Macular Changes Observed on Optical Coherence Tomography Angiography in Patients Infected With Human Immunodeficiency Virus Without Infectious Retinopathy

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Purpose: As the human immunodeficiency virus (HIV) pandemic is far from over, whether there are subclinical macular changes in HIV-positive patients is something that should not be overlooked. We aimed to apply optical coherence tomography angiography (OCTA) to assess the macular structure and microvasculature changes in patients with HIV without infectious retinopathy.

Methods: HIV-positive and -negative participants were included and classified into three groups: HIV-negative, HIV-positive, and HIV-positive with microvasculopathy. OCTA parameters regarding macular structure and microvasculature were analyzed.

Results: Compared with the HIV-negative group, the superficial retinal vessel density (VD) in the parafovea sectors and the whole Early Treatment of Diabetic Retinopathy Study (ETDRS) grid and the choroidal vascularity index (CVI) in the whole ETDRS grid were significantly decreased in the HIV-positive and HIV-positive with microvasculopathy groups (p < 0.05). No differences were found in OCTA parameters between the HIV-positive and HIV-positive with microvasculopathy groups. Retinal, retinal nerve fiber layer-ganglion cell layer-inner plexiform layer (RNFL-GCL-IPL), RNFL, GCL-IPL, and INL thickness showed a negative association with the duration of HIV diagnosis or antiretroviral therapy (ART) (all p < 0.05). All OCTA microvasculature parameters showed no association with HIV-related clinical variables (all p > 0.05).

Conclusions: Subclinical macular changes existed in HIV-infected patients without clinical infectious retinopathy. Substructures from inner retinal layers might be associated with HIV infection or ART duration.

Keywords: HIV, macular, non-infectious, microvasculopathy, microvasculature, optical coherence tomography angiography, structure
INTRODUCTION

The human immunodeficiency virus (HIV) pandemic has lasted four decades. Although remarkable achievements have been witnessed in it, it is still far from over (1). Since universal recommendations in the mid-90s, the “treat-all” policy on antiretroviral therapy (ART) greatly contributed toward reducing the visual morbidity and mortality of HIV infection (2–5). However, a higher risk of non-AIDS comorbidities, such as cardiovascular diseases, bone disease, renal and hepatic dysfunction, and neurological disease and cancers should be considered (3, 4).

There were hypotheses about accelerated neuroretinal degeneration because of persistent HIV infection and ART or other factors (6). For patients with HIV infection without ocular opportunistic infections, subtle macular or peripapillary changes were confirmed by various previous studies (7–9). Some results or associations between these structural changes and clinical features were inconsistent (9–11), which might be due to differences in research design and detection machinery.

Optical coherence tomography angiography (OCTA) is a non-invasive instrument possessing an advantage to image retinal and choroidal blood flow and obtain quantitative thickness measurements (12, 13). Besides the wide applications of OCTA in various fundus diseases (13–17) and many systemic diseases (18–20), this non-invasive technology had been proved to be feasible for detecting microvasculopathy in patients with HIV/AIDS with and without clinical retinal diseases (21, 22).

We sought to apply OCTA to assess the macular structure and microvasculature changes in patients with HIV, while there were no clinical infectious retinopathy or only asymptomatic cotton wool spots.

MATERIALS AND METHODS

Participant Recruitment

This prospective cohort study was conducted between August 2019, and October 2019, and approved by the ethics committee of Beijing Youan Hospital, Capital Medical University.

Participants with or without HIV infection were initially included. Patients with a history of diabetes mellitus and cardiovascular and cerebrovascular diseases were excluded. After a routine ocular examination of the anterior segment and fundus, eyes without visible ocular abnormalities or with HIV microvasculopathy were also included. HIV microvasculopathy was diagnosed as asymptomatic cotton wool spots by ophthalmoscopy, which could coexist with small intraretinal hemorrhages, microaneurysms, and telangiectasia (23, 24). The HIV-infected group in this study was defined as having no visible ocular abnormalities in patients with HIV infection. Participants were classified into three groups: HIV-negative, HIV-positive, and HIV-positive with microvasculopathy. Only the right eye was selected. The left eye was recruited when the right eye was substandard. Eyes with a history of intraocular surgery, ocular trauma, amblyopia, glaucoma, and other ocular diseases were excluded. The study was reviewed and approved by the ethics committee of Beijing Youan Hospital, Capital Medical University (LL-2018-150-K). Written informed consent was obtained from all participants.

Ocular and Systemic Examinations

The main ocular examinations included slit-lamp biomicroscopy for anterior segment, fundus imaging by Optos Daytona, and axial length by Zeiss IOL Master 500.

HIV infection was identified by self-reporting and a previous positive test. For patients with HIV infection, critical HIV-related parameters were collected, including the duration of infection, duration of ART, CD4/CD8, nadir CD4 counts, and blood HIV-RNA.

Macular Measurements

The OCT device (VG200; SVision Imaging, Ltd., Luoyang, China) used for macular examination was the same as described in previous studies (21, 25). It is a swept-source (SS) OCT with a central wavelength of 1,050 nm (990–1,100 nm full width) and a scanning rate of 200,000 A-scans per second. With automatic pupil focusing and OCT focusing, both 3 and 6 mm scan patterns centering on the fovea were conducted in this study. Rescan was conducted if the image quality was dissatisfied with apparent flaws. Images with a high signal strength index (SSI) were further evaluated, while images with flow projection artifacts or camera artifacts were excluded.

OCTA parameters were automatically calculated. For segmentation errors, manual corrections can be used to fix them. Macular sectors were performed according to the Early Treatment of Diabetic Retinopathy Study (ETDRS) grid, which was also described in our previous study (21). Within the ETDRS grid, parameters from the inner circle were further classified into the central fovea and parafovea (temporal, superior, nasal, and inferior); while parameters from the outer circle were excluded because of an incomplete edge in the 6 × 6 mm scanning area.

OCTA parameters were stratified into macular microvasculature and macular structural parameters. Microvasculature parameters included the foveal avascular zone (FAZ) from a 3 × 3 mm scan pattern, superficial retinal vessel density (VD), inner retinal VD, and choroidal vascularity index (CVI) from a 6 × 6 mm scan pattern, which also contained quantitative measurements of retinal and choroidal thicknesses. Besides, there were detailed measurements of the retinal nerve fiber layer (RNFL), ganglion cell layer (GCL), inner plexiform layer (IPL), RNFL, GCL-IPL, and INL from the inner retinal layer, as well as photoreceptor-retinal pigment epithelium (PR-RPE). The classification of each OCTA parameter was also described in our previous study (21).

Abbreviations: HIV, Human immunodeficiency virus; OCTA, Optical coherence tomography angiography; VD, Vessel density; ETDRS, Early Treatment of Diabetic Retinopathy Study; CVI, Choroidal vascularity index; INL, Inner nuclear layer; RNFL, Retinal nerve fiber layer; GCL, Ganglion cell layer; IPL, Inner plexiform layer; ART, Antiretroviral therapy; FAZ, Foveal avascular zone; PR-RPE, Photoreceptor-retinal pigment epithelium; AL, Axial length; CWS, Cotton wool spot.
TABLE 1 | Systemic variables and clinical characteristics of participants in this study.

| Characteristic | HIV-positive (N = 46) | HIV-positive with microvasculopathy (N = 20) | HIV-negative (N = 36) | p-value |
|----------------|----------------------|--------------------------------------------|----------------------|---------|
| Age (yrs), mean ± SD | 36.2 ± 10.0 | 36.5 ± 9.1 | 40.0 ± 9.7 | 0.181 |
| Gender (no. male: no. female) | 40:6 | 19:1 | 29:7 | 0.390 |
| Axial length (mm), median (IQR) | 24.0 (23.2, 25.9) | 24.3 (23.2, 25.0) | 24.0 (23.5, 25.2) | 0.961 |
| CD4 count (μl), median (IQR) | 102.0 (45.5, 262.5) | 16.0 (8.0, 36.0) | / | <0.001* |
| CD4/CD8, median (IQR) | 0.13 (0.07, 0.31) | 0.04 (0.03, 0.09) | / | 0.001* |
| HIV-RNA(log), median (IQR) | 4.4 (1.3, 5.3) | 5.3 (3.4, 5.6) | / | 0.052 |
| Duration of HIV infection (mos), median (IQR) | 4.0 (0.8, 78.0) | 1.0 (0.5, 12.0) | / | 0.061 |
| Duration of ART (mos), median (IQR) | 1.0 (0, 27.0) | 1.0 (0.5, 12.0) | / | 0.006* |
| SSI (3°), mean ± SD | 202.5 ± 121.89 | 193.6 ± 91.35 | 229.9 ± 107.17 | 0.178 |
| SSI (6°), mean ± SD | 187.8 ± 94.22 | 183.3 ± 83.43 | 215.4 ± 107.17 | 0.163 |

N, number of patients; ART, antiretroviral therapy; HIV, human immunodeficiency virus; SD, standard deviation; SSI, signal strength index; IQR, interquartile range; p-value < 0.05 is indicated by an asterisk (*).
### TABLE 2 | Statistical results of macular microvasculature parameters between groups.

|                          | Central fovea | Superior | Inferior | Nasal | Temporal | Whole ETDRS grid |
|--------------------------|---------------|----------|----------|-------|----------|------------------|
|                          | $F$           | $p$-value| $F$      | $p$-value| $F$      | $p$-value| $F$           | $p$-value| $F$              | $p$-value| $F$              | $p$-value| $F$              | $p$-value| $F$              | $p$-value|
| **Superficial retinal VD** |               |          |          |       |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| Groups                   | 1.052         | 0.353    | 8.665    | <0.001* | 12.586   | <0.001* | 8.690        | <0.001* | 15.952          | <0.001* | 9.868           | <0.001* |                 |          |                 |          |
| HIV-positive vs.         | /             | 0.559    | /        | 0.001*  | /        | <0.001* | /            | <0.001* | /               | <0.001* | /                | 0.004*  |                 |          |                 |          |
| HIV-negative             |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| HIV-positive with        | /             | 0.808    | /        | 0.008*  | /        | 0.001*  | /            | 0.022*  | /               | <0.001* | /                | 0.001*  |                 |          |                 |          |
| microvasculopathy        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| vs. HIV-negative         |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| HIV-positive vs.         | /             | 1.000    | /        | 1.000   | /        | 1.000   | /            | 1.000   | /               | 1.000   | /                | 1.000   |                 |          |                 |          |
| HIV-positive with        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| microvasculopathy        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| **Inner retinal VD**     |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| Groups                   | 0.238         | 0.788    | 0.780    | 0.461  | 4.093    | 0.020*  | 0.534        | 0.588   | 0.498           | 0.609   | 0.258           | 0.773   |                 |          |                 |          |
| HIV-positive vs.         | /             | 1.000    | /        | 0.751  | /        | 0.092   | /            | 1.000   | /               | 1.000   | /                | 1.000   |                 |          |                 |          |
| HIV-negative             |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| HIV-positive with        | /             | 1.000    | /        | 1.000  | /        | 0.030*  | /            | 0.946   | /               | 1.000   | /                | 1.000   |                 |          |                 |          |
| microvasculopathy        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| vs. HIV-negative         |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| HIV-positive vs.         | /             | 1.000    | /        | 1.000  | /        | 1.000   | /            | 1.000   | /               | 1.000   | /                | 1.000   |                 |          |                 |          |
| HIV-positive with        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| microvasculopathy        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| **CVI**                  |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| Groups                   | 11.195        | <0.001*  | 18.347   | <0.001* | 19.270   | <0.001* | 8.702        | <0.001* | 8.216           | <0.001* | 15.992          | <0.001* |                 |          |                 |          |
| HIV-positive vs.         | /             | <0.001*  | /        | <0.001* | /        | <0.001* | /            | <0.001* | /               | <0.001* | /                | <0.001* |                 |          |                 |          |
| HIV-negative             |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| HIV-positive with        | /             | 0.1034   | /        | 0.001*  | /        | <0.001* | /            | 0.088   | /               | 0.082   | /                | 0.005*  |                 |          |                 |          |
| microvasculopathy        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| vs. HIV-negative         |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| HIV-positive vs.         | /             | 0.218    | /        | 0.994  | /        | 1.000   | /            | 0.759   | /               | 0.946   | /                | 0.606   |                 |          |                 |          |
| HIV-positive with        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| microvasculopathy        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| **FAZ**                  |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| Groups                   | 0.251         | 0.779    | /        | /      | /        | /       | /            | /       | /               | /       | /                | /       |                 |          |                 |          |
| HIV-positive vs.         | /             | 1.000    | /        | /      | /        | /       | /            | /       | /               | /       | /                | /       |                 |          |                 |          |
| HIV-negative             |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| HIV-positive with        | /             | 1.000    | /        | /      | /        | /       | /            | /       | /               | /       | /                | /       |                 |          |                 |          |
| microvasculopathy        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| vs. HIV-negative         |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| HIV-positive vs.         | /             | 1.000    | /        | /      | /        | /       | /            | /       | /               | /       | /                | /       |                 |          |                 |          |
| HIV-positive with        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |
| microvasculopathy        |               |          |          |        |          |        |               |          |                 |          |                 |          |                 |          |                 |          |

HIV, human immunodeficiency virus; ETDRS, early treatment of diabetic retinopathy study; FAZ, foveal avascular zone; $F$, the statistic of one-way ANOVA; VD, vessel density; CVI, choroidal vascularity index. $p$-value $< 0.05$ is indicated by an asterisk (*).
3-mm diameter inner circle of the ETDRS chart. All OCTA parameters were captured in the fovea and parafoveal area, while CWSs were located in areas rich in RNFL. Second, the mean duration from HIV diagnosis (4 months in the HIV infection group and 1 month in the HIV microvasculopathy group) is very short for significant changes to have occurred. Macular structure and microvasculature changes after CWSs resolution deserve further investigation.

The HIV epidemic is still a challenge in China (29). Ongoing support and care for patients with HIV are still needed in the future, especially for patients beyond viral suppression (30, 31). Various studies had tried to explore retinal vasculature changes in patients with HIV infection with retinal vascular calibers measurements by fundus photographs (32). Studies about retinochoroid microvasculature using OCTA were limited. A previous study found retinal microvasculature changes, including decreased macular VD and perfusion density, in patients with HIV infection (33), similar to our findings. Although OCTA parameters might be different between various OCTA devices and algorithms, the device with a wavelength of 1,050 nm in this study should have its ascendancy over other OCTA devices with shorter wavelengths (34). We also observed decreased retinochoroid microvascular parameters in the HIV infection group or HIV microvasculopathy group, including superficial retinal VD and CVI. Macular microvasculature parameters showed no association with HIV diagnosis or ART duration, which faithfully reflected that a short duration from HIV diagnosis or ART was not enough to changes microvasculature.

Retinal structural assessments in patients with HIV infection using OCT had been conducted by various studies (35–37). There were hypotheses about the presence of accelerated neuroretinal degenerations in these HIV-positive patients (6), which were in line with the reduced macular structure and microvasculature in our study. The persistence of inflammatory state in patients living with HIV are associated with non-AIDS morbidities, such as cardiovascular diseases and neoplastic diseases (38). Whether these neuroretinal degenerations were associated with chronic inflammation and persistent HIV reservoirs (3) deserves further studies. Besides, despite effective HIV suppression, the comorbidities and aging of patients with HIV infection were still challenges. Increased mortality and comorbidity were associated with risk factors in certain populations, such as smoking, obesity, drug and alcohol abuse, and drug toxicity (39, 40), which could also be the potential risk for these macular changes in this study. In this study, various substructures from the inner retinal layers showed a marked negative association with the duration of HIV infection or ART, indicating a degeneration tendency from the persistent HIV infection or ART. It provided a valuable clue for further studies about the relationships between retinal vascular changes and systemic vascular diseases in HIV-positive patients. Such presumed changes could help to monitor or predict systemic vascular diseases in these patients.
### TABLE 3 | Multivariable linear regression analysis between macular structural parameters in the entire Early Treatment of Diabetic Retinopathy Study grid and systemic variables in all patients with human immunodeficiency virus infection (model one).

| Retinal thickness | Choroidal thickness | RNFL-GCL-IPL | RNFL | GCL-IPL | INL | PR-RPE |
|-------------------|--------------------|--------------|-------|---------|-----|--------|
| Uni-variable      | Multi-variable     | Uni-variable | Multi-variable | Uni-variable | Multi-variable | Uni-variable | Multi-variable | Uni-variable | Multi-variable | Uni-variable | Multi-variable | Uni-variable | Multi-variable |
| **B**             | **p-value**        | **B**        | **p-value**   | **B**        | **p-value**   | **B**        | **p-value**   | **B**        | **p-value**   | **B**        | **p-value**   | **B**        | **p-value**   |
| Age              | -0.484 ± 0.015**   | /            | /             | -0.360 ± 0.005* | /            | /             | -0.067 ± 0.029* | /            | /             | -0.293 ± 0.006 | /            | -0.023 ± 0.592 | /            | -0.093 ± 0.426 |
| CD4              | 0.002 ± 0.787      | /            | /             | 0.001 ± 0.974  | /            | /             | 0.009 ± 0.183  | /            | /             | -0.003 ± 0.487 | /            | -0.001 ± 0.08  | /            | 0.008 ± 0.066  |
| CD4/CD8          | -8.767 ± 0.170     | /            | /             | -10.154 ± 0.782| /            | /             | -1.534 ± 0.122| /            | /             | -6.843 ± 0.048 | /            | -0.958 ± 0.494| /            | 0.897 ± 0.795  |
| HIV-RNA (log)    | 1.276 ± 0.28       | /            | /             | -0.111 ± 0.987| 1.113 ± 0.155| /            | 0.267 ± 0.143 | /            | /             | 0.892 ± 0.169 | /            | 0.296 ± 0.252 | /            | -0.180 ± 0.777 |
| Axial length     | 3.002 ± 0.041**    | /            | /             | -25.266 ± 0.003*| 3.462 ± 2.982 | 0.005* | 1.158 ± 1.087 | 0.001* | 2.354 ± 2.049 | 0.026* | 0.514 ± 0.106 | 0.943 ± 0.272 |
| Duration of HIV diagnosis | -0.094 ± 0.007* | -0.094 ± 0.007* | 0.166 ± 0.425 | -0.082 ± 0.075 | 0.002* | -0.020 ± 0.014 | -0.014 ± 0.001* | -0.063 ± 0.057 | 0.006* | -0.171 ± 0.023 | 0.008 ± 0.690 |
| SSI              | -0.015 ± 0.495     | /            | /             | -0.020 ± 0.155| /            | /             | -0.003 ± 0.412| /            | /             | -0.018 ± 0.116| /            | -0.004 ± 0.358 | /            | 0.010 ± 0.448  |

ART, antiretroviral therapy; B, non-standardized beta; HIV, human immunodeficiency virus; RNFL, retinal nerve fiber layer; GCL, ganglion cell layer; IPL, inner plexiform layer; INL, inner nuclear layer; PR, photoreceptor; RPE, retinal pigment epithelium; SSI, signal strength index. p-value < 0.1 are indicated by asterisk (†); p-value < 0.05 are indicated by asterisk (*).

### TABLE 4 | Multivariable linear regression analysis between macular structural parameters in the entire Early Treatment of Diabetic Retinopathy Study grid and systemic variables in all patients with human immunodeficiency virus infection (model two).

| Retinal thickness | Choroidal thickness | RNFL-GCL-IPL | RNFL | GCL-IPL | INL | PR-RPE |
|-------------------|--------------------|--------------|-------|---------|-----|--------|
| Uni-variable      | Multi-variable     | Uni-variable | Multi-variable | Uni-variable | Multi-variable | Uni-variable | Multi-variable | Uni-variable | Multi-variable | Uni-variable | Multi-variable | Uni-variable | Multi-variable |
| **B**             | **p-value**        | **B**        | **p-value**   | **B**        | **p-value**   | **B**        | **p-value**   | **B**        | **p-value**   | **B**        | **p-value**   | **B**        | **p-value**   |
| Age              | -0.484 ± 0.015**   | /            | /             | -0.360 ± 0.005* | /            | /             | -0.067 ± 0.029* | /            | /             | -0.293 ± 0.006 | /            | -0.023 ± 0.592 | /            | -0.093 ± 0.426 |
| CD4              | 0.002 ± 0.787      | /            | /             | 0.001 ± 0.974  | /            | /             | 0.009 ± 0.183  | /            | /             | -0.003 ± 0.487 | /            | -0.001 ± 0.08  | /            | 0.008 ± 0.066  |
| CD4/CD8          | -8.767 ± 0.170     | /            | /             | -10.154 ± 0.782| /            | /             | -1.534 ± 0.122| /            | /             | -6.843 ± 0.048 | /            | -0.958 ± 0.494| /            | 0.897 ± 0.795  |
| HIV-RNA (log)    | 1.276 ± 0.28       | /            | /             | -0.111 ± 0.987| 1.113 ± 0.155| /            | 0.267 ± 0.143 | /            | /             | 0.892 ± 0.169 | /            | 0.296 ± 0.252 | /            | -0.180 ± 0.777 |
| Axial length     | 3.002 ± 0.041**    | /            | /             | -25.266 ± 0.003*| 3.462 ± 2.982 | 0.005* | 1.158 ± 1.087 | 0.001* | 2.354 ± 2.049 | 0.026* | 0.514 ± 0.106 | 0.943 ± 0.272 |
| Duration of ART  | -0.096 ± 0.016*    | -0.096 ± 0.016* | 0.352 ± 0.132 | -0.096 ± 0.085 | 0.002* | 0.023 ± 0.017 | -0.017 ± 0.001* | -0.073 ± 0.065 | 0.005* | -0.13 ± 0.132 | 0.016 ± 0.465 |
| SSI              | -0.015 ± 0.495     | /            | /             | -0.020 ± 0.155| /            | /             | -0.003 ± 0.412| /            | /             | -0.018 ± 0.116| /            | -0.004 ± 0.358 | /            | 0.010 ± 0.448  |

ART, antiretroviral therapy; B, non-standardized beta; HIV, human immunodeficiency virus; RNFL, retinal nerve fiber layer; GCL, ganglion cell layer; IPL, inner plexiform layer; INL, inner nuclear layer; PR, photoreceptor; RPE, retinal pigment epithelium; SSI, signal strength index. p-value < 0.1 are indicated by asterisk (†); p-value < 0.05 are indicated by asterisk (*).
There are limitations to this study. Although objective macular parameters regarding structure and microvasculature were ample in this study, data about visual function were not involved, such as color vision, contrast sensitivity, multifocal electroretinography, and visual fields. As HIV infection is turning into a type of chronic disease, the presence of many possible systemic confounders could contribute to observed changes. Further trials with longitudinal data and large sample size are warranted.

CONCLUSIONS

With precise structure and microvasculature measurements, OCTA revealed decreased superficial retinal VD and CVI in patients with HIV infection with microvasculopathy or clinically normal fundus. HIV infection or ART duration could influence the inner retinal layer substructures. The application of OCTA was meaningful in the ocular observation of patients with HIV infection.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author(s).

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of Beijing Youan Hospital, Capital Medical University (LL-2018-150-K). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

K-FD and W-BW contributed to the conception of the protocol. K-FD and CC obtained the dataset. K-FD, X-JH, L-YX, and W-JK analyzed the data. K-FD and X-JH contributed to writing the first draft of the manuscript and to the revision and editing of the present version of the manuscript. H-WD and W-BW commented on the manuscript and gave final approval of the version to be published. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmed.2022.820370/full#supplementary-material

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