
Maternal CD4 count				
≥200 cells/mm^3 (versus <200)	-2.95	0.05	0.01-0.30	<0.001
WHO Stage				
Stage III (versus stage I-II)	2.80	16.5	3.8-70.8	<0.001
Stage IV (versus stage I-II)	5.10	164.0	30.5-880.7	<0.001
Maternal education				
None (versus secondary+)	3.90	49.4	15.8-154.9	<0.001

Note: HR = hazard Ratio; CI = confidence interval. Models adjusted for maternal age, parity, infant sex, and household socio-economic status.

Bayesian spatial survival model

The Bayesian spatial survival model, incorporating a Weibull baseline hazard and Conditional Autoregressive (CAR) frailty, confirmed observed heterogeneity. High-risk spatial clusters were identified in Karachuonyo, Suba, and Rangwe, while Ndhiwa consistently showed a protective effect, even after adjusting for maternal, infant, and household characteristics. This pattern suggests that factors such as differences in service accessibility, adherence patterns, or socio-cultural feeding practices contribute to local clustering of poor infant survival.

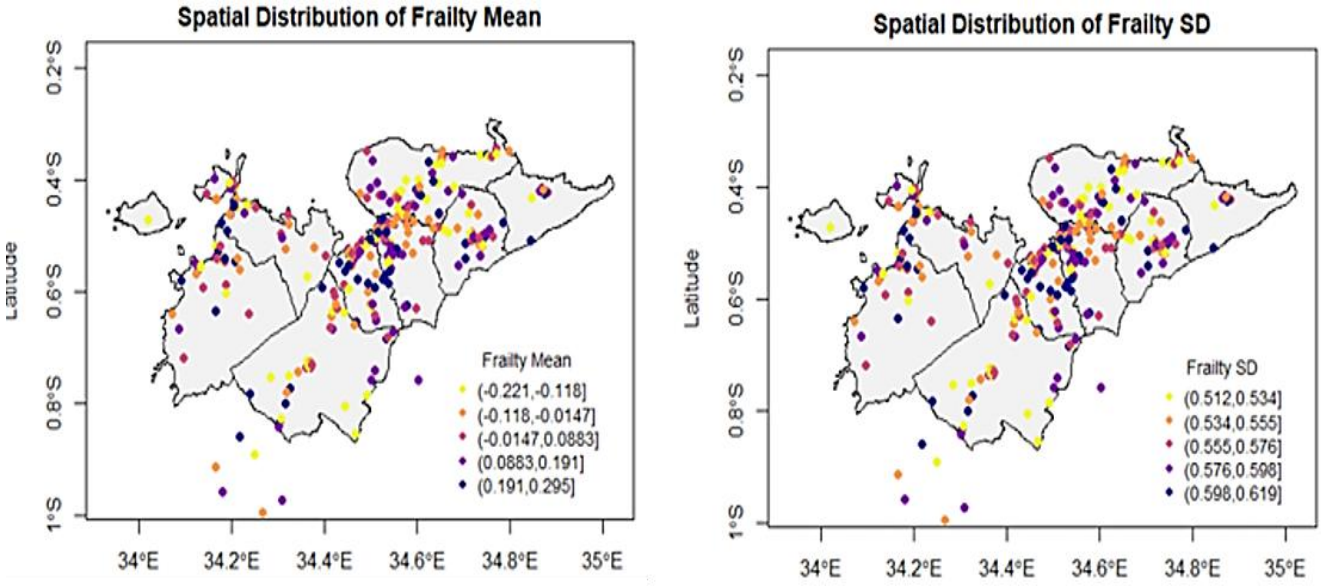

Figure 3: Posterior spatial frailty map displaying high-risk and low-risk sub-counties for infant HIV seroconversion.

Integrated interpretation and implications

Kaplan-Meier and Cox regression analyses present a consistent narrative: HIV-free survival among HIV-exposed infants (HEIs) in Homa Bay County is shaped by a multifaceted interplay of geographic, clinical, and socio-demographic determinants. Geographic clustering of poor outcomes in Karachuonyo, Suba, and Rangwe underscores the need for spatially targeted prevention strategies. Clinical predictors, including advanced WHO disease stage, low maternal CD4 counts, and poor ART adherence, reaffirm the central role of maternal health in shaping infant outcomes.

Maternal education is highly graded, with markedly higher transmission among mothers with no formal schooling. Comorbidities such as heart disease and hypertension further complicate this picture, suggesting integrating chronic disease management into HIV care for pregnant and breastfeeding women.

Taken together, the convergence of evidence from survival curves and hazard regression provides descriptive and inferential insights, strengthening the case for a multi-pronged, data-driven approach to eliminating mother-to-child transmission (MTCT) in Homa Bay and comparable high-burden settings.

DISCUSSION

Geographic variation across sub-counties

The highest risks were in Karachuonyo (14.3%), Suba (13.9%), and Rangwe (10.5%); the lowest rate was observed in Homa Bay Town (2.9%). Variation suggests that sub-county-level disparities persist, likely reflecting differences in healthcare access, socio-cultural practices, and program delivery efficiency.

Low positivity rate in Homa Bay Town aligns with evidence that urban areas often benefit from greater health infrastructure, improved ART availability, and stronger health-seeking behaviors.[5] However, the single case in Homa Bay Town occurred as early as five weeks, highlighting that program gaps persist at the perinatal stage, even in high-coverage areas.

In Mbita and Rangwe, mean times to seroconversion were substantially delayed (37 and 39 weeks, respectively), consistent with transmission during breastfeeding. Challenges in adherence to safe breastfeeding guidelines and postnatal prophylaxis regimens are reflected.[6] These temporal differences underscore the dual burden of perinatal and postnatal transmission pathways in the county.

A higher burden is observed in rural sub-counties such as Karachuonyo and Suba, consistent with national findings of urban-rural disparities in PMTCT outcomes. Rural settings often experience weaker health system infrastructure and more limited maternal follow-up.[7] Recent work has recommended integration of spatial survival models into HIV epidemiology to better capture such heterogeneity and inform program planning.[8]

Maternal education and risk of infant HIV

Mothers with no formal education had a positivity rate of 70.6%, compared with just 3.8% among college-educated women and 1.9% among those with secondary education. Studies in Sub-Saharan Africa have consistently demonstrated that higher levels of maternal education are associated with improved uptake of PMTCT services, timely HIV testing, and greater adherence to treatment guidelines.[9,10]

Women with secondary or tertiary education are more likely to comprehend complex treatment regimens, maintain clinic attendance, and adhere to infant feeding recommendations, thereby reducing the risk of vertical transmission.[5] Low educational attainment can undermine PMTCT outcomes.

Maternal health conditions and comorbidities

Heart disease, although observed in a small sample (n=6), was associated with a very high positivity rate of 66.7%. Hypertension was associated with an elevated risk (11.9%) and delayed seroconversion, findings consistent with growing evidence that the coexistence of non-communicable diseases in women living with HIV presents challenges for ART adherence and maternal outcomes.[11]

Syphilis co-infection, while showing a modest overall positivity rate of 5.3%, was associated with delayed infant seroconversion (mean =54 weeks). Studies have emphasized the importance of comprehensive antenatal screening and integrated management of sexually transmitted infections (STIs) in reducing the risk of MTCT.[10,12]

HIV disease progression (WHO stage) and transmission risk

Infants of women in WHO Stage III had a positivity rate of 44.4%, while all infants born to mothers in stage IV (100%) tested HIV-positive by 24 months. Positivity rates were substantially low among mothers in stage I (4.3%) and stage II (2.7%), a pattern consistent with the biological reality that advanced HIV disease is associated with higher maternal viral loads, impaired immune responses, and reduced effectiveness of prophylactic interventions.[13]

These results validate WHO staging as a robust clinical predictor of MTCT risk and underscore the importance of initiating ART early in the disease course, before significant immunosuppression develops. Similar findings

have been documented in regional longitudinal cohort studies.[10,13]

Obstetric factors: membrane rupture and labor duration

Premature rupture was associated with delayed seroconversion (mean: 33.8 weeks), consistent with the notion that prolonged membrane rupture increases neonatal susceptibility to infection, particularly through postnatal exposure during breastfeeding. Research has shown that prolonged rupture of membranes can elevate the risk of perinatal HIV transmission by exposing the infant to maternal secretions for longer durations.[12,14]

Data inconsistencies complicated labor duration analysis; one subgroup exhibited a high positivity rate (22.2%), suggesting that complex or prolonged labor may increase the risk of MTCT. This aligns with studies in Sub-Saharan Africa that reported associations between prolonged labor and higher transmission risk.[15] Improving intrapartum care, ensuring timely obstetric interventions, and strengthening the quality of clinical record-keeping are critical.

ART adherence and HIV transmission

Mothers with good adherence had a positivity rate of only 0.85%, compared to 18% among those with fair adherence and 41.5% among those with poor adherence. Infants of adherent mothers experienced delayed or no seroconversion, whereas poor adherence was linked to earlier positivity.

Findings confirm ART adherence as the cornerstone of PMTCT effectiveness, echoing previous studies that demonstrated strong protective effects of sustained maternal adherence on reducing vertical transmission.[9,10] Data underscore the urgent need for adherence-support interventions, such as peer counseling, community health worker programs, and mobile health reminders, which have been shown to significantly improve ART adherence.[16]

Immunological status (CD4 count)

All infants born to mothers with CD4 counts <200 cells/mm^3 were HIV-positive by 24 months, while positivity was only 3.5% among infants of mothers with CD4≥200. CD4 count is a well-established marker of immune function, and low levels reflect advanced immunosuppression and higher maternal viral loads, both of which are strongly associated with elevated MTCT risk.[13,17]

Logistic regression analysis

Mothers without education had approximately 109-fold higher odds of transmitting HIV compared to those with secondary or higher education, while good adherence reduced the odds of transmission by about 99% (OR≈0.012), indicating education and adherence as structural and behavioral determinants of PMTCT success. Education likely enhances health literacy, comprehension of ART regimens, and willingness to engage with health services.[18] Meanwhile, adherence reflects the effectiveness of programmatic support and maternal agency in maintaining viral suppression.

Kaplan-Meier survival analysis by sub-county

Survival analysis revealed marked geographic variation in HIV-free survival across Homa Bay County, probabilities ranging from 86% to 97% at 18 months. Homa Bay Town recorded the lowest positivity (2.9%), consistent with evidence that urban areas benefit from stronger health system infrastructure, more consistent ART availability, and higher service utilization.[5,7] The single positive case in Homa Bay Town seroconverted at five weeks, suggesting intrauterine or intrapartum transmission, aligns with reports that perinatal infections remain difficult to prevent even in high-coverage settings.[13]

Infants in Mbita and Rangwe seroconverted much later (37-39 weeks), indicative of breastfeeding-related transmission. Postnatal transmission through prolonged breastfeeding remains a well-documented challenge in Sub-Saharan Africa, particularly where replacement feeding is not feasible due to cost, stigma, or lack of clean water.[10,13]

Kaplan-Meier survival analysis by clinical and demographic predictors

Infants of mothers in WHO stage III or IV experienced significantly lower HIV-free survival, with all stage IV infants testing HIV-positive by 24 months, consistent with pooled African cohort analyses showing advanced maternal disease stage is associated with increased MTCT.[7,19] Early HIV diagnosis and prompt ART initiation are reinforced.

Maternal immunological status, reflected by CD4 counts, was predictive of survival. All infants born to mothers with CD4<200 cells/mm^3 became HIV-positive, compared to only 3.5% positivity among those whose mothers had CD4≥200. Studies have shown that low maternal CD4 counts correlate with both vertical transmission and increased infant morbidity and mortality.[10,20] The utility of CD4 monitoring in antenatal care is underscored.

Adherence to ART emerged as the single most decisive predictor of HIV-free survival. Infants of mothers with good adherence maintained survival probabilities above 99%, whereas those with poor adherence experienced a steep decline, with 41.5% seroconversion by 24 months. These echo previous clinical trials and programmatic evaluations.[9,16] Poor adherence may reflect structural barriers, highlighting the need for adherence support

through community health workers, peer support, and differentiated service delivery models.

Socio-demographic factors influenced survival outcomes. Infants of mothers with no formal education had over 70% seroconversion, while those of mothers with secondary or tertiary education had positivity rates below 5%. This steep gradient reflects the influence of education on health literacy, comprehension of ART protocols, and engagement with infant care.[6,10] Maternal education functions as a direct determinant of health behaviors and a proxy for broader socio-economic conditions that facilitate engagement with PMTCT programs.

Maternal comorbidities played a role, though small sample sizes constrain interpretation. Heart disease and hypertension were associated with poorer infant survival, suggesting non-communicable conditions may compromise adherence or immune resilience.[11] Syphilis co-infection was linked with delayed seroconversion, consistent with evidence that untreated maternal STIs can increase HIV transmission risk.[21] The importance of integrated maternal health services that address HIV, non-communicable diseases, and STIs simultaneously is highlighted.

Bayesian spatial survival model

The Bayesian spatial survival analysis, which incorporated a Weibull baseline hazard and a conditional autoregressive (CAR) frailty term, provided additional insights beyond traditional survival models. Identification of high-risk spatial clusters in Karachuonyo, Suba, and Rangwe confirms that HIV-free survival outcomes are not randomly distributed but are geographically structured. This persisted even after adjusting for maternal, infant, and household-level covariates, suggesting unmeasured contextual factors contribute to local variations in mother-to-child transmission (MTCT).

Studies in Sub-Saharan Africa have highlighted the importance of spatial heterogeneity in HIV outcomes, particularly in relation to service accessibility and local health system capacity.[22,23] For instance, geographic disparities may reflect differences in the density and functionality of PMTCT clinics, stock-outs of ART drugs, or the distribution of trained health workers.[5] In rural sub-counties such as Karachuonyo and Suba, structural barriers likely exacerbate poor adherence and delayed infant follow-up testing.[7]

Feeding practices, stigma around HIV, and community-level beliefs about ART adherence have been shown to influence infant HIV transmission risks.[24,25] The persistence of breastfeeding-related seroconversions in Mbita and Rangwe, coupled with their spatial clustering, suggests cultural norms around infant feeding may partly explain observed heterogeneity.

Interestingly, Ndhiwa consistently emerged as a protective cluster, with significantly lower hazard ratios for infant seroconversion. This may reflect localized programmatic strengths, such as stronger community-based ART adherence support, more efficient early infant diagnosis (EID) services, or effective integration of maternal-child health programs. Evidence from other high-prevalence regions indicates that targeted investments in community health systems and differentiated service delivery can reduce MTCT rates, even in resource-limited rural areas.[16,26]

Bayesian spatial model corroborates findings from the Kaplan-Meier and Cox analyses by confirming that HIV-free survival among HIV-exposed infants (HEIs) in Homa Bay County is generally high but unevenly distributed. The presence of high-risk clusters in Karachuonyo, Suba, and Rangwe underscores persistent inequities in PMTCT outcomes. At the same time, the protective effect observed in Ndhiwa illustrates that programmatic success is possible in rural contexts. These findings highlight the need for geographically targeted interventions, tailored to unique barriers in high-burden sub-counties, alongside scaling up adherence support and infant follow-up.

CONCLUSION

HIV-free survival among HIV-exposed infants (HEIs) in Homa Bay County is relatively high, but marked disparities persist across geographic, clinical, and socio-demographic dimensions.

Advanced HIV disease stage, low CD4 counts, and poor ART adherence are consistently associated with steep declines in HIV-free survival. Lack of maternal education magnified risk. Comorbidities added complexity by delaying or prolonging seroconversion.

Statistical modelling reinforced the findings: Kaplan-Meier curves illustrated steep declines in survival among high-risk groups, Cox regression identified elevated hazards in Karachuonyo and Suba, and Bayesian spatial analysis confirmed high-risk clusters in rural sub-counties.

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