

# Projected Effects of Disruptions to Human Immunodeficiency Virus (HIV) Prevention Services During the Coronavirus Disease 2019 Pandemic Among Black/African American Men Who Have Sex With Men in an Ending the HIV Epidemic Priority Jurisdiction

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**Background.** Disruptions in access to in-person human immunodeficiency virus (HIV) preventive care during the coronavirus disease 2019 (COVID-19) pandemic may have a negative impact on our progress towards the Ending the HIV Epidemic goals in the United States.

**Methods.** We used an agent-based model to simulate HIV transmission among Black/African American men who have sex with men in Mississippi over 5 years to estimate how different reductions in access affected the number of undiagnosed HIV cases, new pre-exposure prophylaxis (PrEP) starts, and HIV incidence.

**Results.** We found that each additional 25% decrease in HIV testing and PrEP initiation was associated with decrease of 20% in the number of cases diagnosed and 23% in the number of new PrEP starts, leading to a 15% increase in HIV incidence from 2020 to 2022.

**Conclusions.** Unmet need for HIV testing and PrEP prescriptions during the COVID-19 pandemic may temporarily increase HIV incidence in the years immediately after the disruption period.

**Keywords.** agent-based modeling; COVID-19; HIV testing; men who have sex with men; pre-exposure prophylaxis.

In 2019, the United States Department of Health and Human Services announced the Ending the HIV Epidemic initiative with the goal of ending the human immunodeficiency virus (HIV) epidemic in the United States by 2030. This plan includes 4 primary strategies: diagnosing all individuals with HIV infection, promoting rapid and consistent access to effective HIV treatment, preventing new HIV transmission events, and responding to emerging outbreaks [1]. Although we have made significant strides towards the goals of this initiative,

the HIV epidemic in the United States continues, particularly in the Deep South. According to recent data from the Centers for Disease Control and Prevention in 2017, approximately half (49.6%) of the men who have sex with men (MSM) in the United States who were diagnosed with HIV resided in the Southern United States [2]. Black/African American MSM bear a disproportionate burden of the HIV epidemic both in the country as a whole and in the South. Among Black/African MSM diagnosed with HIV in 2017, 63% resided in the South [2]. These disparities are the culmination of a myriad of social and structural barriers to accessing HIV testing and effective HIV prevention strategies such as pre-exposure prophylaxis (PrEP), caused fundamentally by structural and systemic racism; stigma, medical mistrust, and lack of appropriate health insurance coverage are only a few examples of these barriers [3]. Given the significant impact of the HIV epidemic on Black/African American MSM in the United States, the goals of the Ending the HIV Epidemic cannot be achieved without addressing these inequities.

It is likely that the coronavirus disease 2019 (COVID-19) pandemic has negatively impacted access to HIV prevention

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and treatment services and potentially exacerbated these disparities. Beginning in March 2020, many clinical settings reduced in-person operations as a result of physical distancing policies enacted to mitigate the spread of COVID-19, thereby reducing access to healthcare in many communities. Several studies have begun to assess how these restrictions may have affected access to HIV preventive services. In a nationwide survey of HIV care providers, Brawley [4] found that 40.7% had only prescribed refills for existing PrEP prescriptions and 4.8% had not prescribed PrEP at all during “stay-at-home” orders. At one clinical site in Boston, orders for HIV tests decreased by 85%, the number of patients initiating PrEP decreased by 72%, and the number of patients with lapses in PrEP prescription refills increased by 191% during a stay-at-home order [5]. Surveys of PrEP-using MSM in the Southern United States have shown that many have foregone HIV testing and have experienced difficulties obtaining their PrEP prescriptions since the beginning of the pandemic [6]. It is possible that changes in sexual risk behavior undergone during the pandemic may have mitigated some of the effects of these lapses in PrEP coverage and initiation; however, collectively, these studies indicate that there have been significant interruptions in the provision of HIV prevention services, which may have left cases undiagnosed and prevented MSM at risk for HIV infection from getting a prescription for PrEP.

Despite these preliminary studies, there are limited data on the population-level impact of the COVID-19 pandemic on HIV testing and PrEP outcomes among Black/African American MSM in the United States. In light of this empirical research gap, mathematical modeling studies have begun to evaluate the short- and long-term impact of COVID-19-related disruptions on access to HIV testing and PrEP care among at-risk MSM. One recent study using a network-based model of MSM in Atlanta found that reductions in PrEP use during COVID-19 only had a moderate impact on HIV incidence compared with reductions in use of HIV treatment [7]. Although the stay-at-home orders in Atlanta and other areas of the Southern United States are similar, MSM living in more suburban and rural areas of the region (and who have already faced significant structural barriers to accessing healthcare before the pandemic) may have been more heavily impacted by these service disruptions [8, 9].

In this study, we aimed to assess the impact of clinical service disruptions during the COVID-19 pandemic on progress towards the goals of the “Diagnose” and “Prevent” pillars of the Ending the HIV Epidemic initiative among Black/African American MSM in the Deep South using an agent-based network model. Our study specifically focuses on Black/African American MSM in Jackson, Mississippi, because we sought to understand how these service disruptions may have affected existing disparities and altered the trajectory of the HIV epidemic in this community. Jackson, Mississippi was an appropriate

setting to study the impact of the COVID-19 pandemic on these outcomes among Black/African American MSM in the United States because it is particularly affected by both pandemics [10–12].

## METHODS

### Study Design

We used TITAN, a previously described agent-based model [13], to simulate HIV transmission among Black/African American MSM in Jackson, Mississippi and to observe the effect of reduced clinical operations during the COVID-19 pandemic on the number of persons with undiagnosed HIV infection, the number of persons newly initiating PrEP, and HIV incidence. Agent-based modeling itself simulates interactions between individual entities, called agents, to generate population-level outcomes using stochastic processes. We simulated a population of 6825 Black/African American MSM of ages 18 to 64 between April 2020 and December 2025 with a monthly discrete time-step. Using this study design, we estimated how changes in sexual behavior and disruption of in-person clinical practices affected HIV transmission, focusing specifically on how many infections went undiagnosed over the study period and how many at-risk individuals initiated the use of PrEP relative to a counterfactual scenario where these disruptions did not occur. Additional details regarding model structure, parameterization, and calibration are included in the [Supplemental Appendix](#).

### Patient Consent Statement

This study was deemed not to be human subjects research.

### Data Sources

Model parameters are shown in [Supplemental Table 1](#). Where possible, we worked with primary data collected from the target study population to parameterize the model. To parameterize agent sexual behaviors, we conducted a secondary analysis of baseline data from the Focus on the Future trial, a randomized controlled trial of a brief, safer sex behavior promotion intervention conducted among young Black/African American MSM in Mississippi [14]. To parameterize PrEP use behaviors (eg, initiation, adherence, discontinuation), we conducted a secondary analysis of data collected from an ongoing prospective cohort study of MSM initiating PrEP in Mississippi. Initial HIV prevalence and progression along the continuum of care was informed by HIV surveillance estimates from the Mississippi State Department of Health [15]. Where required, we drew values for parameters from the published literature, prioritizing estimates from studies of Black/African American MSM in Mississippi or the Southern United States. If these values were unavailable, we used data from national studies.

## Model Description

### Demography

The model population was estimated to be 6825 persons [16]. Agents either left the model by death at rates derived from the National Vital Statistics System for Black/African American men in Mississippi or by aging out at 65 [17]. These agents were replaced by new agents using distributions of the initial population.

### Sexual Networking

In our model, HIV transmission could occur through sexual contact occurring between agents situated in sexual networks. Under the assumption that that all agents could engage in sexual activity, a target number of sexual partners per year was assigned to each agent, drawn from a negative binomial distribution ( $r = 12.5$ ,  $P = .931$ ) [14]. Based on data from the Focus on the Future Trial, the number of anal sex acts per month was assigned to each partnership from a Gamma distribution ( $k = 0.730$ ,  $\theta = 4.339$ ) [14]. The probability of condom use during anal sex was drawn from normal distribution (mean = 0.403; standard deviation = 0.025).

### Human Immunodeficiency Virus Transmission

We estimated the per-act probabilities of transmission for sexual risk behaviors through a recent meta-analysis [18]. We accounted for the increased infectiousness of acute HIV infection by increasing the probability of transmission by a factor of 10 for a period of 3 months [19]. After this acute stage, agents experienced a chronic state of infection in which all agents with HIV infection were subject to a probability of developing acquired immune deficiency syndrome that was determined by engagement with HIV treatment.

### Human Immunodeficiency Virus Prevention and Treatment Engagement

The model population was initialized with an HIV prevalence of 48%, where 83% were assumed to be diagnosed, 69% were assumed to be using antiretroviral treatment (ART), and 50% were assumed to be virally suppressed based on existing surveillance data [15]. Agents who became newly infected were subject to monthly probabilities of being diagnosed, engaging with ART, and achieving viral suppression. Agents who were not infected with HIV or those who were infected but were unaware of their HIV status were subject to a probability of obtaining HIV testing. Human immunodeficiency virus-negative agents initiated PrEP with a probability of 0.049.

### Model Scenarios

As a base case for comparison, we simulated a counterfactual scenario over a 5-year period from April 2020 to December 2025 to simulate the “status quo” where levels of clinical service engagement are maintained in the absence of the COVID-19 pandemic

and its impacts. Because the model was calibrated using trends in HIV diagnoses and treatment informed by the Mississippi State Department of Health, we assumed a stable incidence rate of HIV infections with an increasing percentage of cases treated based on past trends in these outcomes. In addition, we assumed increasing PrEP coverage over time based on data from the cohort. In all other scenarios, a stay-at-home order in Mississippi was initiated by Executive Order 1463 and lasted from March 2020 to June 2020 [20]. Beyond this period, we accounted for a single, 18-month period of clinical service disruption that began in March 2020 and ended in September 2021 [21].

To estimate the longer-term effects of the stay-at-home orders and subsequent reductions in in-person clinical operations on missed diagnoses of HIV and initiation of PrEP, we simulated the disruption of in-person clinical practice by reducing probabilities of HIV testing and PrEP initiation. Because the extent to which HIV testing and PrEP initiation has been reduced during the pandemic is unknown, we simulated scenarios that decreased the probabilities of HIV testing and PrEP initiation by percentages ranging from 0% to 75% in 25% increments (0%, 25%, 50%, and 75%). We classified these levels of disruption as corresponding to the following real-world scenarios: no disruption to in-person clinical practice (status quo), minimal levels of disruption (physical distancing and reduced access to some clinical operations such as testing, 25%), moderate levels of disruption (partial shutdown of in-person clinics with more physical distancing restrictions, 50%), and severe levels of disruption (complete shutdown of nonessential operations, 75%). Although the 75% can be viewed as the “worst-case” scenario of the impact of disruption on in-person clinical visits, the 25% and 50% levels of disruption can be seen as implicitly including the use of certain mobile health (mHealth) interventions, such as the use of self-testing or telehealth appointments. Although there is little evidence on how prevalent these technologies are among Black/African American MSM in the Deep South, this uncertainty is accounted for in the differing levels of disruption modeled. Additional mitigation effects due to changes in sexual behavior are addressed in the sensitivity analysis. In our primary analysis, we simulated service disruptions lasting for 1 duration of 18 months.

The main measures of comparison in our study were the number of new HIV infections, the absolute and relative changes in the number of new HIV diagnoses, and the absolute and relative changes in the number of new PrEP starts over the 5-year study period (2020–2025). Comparing these values among the model scenarios and the counterfactual scenario, we were able to measure how in-person clinical disruptions affected HIV diagnosis, PrEP uptake, and underlying HIV incidence at the population level.

### Model Calibration and Validation

The primary targets for model calibration were the number of new HIV diagnoses from 2014 to 2019, which were obtained

**Table 1. Projected Values of Selected Population-Level Outcomes by Model Scenario Among Black/African American MSM in Mississippi, 2020 to 2022**

	Level of Disruption	2020	2021	2022
Average Number of New Infections Per Year	0% (baseline)	201.3 [149.5–256.1]	198.8 [145.5–261.1]	198.7 [149.0–256.1]
	25%	205.7 [151.5–262.0]	212.8 [152.0–267.0]	209.7 [155.0–273.1]
	50%	210.9 [158.5–266.1]	228.3 [168.0–293.0]	221.6 [160.0–280.5]
	75%	216.2 [160.5–281.0]	243.7 [180.0–314.5]	237.2 [172.0–311.1]
Average Number of Diagnoses Per Year	0% (baseline)	192.7 [159.5–231.5]	182.0 [147.5–222.6]	186.3 [156.0–220.5]
	25%	156.2 [129.5–185.0]	156.9 [128.0–191.0]	203.4 [164.0–242.0]
	50%	117.2 [91.0–143.0]	116.5 [92.5–142.0]	221.7 [186.0–260.5]
	75%	77.0 [57.5–96.0]	64.4 [47.5–82.0]	243.8 [202.0–291.1]
Average Number of New PrEP Starts Per Year	0% (baseline)	49.9 [32.0–68.5]	49.5 [34.0–69.0]	50.3 [31.0–70.0]
	25%	38.6 [24.0–55.5]	39.1 [24.5–54.5]	50.4 [31.0–70.0]
	50%	27.3 [16.0–41.0]	28.2 [16.0–41.0]	51.3 [34.0–70.0]
	75%	15.1 [8.0–25.0]	15.9 [8.0–25.0]	52.1 [33.0–71.5]
Average PrEP Coverage Per Year	0% (baseline)	26.8% [18.2%–38.5%]	26.8% [18.2%–38.8%]	26.8% [17.8%–38.6%]
	25%	23.8% [15.1%–35.7%]	22.6% [14.7%–33.8%]	25.3% [17.8%–36.3%]
	50%	20.6% [12.0%–32.8%]	17.8% [10.5%–28.9%]	23.5% [16.5%–34.4%]
	75%	17.3% [9.3%–29.3%]	12.6% [6.8%–23.3%]	21.6% [14.9%–30.8%]

Abbreviations: PrEP, pre-exposure prophylaxis.

from the Mississippi State Department of Health [15]. We used an indirect, iterative method with Latin hypercube sampling to derive the subset of model runs that were the best fit for the calibration target data. With this approach, we identified plausible ranges for a set of parameters with the most uncertainty associated with their “true” values for the study population as their initial estimates were drawn from other populations and generated 10 000 sets of parameters. After methods developed by Zang et al [22], we calculated a goodness-of-fit statistic for each set of parameters and identified the sets of parameters that generated outputs within 10% of the targets to use in subsequent analyses (Supplementary Figure 1, Supplemental Table 2). During model validation, we used 500 best-fitting sets of parameters to project the trajectory of the local HIV epidemic for 12 months to assess the ability of the model to reproduce the number of new HIV diagnoses in 2019 as the primary validation target.

### Sensitivity Analyses

In our main analysis, we assumed no change in average number of sexual partners during the service disruption period because of the variability in findings surrounding this change among MSM during the pandemic [23, 24]. In a sensitivity analysis, we simulated scenarios in which agents were unable to acquire new sexual partners, and the number of anal intercourse acts per month was decreased by 50% during the period of the stay-at-home order [20].

## RESULTS

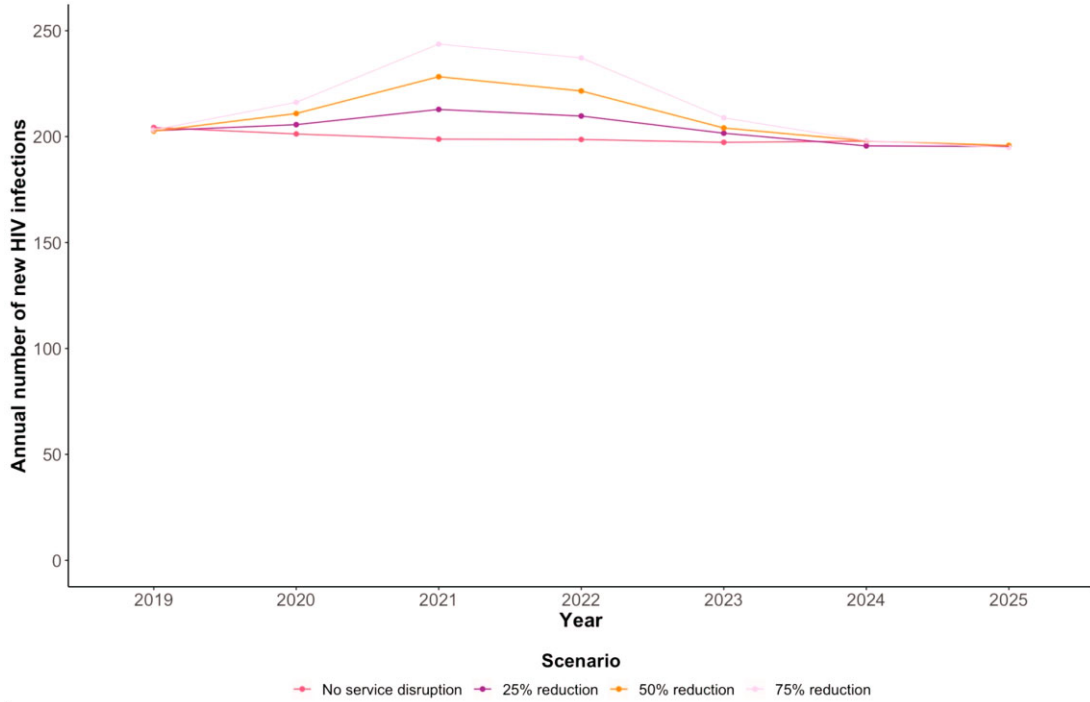
After calibrating the model and calculating the goodness-of-fit statistic for each set of parameters, we found that our calibrations matched well with our primary validation target of the

number of HIV diagnoses in 2019 (Supplemental Figure 1). In the counterfactual scenario, in which there was no disruption to in-person clinical practices, there were 1392 cumulative new infections from 2019 to 2025 (95% simulation interval, 1026–1797) (Table 1), resulting in an annual average of 204 new infections in 2019 (95% simulation interval, 156.0–262.1) that gradually lowered to 195.6 new infections in 2025 (95% simulation interval, 139.4–255.0) (Figure 1). An average of 1312 newly diagnosed cases occurred during the study period (1075–1566) with an annual average of 195.9 per year (Figure 2). There were 50 new PrEP starts per year (31–71) (Figure 3), yielding a final PrEP coverage of 27% in 2025 (18%–39%) (Figure 4).

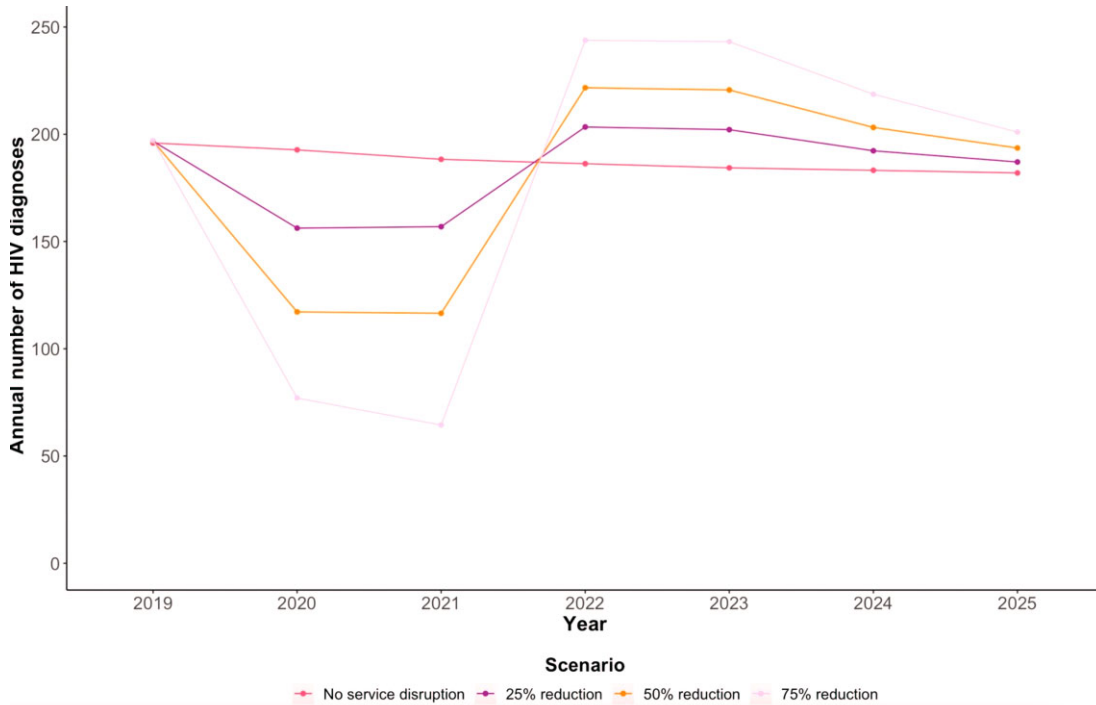
Across all scenarios simulating disruption to in-person clinical practices due to the COVID-19 pandemic, the total number of new infections increased above the levels observed in the counterfactual scenario (Figure 1), with these increases being most pronounced through the period of service disruption (March 2020 to September 2021). These increases in HIV incidence were evident into 2022 in scenarios with mild and moderate levels of disruption and into 2023 in a scenario with severe levels of disruption (Figure 1).

Accordingly, the number and proportion of cases diagnosed during 2020 and 2021 decreased in a manner directly proportional to the level of reduction in HIV testing activities (Figure 2). After a return to prepandemic levels of service provision in late 2021, the number of HIV diagnoses was elevated relative to the number observed in the counterfactual scenario throughout the period from 2022 to 2025 due to the increases in detection of excess cases that accumulated during the period of service disruption (Figure 2).

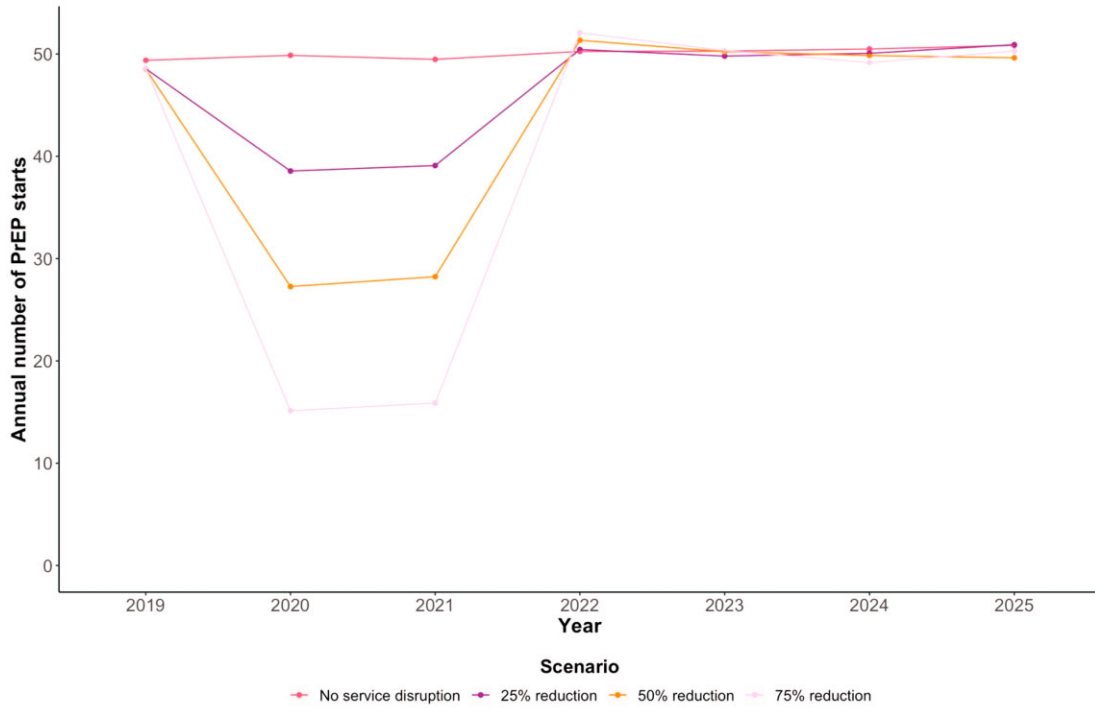
By design, fewer agents began using PrEP during the period of service disruption (Figure 3), leading to significant decreases



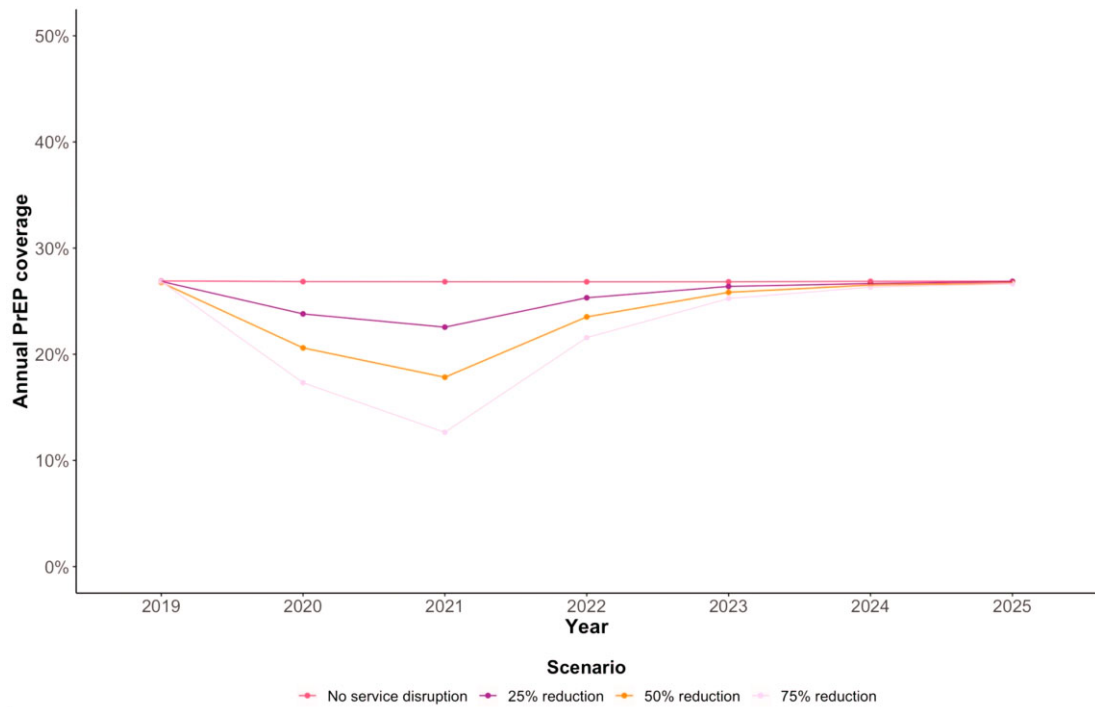
**Figure 1.** Predicted annual number of new human immunodeficiency virus (HIV) infections among Black/African American men who have sex with men in Mississippi under conditions of varying levels of disruption in access to HIV prevention services, 2019 to 2025.



**Figure 2.** Predicted annual number of new human immunodeficiency virus (HIV) diagnoses among Black/African American men who have sex with men in Mississippi under conditions of varying levels of disruption in access to HIV prevention services, 2019 to 2025.



**Figure 3.** Predicted annual number of pre-exposure prophylaxis (PrEP) initiation events among Black/African American men who have sex with men in Mississippi under conditions of varying levels of disruption in access to human immunodeficiency virus prevention services, 2019 to 2025.



**Figure 4.** Predicted population-level pre-exposure prophylaxis (PrEP) coverage among Black/African American men who have sex with men in Mississippi under conditions of varying levels of disruption in access to human immunodeficiency virus prevention services, 2019 to 2025.

in population-level PrEP coverage (Figure 4) in 2020 and 2021. Under a scenario with the most severe levels of disruption, population-level PrEP coverage is approximately halved, from 26.8% (18.2%–38.8%) in the counterfactual scenario to 12.6% (6.8%–23.3%).

In our sensitivity analysis (Supplemental Figure 2), we found that our results were robust against short-term changes in sexual behavior during the stay-at-home order from March 2020 to June 2020. Even when accounting for a potential decrease in sexual risk behavior during the pandemic period, the number of new HIV infections increases significantly above the base scenario levels during the period of 2020 to 2022.

## DISCUSSION

To our knowledge, this is among the first studies to model how reductions to in-person clinical practices impacted the number of HIV cases diagnosed and access to PrEP among Black/African American MSM in the Deep South. We found that disruption to in-person clinical practice is associated with a temporary increase in the number of new infections, a decrease in the number of infections diagnosed, and a decrease in the percentage of cases diagnosed in the scenarios modeled. The results demonstrate that decreases in the number of HIV tests ordered and conducted [4–6] may lead to small, temporary increases in HIV transmission owing to delays in diagnosis and initiation of ART. Although the model predicts that many of these epidemiological outcomes would return to the prepandemic levels beginning in 2023, even a moderate increase in HIV incidence exacerbates an already unmet need for access to HIV prevention and treatment among Black/African American MSM.

To ensure that individuals who may have gone undiagnosed during periods of reductions in clinical operations are linked to proper care, HIV testing should be encouraged for those who may have foregone regular HIV testing throughout the pandemic. Recent studies have suggested that Black/African American MSM in Jackson experience more stigma and medical mistrust in access to HIV prevention and treatment [25]. Because medical mistrust has likely further increased during the pandemic [26], particular attention should be devoted to ensuring that members of this population are able to access testing and be linked to prevention and treatment services in care environments that acknowledge and actively work to undo this mistrust.

To prevent further interruptions to our progress toward the Ending the HIV Epidemic goals, disruptions to clinical activities related to testing, prescribing PrEP, and accessing care should be avoided as much as possible. One way to achieve this goal is to develop a robust telehealth infrastructure. Rogers et al [27, 28] describe the benefits of the implementation of telemedicine at a lesbian, gay, bisexual, transgender and

queer or questioning (LGBTQ) health clinic in Rhode Island, reporting high satisfaction from patients for this method of HIV prevention and care. In the Southern United States, one study provided further empirical evidence of the importance of the use of telehealth services for HIV care in South Carolina during the pandemic, but some of the participating clinics did not have the capacity to implement the use of telehealth in a timely manner, resulting in further service disruption [29]. Cost reimbursement to providers of telehealth and address so-called “digital poverty” such that all patients have adequate technology to access it remain among the chief structural barriers to scale-up of this approach [30]. Community-based telehealth kiosks have shown promise in expanding access to those who may have access to the technologies needed for these services [31]. More research must be conducted on addressing disparities in access to telehealth services. Although there are current efforts to implement certain telehealth and mobile health interventions within Mississippi and the Deep South, there is little evidence about current trends in telehealth use among MSM for PrEP services [32]. Nonetheless, the implementation of more telehealth practices has the potential to prevent further and future disruptions to clinical appointments and to connect more patients residing in rural areas to high-quality clinics that may be in metropolitan areas.

At-home testing kits represent an additional resource for mitigating the effects of disruptions to in-person clinical operations because several studies have shown that both patients and providers perceived access to testing as much more limited during the early pandemic months [5, 6]. A pilot program in Oregon implemented during the pandemic found that offering free, home-based testing for HIV during a period of physical distancing helped to alleviate barriers and increased access to testing [33]. Another study, based in Ottawa, demonstrated that self-testing is a viable way to maintain access to HIV testing during pandemics [34]. Although these studies were not based in the Southern United States, they offer evidence that at-home testing kits could be a promising alternative to in-person testing if access was otherwise limited. More research is needed on how to properly implement this intervention and ensure that there are as few barriers to accessing the at-home kits as possible and that individuals can be effectively linked to care after a diagnosis.

There are several limitations that may be present in our analysis. First, in parameterizing the model, we attempted to use local data from Black/African American MSM in Jackson, Mississippi as often as possible. However, not all the values we used were derived from data sources specific to this population. Our method of model calibration may have alleviated some of the uncertainty that these parameters may have introduced. There also may have been a nonaverage disruption, because we cannot say with certainty what the level of disruption

to in-person clinical practices was during the pandemic. Furthermore, as with all modeling studies, we made several simplifying assumptions, particularly around sexual behavior during the early pandemic months, because empirical studies have reported mixed findings [23, 24]. However, our sensitivity analysis demonstrates that our findings are robust to varying assumptions. Finally, we also cannot validate the networks created by our model with the real-world sexual network of Black/African American MSM in Jackson. Because the model provides a good fit to its calibration targets, we can be confident that our model is reasonably representing recent patterns of HIV transmission and their underlying causal mechanisms.

## CONCLUSIONS

Our analysis predicts that disruptions to in-person clinical practices during the COVID-19 pandemic may have caused a temporary but meaningful increase in the number of new HIV infections among Black/African American MSM in Jackson, Mississippi. These disruptions and their implications have likely hindered our progress toward the Ending the HIV Epidemic goals in the short term. As in-person clinical operations resume more typical levels, we must ensure that those individuals who have undiagnosed infections are linked to care as soon as possible. The implementation of a strong telehealth infrastructure for HIV prevention and care and expanding the use of at-home testing kits could potentially help prevent future periods of lower access, but more research needs to be done on these interventions to address potential inequities in access to these resources. Mitigating strategies such as these could lead to disruption levels more akin to the 25% or no disruption levels, which would significantly improve HIV outcomes among Black/African American MSM in the Deep South when compared with higher levels of disruption.

## Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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that the editors consider relevant to the content of the manuscript have been disclosed.

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