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Clinical, Immunological and Social Correlates of Opportunistic Infections Among Children Living with Human Immunodeficiency Virus in North-Central Nigeria: A Multicentre Cross-sectional Analysis

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ABSTRACT

Background: Opportunistic infections (OIs) remain clinically relevant among children living with human immunodeficiency virus (HIV), particularly in settings where late diagnosis, advanced HIV disease (AHD), malnutrition, social vulnerability and interrupted treatment support overlap. Despite global antiretroviral therapy (ART) scale-up, children continue to have lower treatment access and continuity than adults. This study examined clinical, immunological, social correlates of documented OIs among children receiving HIV care in Plateau State, North-Central Nigeria. **Methods:** This multicentre cross-sectional study included 404 HIV-infected children aged 6 weeks to 18 years attending 12 paediatric HIV facilities from March to September 2017. Multistage sampling was used. Data were obtained from caregiver interviews, clinical and anthropometry assessment, and medical/laboratory records. Associations with OI status were examined using Pearson chi-square or Fisher's exact tests, Mann-Whitney U test for non-normal continuous variables, crude odds ratios (ORs), trend analysis and exploratory unadjusted joint-exposure analyses. Results: OIs were present in 228/404 children (56.4%). Mean age was 10.6±4.1 years; (60.4%) were female, 64.1% had low socioeconomic status, and 45.0% were orphans. OI prevalence showed a marked CD4 gradient: 47.4% at <200 cells/µL, 31.8% at 200-349 cells/µL, 29.0% at 350-499 cells/µL, and 8.5 at ≥500 cells/µL (trend p<0.001). Crude correlates included female sex (OR 1.90, 95% CI 1.08–3.32; p=0.024), poor ART adherence (OR 1.97, 95% CI 1.06–3.66; p=0.029), poor CPT adherence (OR 1.82, 95% CI 1.02–3.23; p=0.039), anaemia (OR 3.13, 95% CI 1.43–6.84; p<0.001) and guardian rather than parental care (OR 3.30, 95% CI 1.89–5.78; p<0.001). ART status, CPT status and household crowding considered alone were not significant. **Conclusion:** OIs clustered across immunological, adherence, socioeconomic and caregiving domains. Paediatric HIV services should prioritise children with severe immunosuppression, advanced clinical disease, adherence difficulties, incomplete immunisation, anaemia, orphanhood and non-parental care. Targeted clinical surveillance should integrate adherence support, tuberculosis screening, immunisation review, nutritional assessment and social services referrals.

Keywords: Paediatric HIV, Opportunistic infections, Risk factors, CD4 count, Socioeconomic status, Nigeria, Interaction analysis

How to cite this article

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INTRODUCTION

Antiretroviral therapy (ART) has transformed HIV from into manageable chronic disease condition for many, yet, children living with HIV (CLHIV) in resource-limited settings remain vulnerable to opportunistic infections (OIs).[1-3] Their occurrence reflects gaps early diagnosis, treatment coverage, adherence and retention within under-resourced health system.[1,2]

Opportunistic infections are bacterial, viral, fungal, protozoal or mycobacterial infections that occur more frequently, recur often or produce more severe disease when host immunity is impaired. In CLHIV, these infections arise as progressive viral replication and CD4-cell depletion weaken cellular and humoral immunity, causing otherwise uncommon infections or recurrent, persistent, disseminated or unusually severe form of common childhood infections.[3–6]

The occurrence of OIs may indicate late HIV diagnosis, severe immunosuppression, virological failure, poor ART adherence or missed preventive services. They contribute significantly to hospital admission, prolonged treatment, disability, costs and HIV-related mortality, while several define WHO stage 3 or 4 disease and warrant intensified investigation, treatment and follow-up.[3–7]

In paediatric HIV care, OIs are important markers of immune compromise and programme vulnerability. WHO and Nigerian guidance emphasize rapid ART initiation, CPT, tuberculosis screening, immunization, growth monitoring and identification of advanced HIV disease (AHD) as essential elements of care.[3-6] WHO regards all HIV-infected children younger than five years, older children and adolescents with very low CD4 count or WHO stage 3 or 4 disease as having AHD require intensified assessment and intervention.[4,6]

The burden of paediatric HIV and associated OIs remains concentrated in sub-Saharan Africa, where health-system constraints, poverty, malnutrition and caregiver instability may amplify infection risk.[7-9] Recent African studies have shown that OIs continue to occur among children on ART and are associated with advanced WHO stage, low CD4 count, anaemia, poor adherence and gaps in preventive therapy.[10-16] Nigerian data, especially North-central remain comparatively limited, although studies from Jos and other settings demonstrate the continuing relevance of tuberculosis exposure, latent tuberculosis infection and immunosuppression.[17,18]

Risk profiling in paediatric HIV should include caregiver status, orphanhood, poverty, food insecurity, transport constraints, disclosure, adherence support and retention in care alongside biomedical markers.[19-24] Anaemia and undernutrition also interact with immune dysfunction and may increase vulnerability to infection and mortality risk.[25,26]

This study examined crude clinical, immunological, treatment-related and social correlates of documented OIs among children receiving HIV care in Plateau State, North-Central Nigeria. The analyses were unadjusted, stratified and exploratory; therefore, findings represent correlates and high-burden profiles rather than independent causal effects.

METHODS

Study design, setting and population

This multicentre cross-sectional study involved CLHIV attending 12 randomly selected paediatric HIV facilities in Plateau State, North-Central Nigeria. The state includes urban, peri-urban and rural populations, and has 24 active paediatric HIV facilities providing HIV ART, CPT, clinical monitoring, counselling, and psychosocial support.

The study population comprised HIV-infected children aged 6 weeks to 18 years enrolled in HIV care. HIV diagnosis was based on DNA PCR for children younger than 18 months and rapid diagnostic testing algorithms for older children, consistent with national practice. The accessible population was 2,357 across the selected health facilities.

Sampling and data collection

Multistage sampling was used. Twelve (12) facilities were randomly selected from the 24 eligible paediatric HIV services facilities at the time. The sample was

allocated proportionately according to the number of eligible children recorded in each selected facility register, after which systematic sampling was applied to children attending each clinic.

Fisher's formula, ($n = Z^2pq/d^2$) was applied using Z=1.96; p=0.424 from a Sagamu study, q=0.576 and d=0.05. The minimum sample was 375; adding 10% for incomplete data produced a target of 413. Complete data for 404 participants were analysed.

A structured case-record form, caregiver interview, clinical examination, anthropometry, and laboratory/medical records. Variables included sociodemographic characteristics, orphan and caregiver status, household size, over-crowding, ART exposure, ART adherence, CPT exposure, CPT adherence, WHO clinical stage, CD4 counts, haemoglobin concentration, and documented OI.

Variable definitions

OI prevalence, was defined as proportion of participants with at least one previous or current OI documented through caregiver history and/or clinical records. An opportunistic infection was an infection meeting national or WHO-aligned clinical, radiological or microbiological criteria where available. Physician agreement was required for clinically defined diagnoses.[3,5,6] Socioeconomic status was classified using the Olusanya method.[27]

Good ART or CPT adherence meant caregiver-reported intake of at least 95% of prescribed doses in the preceding month. CD4 count was grouped as <200, 200–349, 350–499 and ≥500 cells/µL. Household size was classified as ≤4, 5–8 or >8 members; crowding was ≤2 or >2 usual residents per habitable sleeping room. The caregiver was the adult primarily responsible for treatment, attendance and welfare; a guardian was a responsible non-parent, and orphanage care denoted institutional responsibility. Anaemia was haemoglobin <10 g/dL.

Statistical analysis

Categorical variables were summarised as frequencies and percentages and continuous variables as means with standard deviations or medians with interquartile ranges. Associations with OI status used Pearson chi-square or Fisher's exact tests. Crude ORs and 95% CIs were calculated; zero cells received continuity correction. The CD4 gradient used the Cochran–Armitage trend test, while CD4 count and percentage distributions used Mann–Whitney U tests.

Prespecified joint-exposure analyses described high-burden subgroups using OI prevalence and crude ORs relative to lower-risk references. Relative excess risk due to interaction and the synergy index were reported descriptively on the OR scale. Results were interpreted cautiously because analyses were unadjusted and some cells were sparse. No independent-risk-factor claims are made.

Ethical consideration

Ethical approval was obtained from the Jos University Teaching Hospital Research and Ethics Committee (JUTH/RS/HREC/45/2017), with administrative approval from participating facilities. Caregivers provided written consent and children assented where applicable. Suspected OIs or severe illness received same-day assessment, treatment or referral under national guidelines

RESULTS

Participant characteristic and treatment-related correlates

Among 404 children, 228 (56.4%) OIs. The mean age was 10.6±4.1 years, the median age was 11 years (IQR 8-14). The largest age group was 10-14 years and females represented 244 (60.4%). Most children were on ART (392/404, 97.0%) and CPT (388/404, 96.0%). Good ART adherence was recorded in 324/392 (82.7%) children on ART, while good CPT adherence was documented in 302/388 (77.8%) children on CPT. Treatment-related findings are presented in Table 1.

As shown in Table 1, sex, age group, ART adherence and duration, CPT adherence and duration were significantly associated with OI status (all p<0.05). ART

status (p=0.239) and CPT status (p=0.748) were not statistically significant

Table 1. Participant characteristics and treatment-related correlated of documented opportunistic infections

Risk factor	Category	OI present n (%)	OI absent n (%)	Crude OR (95% CI)	p-value
Sex	Male	20 (12.5)	140 (87.5)	1.00 (reference)	0.024
	Female	52 (21.3)	192 (78.7)	1.90 (1.08-3.32)	
Age group	<5 years	14 (29.2)	34 (70.8)	1.00 (reference)	0.037
	5-9 years	14 (16.3)	72 (83.7)	0.47 (0.20-1.10)	
	10-14 years	24 (13.2)	158 (86.8)	0.37 (0.17-0.79)	
	≥15 years	20 (22.7)	68 (77.3)	0.71 (0.32-1.59)	
ART status	On ART	68 (17.3)	324 (82.7)	1.00 (reference)	0.239
	Not on ART	4 (33.3)	8 (66.7)	2.38 (0.70-8.14)	
ART adherence	Good (≥95%)	50 (15.4)	274 (84.6)	1.00 (reference)	0.029
	Poor (<95%)	18 (26.5)	50 (73.5)	1.97 (1.06-3.66)	
ART duration	>2 years	52 (15.3)	288 (84.7)	1.00 (reference)	0.011
	6 months-2 years	14 (28.0)	36 (72.0)	2.15 (1.09-4.27)	
	<6 months	2 (50.0)	2 (50.0)	5.54 (0.76-40.20)	
	Not initiated	4 (40.0)	6 (60.0)	3.69 (1.01-13.54)	
CPT status	On CPT	70 (18.0)	318 (82.0)	1.00 (reference)	0.748
	Not on CPT	2 (12.5)	14 (87.5)	0.65 (0.14-2.92)	
CPT adherence	Good (≥95%)	48 (15.9)	254 (84.1)	1.00 (reference)	0.039
	Poor (<95%)	22 (25.6)	64 (74.4)	1.82 (1.02-3.23)	
CPT duration	>2 years	50 (15.2)	278 (84.8)	1.00 (reference)	0.002
	3 months-2 years	14 (29.2)	34 (70.8)	2.29 (1.15-4.57)	
	<3 months	6 (50.0)	6 (50.0)	5.56 (1.72-17.93)	
	Not on CPT	2 (12.5)	14 (87.5)	0.79 (0.18 3.60)	

Note: Percentages are row percentages. Associations are unadjusted. ART, antiretroviral therapy; CPT, cotrimoxazole preventive therapy; OI, opportunistic infection.

Clinical and immunological correlates

Severe immunosuppression (CD4 <200 cells/μL) was present in 38/404 children (9.4%). OI prevalence increased stepwise as CD4 count declined, with the highest prevalence in children with CD4 <200 cells/μL and the lowest prevalence in those with CD4 ≥500 cells/μL (Cochran-Armitage trend p<0.001). Median CD4 count was lower among children with OIs than among those without OIs: 392 cells/μL (IQR 227-572) versus 702 cells/μL (IQR 483-936); Mann-Whitney U p<0.001. CD4 percentage showed a similar pattern: 17% (IQR 11-20) among OI-positive children versus 26.5% (IQR 18-35) among OI-negative children; p<0.001. WHO stage 3 or 4 affected 126/404 children (31.2%). Table 2 summarizes the clinical and immunological findings.

Table 2. Clinical and immunological correlates of documented opportunistic infections

Clinical/immunological factor	Category	OI present n (%)	OI absent n (%)	Crude OR (95% CI)	p-value
CD4 count	≥500	22 (8.5)	238 (91.5)	1.00 (reference)	<0.001
	350-499	18 (29.0)	44 (71.0)	4.43 (2.22-8.83)	
	200-349	14 (31.8)	30 (68.2)	5.05 (2.36-10.78)	
	<200	18 (47.4)	20 (52.6)	9.74 (4.50-21.07)	
WHO clinical stage	Stage 1	2 (1.7)	118 (98.3)	1.00 (reference)	<0.001
	Stage 2	40 (25.3)	118 (74.7)	20.00 (4.72-84.66)	
	Stage 3	28 (22.6)	96 (77.4)	17.21 (4.00-74.07)	
	Stage 4	2 (100.0)	0 (0.0)	237.00 (8.88-∞)†	
Anaemia status	≥10 g/dL	58 (17.6)	272 (82.4)	1.00 (reference)	<0.001
	<10 g/dL	12 (40.0)	18 (60.0)	3.13 (1.43-6.84)	
	Missing	2 (4.5)	42 (95.5)	0.22 (0.05-0.95)	

Note: All estimates are unadjusted. †Continuity-corrected estimate due to a zero cell. Cd4 precentage was available for 348 participants.

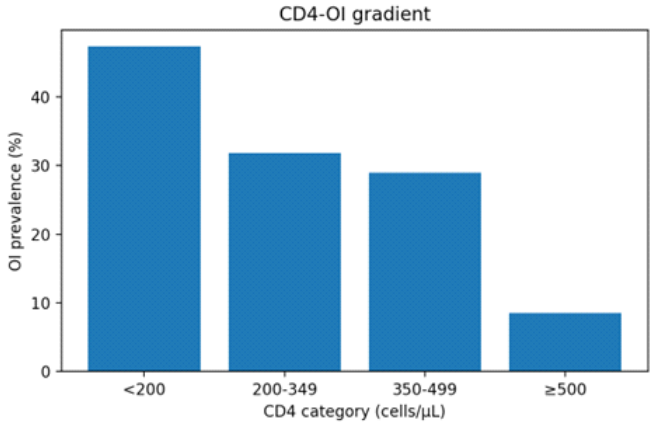

Figure 1

Socioeconomic and environmental and caregiving correlates

Low socioeconomic status was recorded in 254/396 children (64.1%). OI prevalence was 0.0% in the high, 16.4% in he middle and 21.3% in the low socioeconomic group. Because no OI events occurred in the high socioeconomic group, estimates using this group as the reference were continuity-corrected and had wide confidence intervals. Most children (320/404; 79.2%) lived in households with more than two persons per room. OI prevalence was higher in households with more than eight members.

Orphanhood affected 45.0% of the children. Maternal death, paternal death, double orphanhood and guardian care each showed higher OI prevalence than their respective reference categories. Guardian care had a particularly high crude burden compared with children cared for by parents. OI prevalence was highest among unimmunized children, although this subgroup was small. See Table 3.

Table 3. Socioeconomic, environmental and caregiving correlates of documented opportunistic infections

Factor	Category	n	OI prevalence (%)	Crude OR (95% CI)	p-value
Socioeconomic status	High	32	0.0	1.00 (reference)	0.011
	Middle	110	16.4	13.00 (0.76-221.92)†	
	Low	254	21.3	17.67 (1.06-293.21)†	
Household size	≤4	100	16.0	1.00 (reference)	0.009
	5-8	194	13.4	0.81 (0.41-1.60)	
	>8	110	27.3	1.97 (1.00-3.88)	
Crowding index	≤2 persons/room	84	11.9	1.00 (reference)	0.111
	>2 persons/room	320	19.4	1.78 (0.87-3.64)	
Current residence	Urban	84	14.3	1.00 (reference)	0.006
	Peri-urban	82	7.3	0.47 (0.17-1.33)	
	Rural	66	24.2	1.92 (0.84-4.41)	
Maternal survival	Alive	304	15.1	1.00 (reference)	0.014
	Dead	100	26.0	1.97 (1.14-3.40)	
Paternal survival	Alive	282	14.9	1.00 (reference)	0.019
	Dead	122	24.6	1.86 (1.10-3.15)	
Orphan status	Non-orphan	222	13.5	1.00 (reference)	0.009
	Single orphan	134	20.9	1.69 (0.96-2.98)	
	Double orphan	44	31.8	2.99 (1.42-6.27)	
Caregiver type	Parent	314	14.0	1.00 (reference)	<0.001
	Guardian	80	35.0	3.30 (1.89-5.78)	
	Orphanage	10	0.0	0.29 (0.02-5.03)†	
Immunization status	Complete	300	15.3	1.00 (reference)	0.002
	Partly	98	22.4	1.60 (0.90-2.82)	
	Not immunized	6	66.7	11.04 (1.97-62.06)	

Note: All estimates are unadjusted. †Continuity-corrected estimate due to a zero cell. Denominators vary because of missing data, particularly for current residence

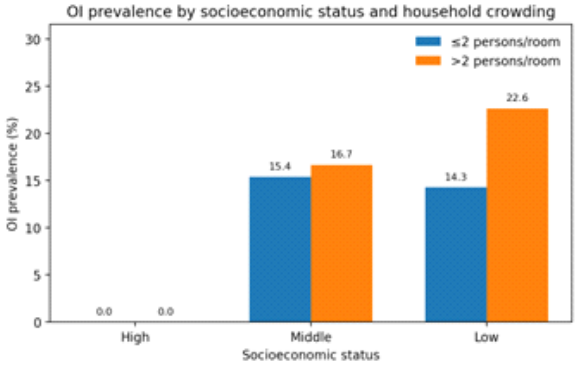

Figure 2. OI prevalence by socioeconomic status and household crowding.

Table 4. Socioeconomic status-stratified OI prevalence by crowding

Socioeconomic status	Crowding	n	OI present	OI prevalence (%)
High	≤2 persons/room	16	0	0.0
High	>2 persons/room	16	0	0.0
Middle	≤2 persons/room	26	4	15.4
Middle	>2 persons/room	84	14	16.7
Low	≤2 persons/room	42	6	14.3
Low	>2 persons/room	212	48	22.6

Note: This table is descriptive and does not present adjusted estimates.

Exploratory joint-exposure analysis

The joint-exposure profiles identified disproportionate burden (Table 5 and Figure 3). The highest joint-exposure OI prevalence occurred among children with both low socioeconomic status and severe immunosuppression (45.5%; crude OR of 27.72 relative to high socioeconomic status with normal Cd4). Maternal death with low socioeconomic status also showed elevated joint burden (32.4% and a crude OR of 19.89 relative to maternal survival with high socioeconomic status).

Poor ART plus poor CPT adherence and household crowding plus incomplete immunization, also showed elevated crude OI prevalence. However, the interaction estimates were unstable in several combinations because of sparse cells and zero-event reference groups. These analyses are best interpreted as pragmatic risk-stratification summaries rather than formal causal interaction tests.

Table 5. Exploratory joint exposure profiles for documented opportunistic infections

Joint-exposure group	n	OI prevalence (%)	Crude OR (95% CI)	RERI	Synergy index	Interpretation
Low SES + severe immunosuppression vs high SES + normal CD4	22	45.5	27.72 (1.48-519.51)†	21.23	4.87	Highest crude joint burden; sparse reference cell
Orphan + short/no CPT vs non-orphan + long CPT	24	16.7	2.63 (0.77-8.95)	-7.51	0.18	Elevated joint OR but no positive additive excess
Female adolescents ≥15 vs male children <10	58	17.2	3.44 (1.02-11.62)	-13.71	0.15	Exploratory demographic risk profile
Poor ART + poor CPT adherence vs good ART + good CPT adherence	64	28.1	2.21 (1.17-4.15)	-3.79	0.24	Clinically relevant adherence profile
Crowded + incomplete immunization vs uncrowded + complete immunization	84	21.4	8.45 (1.88-37.95)	-18.32	0.29	Elevated crude joint burden; interpret cautiously
Mother dead + low SES vs mother alive + high SES	74	32.4	19.89 (1.15-342.73)†	10.94	2.38	High-burden social vulnerability profile

Note: All estimates are unadjusted. ORs compare the named joint-exposure group with the named reference group. RERI and synergy index are calculated on the OR scale and are descriptive only. †Continuity-correctedestimate due to a zero cell

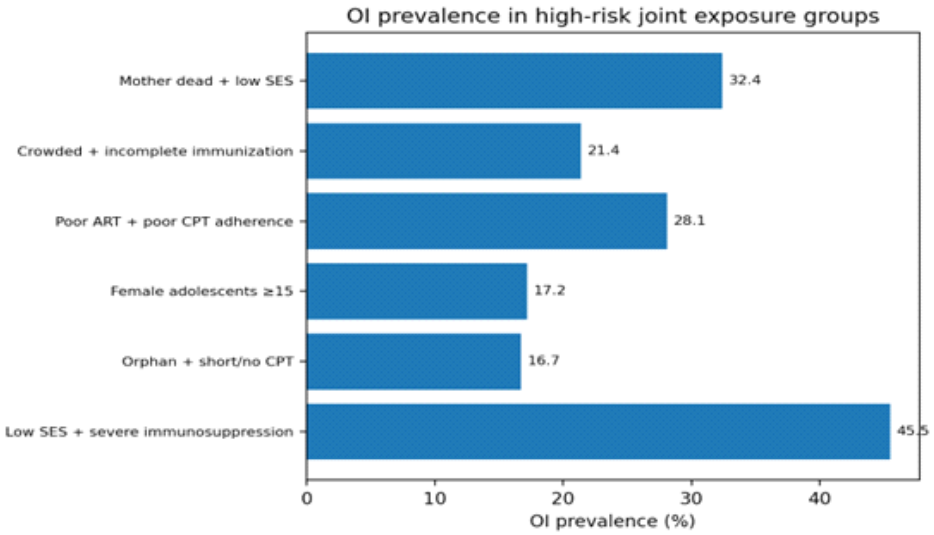

***Figure 3**. OI prevalence in prespecified joint-exposure groups*

DISCUSSION

This multicentre analysis found OIs in 56.4% of children in HIV care. Although most participants were on ART and CPT, OIs clustered with markers of advanced disease, immune depletion, anaemia, adherence gaps, incomplete preventive care and social vulnerability. The findings are consistent with recent African cohort and systematic-review evidence showing that OIs persist during ART scale-up, particularly among children with advanced WHO stage, low CD4 count, poor ART adherence, anaemia and missed preventive interventions.[10-16]

Immunological and clinical gradients

The clearest biological signal in this study was CD4 gradient; revealing that OI prevalence was highest below CD4 <200 cells/μL and lowest at CD4 ≥500 cells/μL, with substantially lower median CD4 indices among OI-positive children. This pattern is biologically plausible and consistent with WHO and paediatric OI guidance which emphasis identification of advanced HIV disease and intensified screening for infections such as tuberculosis, severe bacterial disease and other OIs.[4,6,7]

Paradoxically, while 97% of the cohort were on ART, 9.4% still exhibited severe immunosuppression, and 31.2% were in WHO clinical stages 3 or 4. This suggests that "treatment access" does not equate to "treatment success," likely due to the late presentation and adherence gaps identified in this study.

Advanced WHO clinical stage also showed strong crude association with OI status. Nonetheless, the finding supports the clinical value of structured staging, CD4 review where available and prompt assessment of children presenting with advanced disease features.[3-6]

Treatment adherence and preventive therapy

Poor ART adherence (OR 1.97) and poor CPT adherence (OR 1.82) emerging as major correlates. Children with shorter CPT for less than three months had significantly higher OI rates (OR 5.56) within the CPT categories. This reinforces the seminal findings of the CHAP trial in Zambia and the work of Mermin et al. in Uganda, which established CPT as a non-negotiable cornerstone of pediatric HIV care to reduce morbidity.[11-16,20,21] The novelty in our findings lies in the stratification of risk by duration, suggesting that the early period of prophylaxis is a critical window of vulnerability where reinforcing the need for adherence assessment at every visit, early identification of treatment interruption and family-centred support rather than reliance on drug availability alone.[6,20,24]

Social vulnerability, caregiving and household context

The social patterning of OIs was also significant in this study. Low socioeconomic status, orphanhood, maternal or paternal death and guardian care were associated with higher OI prevalence. These findings are consistent with literature showing that orphaned children and adolescents living with HIV may face adherence and retention challenges related to caregiver instability, food insecurity, transport barriers, stigma and reduced continuity of supervision.[19,22-24]

Guardian care showed a stronger crude association than parental care (crude OR 3.30). This does not imply inadequate guardianship; rather, it suggests that children in non-parental care may require more structured support because guardians may face economic pressure, competing household responsibilities, limited HIV literacy or challenges sustaining clinic attendance. Evidence from studies of orphans and vulnerable children supports integrated clinical and social support for retention and adherence.[19,22,23]

Household size, crowding and incomplete immunization also deserve attention. Although the crude crowding association did not reach the conventional 5% threshold, the descriptive pattern showed higher OI prevalence in crowded low-SES households. Incomplete immunization had a strong association (crude OR 11.04) with OI status, but the not-immunized subgroup was small, and the finding should be interpreted as a signal for preventive-service gaps rather than a precise effect estimate. In practice, immunization review should remain part of paediatric HIV care to prevent common childhood illness that could be considered OIs.[3,5,6]

Joint-exposure profiles and implications for differential care

The exploratory joint-exposure analysis showed the greatest burden where low socioeconomic status coincided with severe immunosuppression and maternal death coincided with low socioeconomic status. These combinations suggest that the children most likely to experience OIs may be those in whom biological vulnerability and social vulnerability intersect. This supports a differentiated care model in which high-risk children receive more frequent clinical review, enhanced adherence counselling, tuberculosis screening, immunization catch-up, nutrition assessment and linkage to social-support services.[3-9,19,22-26]

Other joint-exposure patterns were more complex. Orphanhood with short/no CPT, female adolescence, poor dual adherence, and crowding with incomplete immunization showed elevated joint-group ORs, but RERI estimates were negative. These findings are theoretically significant as they support a "differentiated service delivery" model. Instead of a one-size-fits-all approach, these high-risk clusters require a "clinical-plus-social" package of care that includes nutritional support, transport subsidies, and home-based adherence monitoring.

Limitation

The cross-sectional design precludes temporal or causal inference. Caregiver-reported adherence may be affected by recall or social-desirability bias, and diagnostic capacity varied across facilities. Nutritional status and viral load were unavailable, and unmeasured confounding remains possible. Nevertheless, data from 12 facilities broaden the relevance of the findings within North-Central Nigeria.

Recommendations

The findings support integrated paediatric HIV care in which clinical and social risk profiles are assessed together. First, facilities should institutionalize or strengthen advanced HIV disease screening and response for children younger than five years and older children with CD4 <200 cells/μL or WHO stage 3 or 4 disease.[3,4,6] Second, ART and CPT adherence assessment should be strengthened using caregiver-centred counselling, treatment literacy and early tracing after missed visits.[6,20,21,24] Third, immunization status, tuberculosis exposure, anaemia and nutrition should be reviewed systematically during follow-up.[3,5-7,25,26] Fourth, children in low socioeconomic households, orphanhood or guardian care should be prioritized for linkage to

social-protection, transport, nutrition and psychosocial support services.[8,19,22-24]

Future Research Directions

Longitudinal cohort designs to establish the temporal sequence of social determinants and OI onset. There is also a need for qualitative research to explore the specific challenges faced by guardians in managing pediatric HIV adherence. Finally, implementation science research should evaluate the cost-effectiveness of integrating nutritional and economic support into standard HIV clinical care in North-Central Nigeria.

CONCLUSION

This study showed that OIs occurred in 56.4% of children receiving HIV care in Plateau State. Opportunistic infections clustered across clinical, immunological, treatment-adherence, socioeconomic and caregiving domains. Low CD4, advanced clinical stage, poor adherence, shorter CPT exposure, anaemia, orphanhood, guardian care, low socioeconomic status, large households and incomplete immunization were important crude correlates. Exploratory joint-exposure analyses identified subgroups with high joint burden, especially children with low socioeconomic status combined with severe immunosuppression and those with maternal death combined with low socioeconomic status. These findings support targeted paediatric HIV care that combines clinical surveillance with adherence, immunization, tuberculosis screening, nutrition assessment and social-support interventions. Longitudinal studies with viral load, nutritional indices and covariate- adjusted models are needed to clarify temporal pathways and evaluate intervention impact.

Declaration

Ethics approval and consent to participate: Ethical approval was obtained from the Research and Ethics Committee of Jos University Teaching Hospital (JUTH/RS/HREC/45/2017). Written caregiver consent and child assent, where applicable, were obtained before data collection.

Consent for publication: Not applicable; no identifiable participant information is reported.

Availability of data and materials: The dataset may be made available by the corresponding author on reasonable request and subject to institutional ethical approvals.

Competing interests: The authors declare that they have no competing interests.

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