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Herpes Simplex Virus Type-2 Cervicovaginal Shedding Among Women Living With HIV-1 and Receiving Antiretroviral Therapy in Burkina Faso: An 8-Year Longitudinal Study

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Background. The impact of antiretroviral therapy (ART) on herpes simplex virus type-2 (HSV-2) replication is unclear. The aim of this study was to assess factors associated with cervicovaginal HSV-2 DNA shedding and genital ulcer disease (GUD) in a cohort of women living with human immunodeficiency virus type-1 (HIV-1) in Burkina Faso.

Methods. Participants were screened for cervicovaginal HSV-2 DNA, GUD, cervicovaginal and systemic HIV-1 RNA, and reproductive tract infections every 3–6 months over 8 years. Associations with HSV-2 shedding and quantity were examined using random-effects logistic and linear regression, respectively.

Results. Of the 236 women with data on HSV-2 shedding, 151 took ART during the study period. Cervicovaginal HSV-2 DNA was detected in 42% of women (99 of 236) in 8.2% of visits (151 of 1848). ART was associated with a reduction in the odds of HSV-2 shedding, which declined for each year of ART use (odds ratio [OR], 0.74; 95% confidence interval [CI], .59–.92). In the multivariable model, the impact of ART was primarily associated with suppression of systemic HIV-1 RNA (adjusted OR, 0.32; 95% CI, .15–.67). A reduction in the odds of GUD was also observed during ART, mainly in those with HIV-1 suppression (adjusted OR, 0.53; 95% CI, .25–1.11).

Conclusions. ART is strongly associated with a decrease in cervicovaginal HSV-2 shedding, and the impact was sustained over several years.

Keywords. antiretrovirals; HIV-1; herpes simplex virus type-2; HSV-2; female; genital tract; genital ulcer disease; Burkina Faso.
reverse transcriptase inhibitors. Participants were followed approximately every 3–6 months. A subset of women were enrolled in a randomized trial of valacyclovir to suppress HIV-1 genital shedding, with fortnightly visits over a 12-week period in 2004–2005 [18, 19]. All visits corresponding to regular cohort visits were included in this analysis, excluding those with valacyclovir use.

At each visit, a clinician performed a gynecological examination; recorded whether GUD was present, based on detection of vesicles or ulcers; and collected genital samples. Enriched cervicovaginal lavage (eCVL) was performed by infusing 2 mL of normal saline into the vagina for 60 seconds and collecting it into a cryotube. A swab was rotated 360 degrees in the cervical os and placed into the same cryotube [20]. Women with symptoms of reproductive tract infections were treated according to national syndromic management guidelines, which did not include acyclovir during the study period. Visits were deferred during menses.

The research protocol was approved by the institutional review boards at the London School of Hygiene and Tropical Medicine and Centre Muraz and the research ethics committee at the Burkina Faso Ministry of Health. All women provided written informed consent.

HSV-2 serology was assessed using the Kalon IgG2-ELISA kit (Kalon Biologicals). HIV-1 RNA in plasma and eCVL specimens was detected and quantified using real-time polymerase chain reaction (PCR) analysis (Generic HIV Viral Load; Biocentric) [21]. HSV-2 DNA was extracted from 200 µL of eCVL fluid by using the QIAamp DNA mini kit (Qiagen) and was eluted in 100 µL of buffer. HSV-2 DNA was amplified from 5 µL of eluate by TaqMan real-time PCR analysis, using the ABI Prism 7000 Sequence Detection Systems, and was quantified using the HSV-2 Quantitated External Control (Tebu-Bio) [22]. The lower limit of detection was 300 copies/mL (2.50 log10 copies/mL).

Cervical swabs were tested for Neisseria gonorrhoeae and Chlamydia trachomatis, using PCR (Ambicor CT/NG PCR assay; Roche); testing was restricted to swabs dating from 2007 onward, owing to the potential for DNA degradation [23]. Vaginal smears were examined using wet-mount microscopy. Bacterial vaginosis was diagnosed on the basis of the Nugent score assigned to heat-fixed vaginal smears. The presence of sperm was detected using qualitative PCR to detect the Y chromosome [24].

The frequency of GUD and HSV-2 shedding and the quantity of HSV-2 DNA were assessed after stratification by ART status and ART duration. HIV-1 RNA and HSV-2 DNA loads in plasma and eCVL specimens were transformed to log10 copies/mL. Viral suppression was defined as achieving an undetectable HIV-1 RNA load in plasma (defined as a plasma viral load of < 2.50 log10 copies/mL) within the first 12 months of ART, and immune reconstitution was defined as a CD4+ T-cell count increase of ≥100 cells/µL by 12 months after ART initiation [25]; data collected 18 months after ART initiation were evaluated if data collected at 12 months were missing. Logistic regression was used to estimate odds ratios (ORs) associated with (1) detectable shedding and (2) GUD, adjusting for within-woman correlation by using random-effects models. Multivariable logistic regression models were constructed using a hierarchical framework and included factors known to be associated with either GUD or detectable cervicovaginal HSV-2, namely age group [10, 26] and immune reconstitution [27, 28], or to be independently associated with GUD or HSV-2 DNA in univariable analysis, with a P value of <.10. Immune reconstitution and viral suppression were preferentially included in the final model owing to missing values for concurrent CD4+ T-cell counts and plasma viral load.

For the quantitative analyses, visits with undetectable HIV-1 or HSV-2 were assigned half the threshold value [18]. Random-effects linear regression was used to assess factors associated with the quantity of cervicovaginal HSV-2 DNA, restricted to visits with detectable HSV-2. A multiple linear regression model was constructed in the same fashion as the logistic model. Statistical analyses were performed using Stata, version 12.0 (StataCorp).

**RESULTS**

Between 2003 and 2011, 317 women seropositive for HIV-1 and HSV-2 were enrolled, of whom 236 had data collected on cervicovaginal HSV-2, and 81 did not have any stored samples. The characteristics of women with shedding data are shown in Supplementary Table 1. The median age at cohort enrollment was 32 years (interquartile range [IQR], 18–48 years); 14% [33 of 236] were receiving ART at their first visit during which HSV-2 DNA was measured, 54% (128 of 236) initiated ART during the study period, and 4% (10 of 236) did not have any HSV-2 DNA measured after starting ART. The median CD4+ T-cell count was 357 cells/µL (IQR, 196–564 cells/µL) at the first visit with HSV-2 DNA sampling and 177 cells/µL (IQR, 116–233 cells/µL) at ART initiation. The most common ART regimen was zidovudine/lamivudine/efavirenz (42%); 85% (130 of 151) achieved plasma HIV-1 suppression by 12 months of treatment, and 69% (104 of 151) achieved immune reconstitution.

Shedding was measured during 1896 cohort visits, with 1308 occurring during ART. There was a median of 11 visits (IQR, 1–16 visits) per woman during ART and 6 visits (IQR, 1–16 visits) per woman before ART initiation. The median follow-up time was 1.2 years (IQR, 0.2–1.7 years) before ART initiation and 6.2 years (IQR, 5.0–6.6 years) during ART: 48 visits at which women received valacyclovir were excluded from analyses.

HSV-2 DNA was detected at least once in eCVL samples from 42% of women (99 of 236) at 8.2% of cohort visits (151 of 1848), with GUD detected concomitantly in 15% of shedding episodes (22 of 151). Of women with a measurement while not receiving ART, 33% (67 of 203) had detectable HSV-2 DNA at 15% of visits (84 of 551), and 32% (48 of 151) had detectable HSV-2 DNA at 5% of visits (67 of 1297; P < .001) after ART initiation (Table 1). The highest proportion of visits with shedding
Table 1. Variables Associated With the Presence of Cervicovaginal Herpes Simplex Virus Type 2 (HSV-2) DNA and Genital Ulcer Disease (GUD) Among Women Living With Human Immunodeficiency Virus Type 1 (HIV-1) in Burkina Faso

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>HSV-2 DNA Presence</th>
<th></th>
<th></th>
<th>GUD Presence</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Visits, Proportion (%)</td>
<td>OR (95% CI)b</td>
<td>Regression Coefficient (95% CI)</td>
<td>Visits, Proportion (%)</td>
<td>OR (95% CI)b</td>
</tr>
<tr>
<td></td>
<td>Unadjusted</td>
<td>P Value</td>
<td>Adjusted</td>
<td>P Value</td>
<td>Unadjusted</td>
</tr>
<tr>
<td>Age, y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18–24</td>
<td>.25/204 (12.3)</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>25–34</td>
<td>78/874 (8.9)</td>
<td>0.58 (.28–1.18)</td>
<td>0.81 (.33–2.02)</td>
<td>0.09 (.44 to .62)</td>
<td>0.38 (.21 to .98)</td>
</tr>
<tr>
<td>≥35</td>
<td>48/767 (6.3)</td>
<td>0.39 (.19–.83)</td>
<td>.05</td>
<td>0.61 (.23–1.56)</td>
<td>.42</td>
</tr>
<tr>
<td>ART influence</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ART status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Naive</td>
<td>84/551 (15.3)</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Initiated</td>
<td>67/1297 (5.2)</td>
<td>0.26 (.17–.39)</td>
<td>.001</td>
<td>0.34 (.20–.60)</td>
<td>.001</td>
</tr>
<tr>
<td>CD4+ T-cell count (per 100 cells/µL increase)</td>
<td>.07 (.61–.81)</td>
<td>.001</td>
<td>.04 (−.09 to .17)</td>
<td>.57</td>
<td>. . .</td>
</tr>
<tr>
<td>Plasma HIV-1 RNA load (per log_{10} copies/mL increase)</td>
<td>. . .</td>
<td>1.70 (1.41–2.05)</td>
<td>.001</td>
<td>. . .</td>
<td>0.25 (.07–.42)</td>
</tr>
<tr>
<td>Immune reconstitution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>51/502 (10.1)</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>62/1111 (5.6)</td>
<td>0.54 (.31–.94)</td>
<td>.03</td>
<td>0.68 (.37–1.28)</td>
<td>.22</td>
</tr>
<tr>
<td>Viral suppression</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>29/184 (15.8)</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>78/1374 (5.7)</td>
<td>0.31 (.16–.62)</td>
<td>.001</td>
<td>0.32 (.15–.67)</td>
<td>.003</td>
</tr>
<tr>
<td>Mucosal factor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abnormal vaginal discharge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>89/1421 (6.3)</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>62/410 (15.1)</td>
<td>2.96 (2.00–4.38)</td>
<td>.001</td>
<td>2.86 (1.75–4.88)</td>
<td>.001</td>
</tr>
<tr>
<td>Bacterial vaginosis</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>84/1198 (7.0)</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>59/580 (10.2)</td>
<td>1.38 (.94–2.04)</td>
<td>.10</td>
<td>. . .</td>
<td>–0.12 (−.52 to .28)</td>
</tr>
<tr>
<td>GUD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>129/1722 (7.5)</td>
<td>1.0</td>
<td>1.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yes</td>
<td>22/108 (20.4)</td>
<td>3.22 (1.80–5.76)</td>
<td>.001</td>
<td>2.62 (1.28–5.38)</td>
<td>.008</td>
</tr>
</tbody>
</table>
The presence of HSV-2 DNA and the incidence of GUD were not significantly associated with the presence of a hemorrhagic sample, the presence of semen, ART regimen, or the presence of other reproductive tract infections. These findings were independent of age, ART status, and mucosal factors concurrent with the collection of cervicovaginal lavage samples. However, there was a significant relationship between HSV-2 DNA presence and the incidence of GUD in ART-naive participants.

During visits with HSV-2 DNA shedding, the mean quantity of HSV-2 DNA detected per 100 cells/µL was 4.47 log_{10} copies/mL (95% CI, 4.20–4.73; n = 84) in ART-naive participants and 3.96 log_{10} copies/mL (95% CI, 3.70–4.22; n = 67) after ART initiation (regression coefficient, −0.51; 95% CI, −0.88 to −0.14; P = .007; Table 1). Concurrent plasma HIV-1 loads were strongly associated with an increase in the amount of HSV-2 DNA shed (regression coefficient, 0.25 per log_{10} increase in PVL; 95% CI, .07–.42). In the multivariable model, there was weak evidence that concurrent HSV-1 suppression was predictive of an increased quantity of HSV-2 DNA (adjusted regression coefficient, 0.39; 95% CI, −0.11 to .89).

There were 317 women with clinical data on GUD during the study period. GUD was present in 22% of women (65 of 292) with data prior to ART initiation and in 32% (92 of 192) with data after ART initiation; among visits, 7.0% (82 of 1176) before ART initiation and 5.7% (93 of 1633) after initiation revealed GUD (P = .17). There were concurrent vesicles at 43% of visits (23 of 124) with ulcers. HSV-2 DNA was detected at 20% of visits (22 of 108) with GUD present and 7.5% of visits (129 of 1722) without GUD present (P < .001). Overall, there was a decrease in frequency of GUD episodes with an increase in concurrent CD4+ T-cell count (OR, 0.79; 95% CI, .70–.89 per 100 cells/µL increase) and an increase with increasing plasma viral load (OR, 1.49; 95% CI, 1.23–1.79 per log_{10} copies/mL increase). There was an increase in the odds of GUD during the first 3 months of ART (OR, 2.00; 95% CI, .96–4.20) but an overall reduction in the odds of GUD during ART (OR, 0.72; 95% CI, .51–1.03). In the multivariable model, there was weak evidence that GUD was inversely associated with HIV-1 suppression (adjusted OR, 0.53; 95% CI, .25–1.11) and with increasing CD4+ T-cell count (adjusted OR, 0.86; 95% CI, .74–1.01).
DISCUSSION

We describe the impact of ART on cervicovaginal HSV-2 and GUD presence over several years. The frequencies of HSV-2 shedding and GUD increased in the 6 months prior to ART initiation, were sustained at that level for the first 3 months of ART, and decreased thereafter. This differs from findings from a study in Uganda, where there was a rise in the frequencies of HSV-2 shedding and GUD during the first 3 months of treatment [13]. In our study, the most substantial decrease in shedding was seen after 12 months of ART, although we were limited by the small number of samples in the first 3 months. The effect of ART was associated with HIV-1 suppression and immune reconstitution, although the magnitude of the effect was larger for viral suppression. This further supports the synergistic interactions between HIV-1 and HSV-2 replication, where systemic HIV-1 replication might drive HSV-2 replication in the sacral ganglia, compounded by weak immune control [29–31]. This reduction was maintained over time and was independent of age; therefore, it is less likely to be due only to the natural history of HSV-2 [9]. Among women who shed, HSV-2 DNA quantities were correlated with quantities of genital HIV-1 RNA, providing additional proof of local direct viral interactions [32].

The effect of ART on GUD appears to be driven by systemic HIV-1 suppression, although there was a decrease in the frequency of GUD among women with higher CD4+ T-cell counts and a trend toward a reduction in the odds of GUD among women with immune reconstitution during ART. The slightly different dynamics for the effect of ART on GUD, compared with HSV-2 shedding, suggest that the clinical benefits might wane over time.

This is one of the first studies to demonstrate prolonged suppression of HSV-2 shedding during ART; other studies have shown no change in shedding during ART but reductions in GUD [33, 34]. The variations in results are likely due to smaller

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**Figure 1.** Frequency of genital herpes simplex virus type 2 (HSV-2) shedding and genital ulcer disease (GUD) among human immunodeficiency virus (HIV)-positive high-risk women before and after antiretroviral therapy (ART) initiation.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time relative to enrollment, mo</td>
<td>-6 and earlier</td>
</tr>
<tr>
<td>Women with shedding data, no.</td>
<td>80</td>
</tr>
<tr>
<td>Visits with shedding detected, proportion (%)</td>
<td>28/222 (13)</td>
</tr>
<tr>
<td>Women with GUD data, no.</td>
<td>113</td>
</tr>
<tr>
<td>Visits with GUD detected, proportion (%)</td>
<td>34/502 (7)</td>
</tr>
<tr>
<td>GUD detection among visits with shedding detected, proportion (%)</td>
<td>3/28 (11)</td>
</tr>
</tbody>
</table>

GUD episodes were detected during 16% of visits (6 of 37) with shedding detected among women who did not initiate ART.

Data are no. of visits during which HSV-2 shedding was detected/no. of visits HSV-2 shedding was measured, and the proportion (%).
sample sizes and variable duration of follow-up, particularly if studies are limited to early periods after ART initiation.

There are limitations to this study. The frequency of sampling was every 3–6 months, and therefore clinical and asymptomatic episodes of HSV-2 activation might have been missed. GUD was assumed to be caused mainly by HSV-2 in this population, based on studies from the region [35, 36]. Our prior study in this population showed that 52% of GUD cases harbored lesional HSV-2 DNA [7]. Although we only detected HSV-2 DNA at 20% of visits with concurrent GUD, this is consistent with other studies that used more sensitive methods [10, 37].

In conclusion, ART has a significant influence on HSV-2 shedding and GUD episodes, primarily associated with HIV-1 suppression. Following ART initiation, HSV-2 shedding is rapidly suppressed, and the influence of ART is sustained over time.

**STUDY GROUP MEMBERS**

Members of the Yérelo study group are as follows: Eloi Bahembera, Abdramane Berthé, Minata Coulibaly, Marie-Christine Defer, Ramata Diallo, Didier Djagbaré, Charlotte Huet, Issouf Konaté, Florent Ky-Dama, Gilles T. M’Boutik, Nicolas Médé, Inès Millogo, Nicolas Nagot, Abdoulaye Ouédraogo, Djanéba Ouédraogo, Francois Rouet, Anselme Sanon, Hauoa Sawadogo, Roselyne Vallo, and Laurence Vergne (deceased January 2007; Centre Muraz, Bobo-Dioulasso, Burkina Faso); Philippe Mayaud and Helen A. Weiss (London School of Hygiene and Tropical Medicine, United Kingdom); Nicolas Nagot, Pierre Becquart, Vincent Fouloung, Michel Segondy, and Philippe Van de Perre, (Université Montpellier 1 and CHU Montpellier, France); and Jean-Baptiste Andonaba and Adrien Sawadogo (University Hospital of Bobo-Dioulasso, Burkina Faso).

**Supplementary Data**

Supplementary materials are available at http://jid.oxfordjournals.org. Consisting of data provided by the author to benefit the reader, the posted materials are not copiededited and are the sole responsibility of the author, so questions or comments should be addressed to the author.

**Notes**

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**Potential conflicts of interest.** All authors: No reported conflicts. All authors have submitted the ICMJE Form for Disclosure of Potential Conflicts of Interest. Conflicts that the editors consider relevant to the content of the manuscript have been disclosed.

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