*Original Research*

# Adverse Maternal Outcomes Among People With Human Immunodeficiency Virus (HIV) Using Antiretroviral Therapy in Botswana

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**OBJECTIVE:** This study aimed to evaluate maternal outcomes in a large cohort with high prevalence of human immunodeficiency virus (HIV) infection in Botswana after implementation of a treat-all policy.

**METHODS:** In this retrospective cohort study, data were collected from the medical record at the time of discharge from November 2021 to December 2023. Outcomes were recorded in the Tsepamo Birth Outcomes Surveillance and Safe Birth studies at Princess Marina Hospital in Botswana. We evaluated maternal mortality and obstetric morbidities by HIV status, including preeclampsia, eclampsia, hemorrhage, infection, and acute pulmonary or cardiac conditions at the time of hospital discharge.

**RESULTS:** We included 11,754 participants; 2,201 (18.7%) were pregnant people with HIV infection. Ninety-seven percent (2,135) were on antiretroviral therapy (ART) at time of delivery; 1,996 (93.5%) of those with a known ART regimen were on dolutegravir, tenofovir disoproxil fumarate, and lamivudine. Of the 1,090 people with HIV infection with known CD4 counts, 757 (69.4%) had more than 500 cells/microliter, and only 42 (3.9%) had fewer than 200 cells/microliter. Of 1,524 people with HIV infection with known viral loads, 1,436 (94.2%) were undetectable on initial testing. There were no statistically significant differences in incidence of hemorrhage (90 [4.1%] vs 370 [3.9%], adjusted risk ratio [RR] 0.93, 95% CI, 0.73–1.17), infection (38 [1.7%] vs 126 [1.3%], adjusted RR 1.56, 95% CI, 0.97–2.51), eclampsia (6 [0.3%] vs 28 [0.3%], adjusted RR 1.12, 95% CI, 0.50–2.53), acute pulmonary or cardiac conditions (15 [0.7%] vs 43 [0.4%], adjusted RR 1.22, 95% CI, 0.65–2.27), transfusion of 2 or more units of packed red blood cells (33 [36.7%] vs 110 [29.8%], *P*=.21), additional uterotonics (48 [53.3%] vs 173 [47.1%], *P*=.29), use of tranexamic acid (31 [ 34.4%] vs 106 [29.0%], *P*=.31), intensive care unit admission (4 [0.2%] vs 10 [0.1%], *P*=.31), mechanical ventilation (3 [0.1%] vs 6 [0.1%], *P*=.38), pressor support (2 [0.1%] vs 2 [0.0%], *P*=.16), or mortality (5 [0.2%] vs 11 [0.1%], adjusted RR 1.44, 95% CI, 0.46–4.57) in people with HIV infection compared with those without HIV infection. There were few notable differences, including a slightly reduced risk of preeclampsia (184 [8.4%] vs

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**818 [8.6%], adjusted RR 0.84, 95% CI, 0.71–0.98) and, although rare, an increased risk of uterine rupture (12 [0.5%] vs 8 [0.1%], adjusted RR 6.54, 95% CI, 2.33–18.33) in people with HIV infection compared with those without HIV infection.**

**CONCLUSION: There was little difference in adverse maternal obstetric outcomes between people with and those without HIV infection in the treat-all era with integrase strand inhibitors (primarily dolutegravir); notable exceptions included a slightly reduced risk of preeclampsia and, although rare, an increased risk of uterine rupture in those with HIV infection.**

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Before the advent of antiretroviral therapy (ART), human immunodeficiency virus (HIV) infection accounted for approximately 20% of maternal mortality in sub-Saharan Africa.[1] People with HIV infection historically have been susceptible to a heavy burden of maternal morbidity and mortality related to immunosuppression and pregnancy-related sepsis.[2] Robust studies have investigated the neonatal effect of improved management of maternal HIV infection with ART. However, there remains a paucity of data on the effect of universal ART on maternal morbidity and mortality, although available data suggest that people with HIV infection on ART remain at increased risk of maternal morbidity and mortality, including weight changes, diabetes mellitus, hypertensive disorders of pregnancy, and kidney and liver injury.[2–7] A 2021 study from Lesotho comparing pregnancy outcomes of people with and without HIV infection found that regardless of widespread ART availability, people with HIV infection were two to three times more likely to experience adverse pregnancy outcomes compared with people without HIV infection.[5]

Botswana is a unique setting to study the effect of HIV infection and ART on maternal outcomes; it has a high prevalence of HIV infection in the reproductive-aged population (24%) yet has also achieved the Joint United Nations Programme on HIV/AIDS 95-95-95 targets to eliminate HIV, with 95% of the population being aware of their HIV status and 98% on ART.[8] It has led sub-Saharan Africa in initiating ART at the time of HIV diagnosis ("treat all") and was an early adopter of integrase strand inhibitors (primarily dolutegravir) as first-line therapy in 2016.[9] In 2017, there were 380,000 people with HIV infection and 4,100 HIV-related deaths in Botswana.[10] By 2023, the number of people with HIV infection and HIV-related deaths each reduced by approximately 5%.[11] In contrast, maternal mortality rates increased overall from 143.2 per 100,000 live births in 2017 to 175.5 per 100,000 live births in 2022, more than twice the World Health Organization's goal of fewer than 70 per 100,000 live births.[12] Approximately 5.6% of maternal deaths in Botswana in 2022 were attributed to complications of HIV infection in the peripartum period.[12]

The objective of this study was to evaluate maternal outcomes by HIV status in a large observational cohort at the largest tertiary referral hospital in Botswana after implementation of the HIV treat-all policy and incorporation of integrase strand inhibitors. Our hypothesis was that there would be no difference in maternal morbidity and mortality between people with HIV infection on ART and people without HIV infection.

## METHODS

Data were collected at the time of delivery from November 2021 to December 2023 in the Tsepamo Birth Outcomes Surveillance and Safe Birth maternal outcomes surveillance studies at Princess Marina Hospital in Botswana. More than 95% of deliveries in Botswana occur in a health care facility, and Princess Marina Hospital is the tertiary referral hospital for the entire southern region of Botswana.[13] Women admitted to receive obstetric services at Princess Marina Hospital with a gestation of 24 weeks or more that resulted in live birth, stillbirth, or maternal death while still pregnant were included in the analyzed data sets. Patients with unknown HIV status were excluded.

As reported in prior studies, maternal obstetric records were reviewed, and deidentified data were abstracted at the time of hospital discharge.[14–16] Data collected included maternal demographics, medical history, obstetric history, antenatal care data, inpatient course, neonatal and maternal outcomes, and complications. For people with HIV infection, data on ART regimen at conception and delivery, CD4 cell counts, and viral loads during pregnancy also were collected.

The primary outcomes were adverse maternal complications, including hypertensive disorders of pregnancy, eclampsia, obstetric hemorrhage as identified by estimated blood loss, acute kidney injury, infection, acute cardiac or pulmonary events, liver failure, hyperglycemia, loss of consciousness or collapse, and maternal death. *Infection* was defined as a composite of intra-amniotic infection, sepsis, wound infection, urinary tract infection, and pneumonia. *Acute cardiac or pulmonary events* were defined as a composite of stroke, pericardial effusion, cardiac arrest, peripartum cardiomyopathy, respiratory failure, aspiration,

pulmonary effusion, pulmonary embolism, pulmonary edema, and amniotic fluid embolism. Secondary outcomes, including emergency interventions, also were extracted and included use of additional uterotonics beyond oxytocin, use of tranexamic acid, transfusion of blood products (packed red blood cells and fresh-frozen plasma), emergency surgical interventions, antibiotic administration (aside from prophylactic indications), dialysis, intensive care unit admission, mechanical ventilation, and pressor support.

This was a sample of convenience based on available data in the described studies. Descriptive data are presented as mean±SD or counts and percentages. Categorical variables were compared with the $\chi^2$ or Fisher exact test, and continuous variables were compared with the Wilcoxon rank-sum test. We used modified Poisson regression to calculate risk ratios (RRs) and 95% CIs and adjusted for potential confounders, specifically age and parity, with the exception of the uterine rupture outcome, for which we adjusted for age and history of cesarean delivery. We performed a sensitivity analysis and compared differences between people with HIV infection with CD4 values and those without. All tests were two sided, and values of $P<.05$ were considered statistically significant. Statistical analyses were conducted with SAS 9.4.

Ethics approval was granted by the Health Research and Development Council of the Ministry of Health and Wellness of Botswana and the IRBs of the University of Botswana, Harvard T.H. Chan School of Public Health, and Beth Israel Deaconess Medical Center.

## RESULTS

Among 11,875 postnatal discharge records reviewed, 121 had no known HIV status and thus were excluded from the analysis (Fig. 1). Of the 11,754 records included in the analysis, 2,201 (18.7%) were for pregnant people with HIV infection. Demographic characteristics, medical history, and antenatal history of the study population are illustrated in Table 1. Pregnant people with HIV infection were older, had higher gravidity and parity, and were more likely to have fewer than four antenatal visits, history of anemia, and history of tuberculosis than those without HIV infection. Those with HIV infection were more likely to have had at least one prior cesarean delivery compared with those without HIV infection. Otherwise, there were no meaningful differences in history of hypertension, diabetes, renal disease, cardiac disease, or psychiatric disease by HIV status.

Of people with HIV infection, 2,135 (97%) were on ART at time of delivery; 1,691 (76.8%) were on ART at the time of conception. Of the 2,135 people with HIV infection on ART, 2,125 were on known ART regimen. The majority, 1,996 (93.9%), were on an integrase strand inhibitor–based regimen. Of those on integrase strand inhibitor–based regimen, 1,983 people with HIV infection were on dolutegravir, tenofovir disoproxil fumarate, and either lamivudine or emtricitabine, and 13 were on dolutegravir, tenofovir alafenamide, and emtricitabine (Table 2 and Appendix 1, available online at http://links.lww.com/AOG/E290). Seventy-one were on efavirenz-containing ART regimens, and one individual was on a nevirapine-containing regimen. Of the 1,090 participants with known CD4 counts, 757 (69.4%) had more than 500 cells/microliter, 186 (17.1%) had 350–499 cells/microliter, 105 (9.6%) had 200–349 cells/microliter, and only 42 (3.9%) had fewer than 200 cells/microliter. Sensitivity analysis of women with and without known CD4 count showed that women without a known recent CD4 count were less likely to be employed and had fewer antenatal care visits and that there were no deaths among people with HIV infection without recent CD4 count; otherwise, there were no significant differences (Appendix 2, available online at http://links.lww.com/AOG/E290). Of 1,524 with known viral loads, 1,436 (94.2%) were undetectable (fewer than 40 copies/mL) on initial testing, and of those who were initially detectable, 34 (38.6%) became undetectable before delivery (Table 2).

Table 3 shows maternal outcomes by HIV status. There were no significant differences by HIV status in comparisons of the incidence of hypertensive disorders of pregnancy, including preeclampsia (crude RR 0.98, 95% CI, 0.84–1.14), HELLP (hemolysis, elevated liver enzymes, and low platelet count) syndrome (crude RR 1.52, 95% CI, 0.81–2.86), and eclampsia (crude RR 0.93, 95% CI, 0.39–2.24) with crude analysis of our study population. When the analysis was adjusted for age and parity, people with

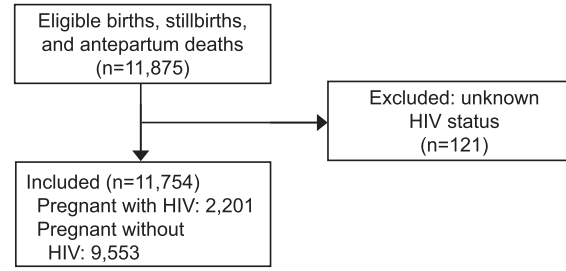


**Fig. 1.** Inclusion flow diagram.

*Agudogo. Maternal Outcomes by HIV Status in Botswana. Obstet Gynecol 2025.*

**Table 1. Demographic Characteristics, Medical and Antenatal, and History of the Study Population**

| Variable* | HIV Infection | |
|---|---|---|
| | Yes (n=2,201) | No (n=9,553) |
| Age (y) | 33.0 (28.0–37.0) | 27.0 (22.0–33.0) |
| Gravidity | 3.0 (2.0–4.0) | 2.0 (1.0–3.0) |
| Parity | 2.0 (1.0–3.0) | 1.0 (0.0–2.0) |
| Secondary education or more | 1,975 (94.0) | 8,937 (97.1) |
| Employed | 1,078 (53.1) | 4,523 (50.6) |
| Single marital status | 1,790 (86.7) | 7,585 (84.0) |
| Prepregnancy weight (kg) | 75.2±16.7 | 77.2±17.8 |
| 90 or less | 1,583 (83.0) | 6,751 (79.5) |
| More than 90 | 324 (17.0) | 1,741 (20.5) |
| No. of antenatal care visits | | |
| Fewer than 4 | 302 (14.0) | 1,021 (10.8) |
| 4–7 | 490 (22.7) | 2,001 (21.3) |
| 8 or more | 1,368 (63.3) | 6,395 (67.9) |
| Gestational age at delivery (wk) | 39.0 (37.0–40.0) | 39.0 (37.0–40.0) |
| Mode of delivery | | |
| Cesarean | 673 (30.6) | 2,723 (28.5) |
| Vaginal | 1,528 (69.4) | 6,830 (71.5) |
| No. of prior cesarean deliveries | | |
| 0 | 618 (58.9) | 3,128 (69.7) |
| 1 | 225 (21.5) | 887 (19.8) |
| More than 1 | 206 (19.6) | 474 (10.6) |
| Hypertension | 90 (4.1) | 322 (3.4) |
| Diabetes | 9 (0.4) | 73 (0.8) |
| Anemia | 93 (4.2) | 246 (2.6) |
| Renal disease | 1 (0.0) | 4 (0.0) |
| Cardiac disease | 11 (0.5) | 43 (0.5) |
| Psychiatric illness | 3 (0.1) | 18 (0.2) |
| Tuberculosis | 20 (0.9) | 39 (0.4) |

HIV, human immunodeficiency virus.
Data are median (interquartile range), n (%), or mean±SD.
* Missing data: age 2; gravidity 56; parity 58; education 451; employment 793; marital status 663; antenatal care visits 177; weight 1,355; gestational age at delivery 325; number of prior cesarean deliveries 3,604; and hypertension, diabetes, anemia, renal disease, cardiac disease, psychiatric illness, and tuberculosis 2.

HIV infection were found to be less likely to have preeclampsia (adjusted RR 0.84, 95% CI, 0.71–0.98) with no significant difference in preeclampsia with severe features (adjusted RR 0.92, 95% CI, 0.8–1.07), HELLP syndrome (adjusted RR 1.15, 95% CI, 0.57–2.34), and eclampsia (adjusted RR 1.12, 95% CI, 0.50–2.53). There were no statistically significant differences in either crude or adjusted models in the incidence of obstetric hemorrhage (adjusted RR 0.93, 95% CI, 0.73–1.17), infection (adjusted RR 1.56, 95% CI, 0.97–2.51), acute cardiac or pulmonary events (adjusted RR 1.22, 95% CI, 0.65–2.27), liver failure, acute kidney injury (adjusted RR 1.45, 95% CI, 0.70–3.01), and maternal death (adjusted RR 1.44, 95% CI, 0.46–4.57). The number of outcomes was small, and these results should be interpreted with caution. Of the 10 people with HIV infection with kidney injury, ART regimen was known in eight, and all of those were on a three-drug regimen containing dolutegravir and tenofovir disoproxil fumarate. In a stratified analysis of risk for infection by recent CD4 cell count, although absolute numbers of infections were small, people with HIV infection with CD4 count below 350 cells/microliter were found to be at an increased risk of infection (infection occurred in six [35.3%] compared with no infection in 141 [13.1%], $P$=.02) (Appendix 3, available online at http://links.lww.com/AOG/E290).

Although rare, people with HIV infection were more likely to require surgery for uterine rupture (12 [0.5%] in people with HIV infection vs eight [0.1%] in those without HIV infection, adjusted RR 6.54, 95% CI, 2.33–18.33). Among people with HIV infection who had surgery for uterine rupture, five had no prior cesarean delivery, five had one prior cesarean delivery, two had more than one prior cesarean delivery, and none had other uterine surgeries apart from cesarean delivery. Among those without HIV infection

**Table 2. Human Immunodeficiency Virus (HIV) Immune Status and Treatment Characteristics Among Women With HIV**

| Variable* | Value |
|---|---|
| On ART regimen | |
| At delivery | 2,135 (97) |
| At conception | 1,691 (76.8) |
| Known ART regimen at delivery | 2,125 |
| Integrase strand inhibitor–based regimen† | 1,996 (93.9) |
| Nonnucleoside reverse transcriptase inhibitor–based regimen‡ | 72 (3.4) |
| Other | 57 (2.7) |
| Known CD4 count in pregnancy | 1,090 |
| CD4 cell count/microliter | |
| Less than 200 | 42 (3.9) |
| 200–349 | 105 (9.6) |
| 350–499 | 186 (17.1) |
| More than 500 | 757 (69.4) |
| Known viral load | 1,524 |
| Undetectable viral load (1st recorded)§ | 1,436 (94.2) |
| Undetectable viral load most proximal to delivery§ | 1,470 (96.5) |
| Initially detectable and undetectable at time most proximal to delivery | 34 (38.6) |

ART, antiretroviral therapy.
Data are n (%) or n
* Missing data: antiretroviral therapy at conception 351, CD4 count 1,111, and viral load 677.
† Includes 1,983 patients on three-drug regimens of either tenofovir disoproxil fumarate, lamivudine, and dolutegravir or tenofovir disoproxil fumarate, emtricitabine, and dolutegravir and 13 patients on dolutegravir and tenofovir alafenamide/emtricitabine/dolutegravir regimen.
‡ Includes 69 patients on tenofovir disoproxil fumarate, emtricitabine, and efavirenz; two on tenofovir disoproxil fumarate, lamivudine and efavirenz; and one on lamivudine, zidovudine, and nevirapine.
§ *Undetectable viral load* was defined as fewer than 40 copies/mL detected.

who had surgery for a uterine rupture, two had no prior cesarean delivery, four had one prior cesarean delivery, one had more than one prior cesarean delivery, one had an unknown number of cesarean delivery, six had no other uterine surgeries apart from cesarean delivery, and two had unknown number of other uterine surgeries apart from cesarean delivery.

Although the total number of maternal mortalities was small at 16, people with HIV infection were twice as likely to experience maternal death (0.2%) compared with people without HIV infection (0.1%), although this did not reach statistical significance. Of the five cases of death among people with HIV infection, mortality causes included peripartum cardiomyopathy (one), severe anemia and stroke (one), septic shock resulting from infection and uterine rupture (one), hypoxic brain injury (one), and pulmonary edema (one). Cause of death among those without HIV infection included suspected amniotic fluid embolism (two); diagnosed or suspected pulmonary embolism (two); pulmonary edema; coronavirus disease 2019 (COVID-19); severe preeclampsia and hypokalemia (one); hemorrhage, infection or abscess, and pulmonary embolism (one); pulmonary edema and myocardial infarction (one); hypoxic brain injury (one); cardiac arrest (one); preeclampsia with severe features (one); and native valve endocarditis (one).

Table 4 shows emergency interventions by HIV status. There was no significant difference in those receiving 2 or more units of packed red blood cells, 5 or more units of packed red blood cells, or fresh-frozen plasma transfusions among those who experienced obstetric hemorrhage. There were no statistically significant differences by HIV status when the use of additional uterotonics, use of tranexamic acid, use of mechanical ventilation, and use of pressor support were compared. In a subanalysis of only women with preexisting anemia, people with HIV infection were more likely to receive 2 or more units of packed red blood cells than women without HIV infection ($P$=.01) and less likely to receive additional uterotonics; there were no differences in other hemorrhage interventions by HIV status. People with HIV infection were more likely to undergo peripartum hysterectomy (0.6% in people with HIV infection vs 0.1% in those without HIV infection), but this was not statistically significant. Although not statistically significant, people with HIV infection were twice as likely to require an intensive care unit admission (0.2% in people with HIV infection vs 0.1% in those without HIV infection).

## DISCUSSION

There have historically been concerns about increased maternal morbidity and mortality related to HIV infection and ART regimens during pregnancy.[5,17,18] In our analysis comparing adverse maternal outcomes in people with and without HIV infection in Botswana, we found overall similar outcomes across a wide range of parameters. Exceptions include a slightly reduced risk of preeclampsia and, although rare, an increased risk of uterine rupture in people with HIV infection. Only those people with HIV infection with a recent CD4 count of fewer than 350 cells/microliter were at an increased risk of infection. There was a higher frequency of maternal mortality and peripartum hysterectomy among people with HIV infection, although the numbers were small and not statistically significant.

Current data quantifying the risk of maternal morbidity and mortality in people with HIV infection

**Table 3. Maternal Outcomes in Women With Human Immunodeficiency Virus (HIV) Infection Compared With Women Without HIV Infection**

| Outcome* | HIV Infection | | Crude RR (95% CI) | Adjusted RR (95% CI) |
|---|---|---|---|---|
| | Yes (n=2,201) | No (n=9,553) | | |
| Preeclampsia | 184 (8.4) | 818 (8.6) | 0.98 (0.84–1.14) | 0.84 (0.71–0.98)† |
| Without severe features | 69 (37.5) | 273 (33.5) | Ref | Ref |
| With severe features | 115 (62.5) | 541 (66.5) | 0.94 (0.83–1.11) | 0.92 (0.80, 1.07)† |
| HELLP syndrome | 13 (0.6) | 37 (0.4) | 1.52 (0.81–2.86) | 1.15 (0.57–2.34)† |
| Eclampsia | 6 (0.3) | 28 (0.3) | 0.93 (0.39–2.24) | 1.12 (0.50–2.53)† |
| Obstetric hemorrhage | 90 (4.1) | 370 (3.9) | 1.06 (0.84–1.32) | 0.93 (0.73–1.17)† |
| Antepartum | 5 (0.2) | 30 (0.3) | 0.72 (0.28–1.86) | 0.66 (0.24–1.81)† |
| Intrapartum | 7 (0.3) | 33 (0.3) | 0.92 (0.41–2.08) | 0.75 (0.32–1.78)† |
| Postpartum | 82 (3.7) | 334 (3.5) | 1.06 (0.84–1.35) | 0.96 (0.75–1.23)† |
| Acute kidney injury | 10 (0.5) | 20 (0.2) | 2.17 (1.02–4.63) | 1.45 (0.70–3.01)† |
| Acute cardiac or pulmonary events‡ | 15 (0.7) | 43 (0.4) | 1.51 (0.84–2.72) | 1.22 (0.65–2.27)† |
| Liver failure | 1 (0.0) | 0 (0.0) | — | — |
| Infection§ | 38 (1.7) | 126 (1.3) | 1.31 (0.91–1.88) | 1.56 (0.97–2.51)† |
| Uterine rupture | 12 (0.5) | 8 (0.1) | 6.51 (2.66–15.91) | 6.54 (2.33–18.33)‖ |
| Maternal death | 5 (0.2) | 11 (0.1) | 1.97 (0.69–5.67) | 1.44 (0.46–4.57)† |

HIV, human immunodeficiency virus; RR, risk ratio; Ref, referent; HELLP, hemolysis, elevated liver enzymes, and low platelet count.
Data are n (%) unless otherwise specified.
* Missing data: preeclampsia 17, type of preeclampsia 4, and acute kidney injury 6.
† Model adjusted for age and parity.
‡ Acute cardiac and pulmonary events included stroke, pericardial effusion, cardiac arrest, peripartum cardiomyopathy, respiratory failure, aspiration, pulmonary effusion, pulmonary embolus, pulmonary edema, and amniotic fluid embolus.
§ Infection included intraamniotic infection, sepsis, wound infection, urinary tract infection, and pneumonia, as well as antibiotics given aside from prophylactic indications.
‖ Model adjusted for age and history of cesarean delivery.

in the modern HIV treat-all (universal access to ART) era with integrase strand inhibitors are scarce. Reported literature has suggested poor birth outcomes and poor maternal health outcomes despite improved access to ART.[5,17,18] Our findings are consistent with an older prospective analysis of 354 people with HIV infection from Uganda (enrolled between 2005 and 2011) in a primarily rural setting that found no increased maternal mortality among people with HIV infection on ART for more than 2 years, although this study found increased mortality with a shorter duration of ART.[19] Given global policy on HIV treatment at the time of this study, these deaths were likely related to HIV-related causes and infections, which aligns with our findings of increased risk of infection among people with HIV infection with CD4 counts below 350 cells/microliter.

The restoration of immune responses with ART has led to uncertainty about the safety of certain ART agents in pregnancy, for example, related to renal and placental pathology.[20–24] Early studies of older ART regimens suggested a return of risk (or potential excess risk) for preeclampsia presumably because of restoration of Th1-driven immune responses.[4,19,25] On the contrary, we found that people with HIV infection in our population of near-universal coverage with ART were less likely to have preeclampsia overall. Although not statistically significant, people with HIV infection in our study trended toward an increased risk of acute kidney injury, and the majority were on tenofovir disoproxil fumarate. Some data have associated HIV infection with an increased risk of acute kidney injury that may be related to the direct nephrotoxic effect of HIV infection or side effects of tenofovir disoproxil fumarate.[23,24] Tenofovir alafenamide, which has fewer nephrotoxic effects, has been suggested as an alternative regimen, particularly in those at increased risk for acute kidney injury.[4,26,27] Rare outcomes such as acute cardiac or pulmonary events and liver failure trended toward a slightly increased risk in people with HIV infection; however, there was no statistically significant difference, possibly related to the sample size not being powered to detect differences in these rare outcomes. Given data in nonpregnant adults concerning for accelerated metabolic decline attributable to ART, ongoing surveillance of the intersection of pregnancy, noncommunicable diseases, and HIV infection is warranted.[28]

Consistent with prior literature, we found that pregnant people with HIV infection had significantly higher rates of preexisting anemia compared with those without HIV infection.[29] We did not find a statistical

**Table 4. Emergency Interventions Required by Human Immunodeficiency Virus (HIV) Status**

| Variable* | HIV Infection | | P |
|---|---|---|---|
| | Yes (n=2,201) | No (n=9,553) | |
| Obstetric hemorrhage | 90 (4.1) | 370 (3.9) | .64 |
| Additional uterotonics | 48 (53.3) | 173 (47.1) | .29 |
| Tranexamic acid administration | 31 (34.4) | 106 (29.0) | .31 |
| Transfused 2 units or more of pRBCs | 33 (36.7) | 110 (29.8) | .21 |
| Transfused 5 units or more of pRBCs | 0 (0.0) | 12 (3.3) | .14 |
| Transfused 3 packs or more of FFP | 2 (2.2) | 21 (5.7) | .28 |
| Among those with preexisting anemia | 149 (6.8) | 321 (3.4) | <.0001 |
| Additional uterotonics | 14 (9.5) | 53 (16.8) | .04 |
| Tranexamic acid administration | 12 (8.2) | 29 (9.2) | .72 |
| Transfused 2 units or more of pRBCs | 57 (38.3) | 83 (25.9) | .01 |
| Transfused 5 units or more of pRBCs | 1 (0.7) | 5 (1.6) | .67 |
| Transfused 3 packs or more FFP | 4 (2.7) | 9 (2.8) | 1.00 |
| Peripartum hysterectomy | 6 (0.6) | 4 (0.1) | .08 |
| Dialysis | 1 (0.1) | 0 (0.0) | .19 |
| Intensive care unit admission | 4 (0.2) | 10 (0.1) | .31 |
| Mechanical ventilation | 3 (0.1) | 6 (0.1) | .38 |
| Pressor support | 2 (0.1) | 2 (0.0) | .16 |

HIV, human immunodeficiency virus; pRBCs, packed red blood cells; FFP, fresh-frozen plasma.
Data are n (%) unless otherwise specified.
* Missing data: hypertension 6; hemorrhage 48; uterotonics 3; tranexamic acid 4; transfused pRBCs and FFP 1 each; dialysis 6; intensive care unit 4; ventilation 5; pressor 5, anemia 1; and transfused pRBCs among those with anemia 1.

difference in hemorrhage rates among people with HIV infection compared with those without HIV infection, contrary to a prior study in South Africa that showed significantly higher rates of postpartum hemorrhage among those with HIV infection.[30] We did find a difference by HIV status in management of women experiencing obstetric hemorrhage with preexisting anemia whereby people with HIV infection were more likely to be transfused and those without HIV infection were more likely to receive additional uterotonics. Although this is consistent with a prior study in South Africa that showed significantly higher rates of transfusion among those with HIV infection, we do not have a clear explanation for the differential management of hemorrhage between those with and those without HIV infection experiencing hemorrhage.[29]

The strengths of our study included our population with a high prevalence of HIV infection and ART use, a large sample size, and our granular medical record review, allowing inclusion of a wide range of adverse maternal outcomes. Limitations of our study include the observational nature, which depended on medical record documentation, and the high missingness of some variables, which could potentially bias our analysis and limited our ability to conduct further adjusted or stratified analyses. We were unable to measure ART class effect given that the majority of our population was on a regimen containing dolutegravir and tenofovir disoproxil fumarate. Certain outcomes that are rare such as maternal death had wide CIs, indicating limited statistical power to detect meaningful differences. Finally, although Botswana is a strong model for HIV research in a setting of high prevalence of HIV infection and high uptake of ART, these findings may not be generalizable in settings where ART coverage is lower or where integrase strand inhibitors are not the standard of care.

Overall, we found that people with HIV infection experienced few clinically meaningful differences in adverse maternal obstetric outcomes by HIV status in the current treat-all ART era; notable exceptions included slightly lower rates of preeclampsia and, although rare, increased rates of uterine rupture. These results provide updated data on maternal outcomes in a cohort of people with HIV infection and stress the importance of maintaining access to ART to prevent maternal morbidity and mortality.

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