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Impact of COVID-19 Response on the HIV Epidemic in Men Who Have Sex With Men in San Francisco County: The Importance of Rapid Return to Normalcy

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Background: In response to the COVID-19 pandemic, San Francisco County (SFC) had to shift many nonemergency health care resources to COVID-19, reducing HIV control resources. We sought to quantify COVID-19 effects on HIV burden among men who have sex with men (MSM) as SFC returns to pre-COVID service levels and progresses toward the Ending the HIV Epidemic (EHE) goals.

Setting: Microsimulation model of MSM in SFC tracking HIV progression and treatment.

Methods: Scenario analysis where services affected by COVID-19 [testing, care engagement, pre-exposure prophylaxis (PrEP) uptake, and retention] return to pre-COVID levels by the end of 2022 or 2025, compared against a counterfactual where COVID-19 changes never occurred. We also examined scenarios where resources are prioritized to reach new patients or retain of existing patients from 2023 to 2025 before all services return to pre-COVID levels.

Results: The annual number of MSM prescribed PrEP, newly acquired HIV, newly diagnosed, and achieving viral load suppression (VLS) rebound quickly after HIV care returns to pre-COVID levels. However, COVID-19 service disruptions result in measurable reductions in cumulative PrEP use, VLS person-years, incidence, and an increase in deaths over the 2020–2035 period. The burden is statistically significantly larger if these effects end in 2025 instead of 2022. Prioritizing HIV care/prevention initiation over retention results in more person-years of PrEP but less VLS person-years and more deaths, influencing EHE PrEP outcomes.

Conclusions: Earlier HIV care return to pre-COVID levels results in lower cumulative HIV burdens. Resource prioritization decisions may differentially affect different EHE goals.

Key Words: HIV/AIDS, COVID-19, microsimulation, San Francisco, MSM

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INTRODUCTION

COVID-19 has already substantially burdened the US health care system, and ongoing challenges because of emerging COVID-19 variants continue to challenge disease control efforts. As of July 2022, the US Centers for Disease Control and Prevention recorded more than 88 million total reported COVID-19 infections, more than 4.9 million total COVID-19 new hospital admissions, and more than 1 million COVID-19 deaths in the United States.[1] The Omicron variant, which became predominant in the United States in December 2021, has generated high hospitalization volumes that have substantially strained local health care systems into 2022.[2] It is unlikely that COVID-19 will be eradicated, and health resources may need to continue to be diverted during COVID-19 surge periods.[3]

The COVID-19 pandemic and its response affected many aspects of daily living, even those indirectly related to COVID-19 infection, as the fast spread and fatal nature of the disease led to widespread shelter-in-place (SIP) orders and quarantine requirements. In particular, the pandemic heavily impacted health care resource allocation, even those specifically directed to other diseases, such as HIV/AIDS. In general, SIP orders led to reduced access and use of HIV testing, prevention, and treatment services, and many studies show that these reductions did not rebound quickly or at all to pre-COVID levels, even with SIP orders concluded.[4–9]

In this study, we focus on San Francisco County (SFC) because it is a major urban county with above-average HIV prevalence compared with the state and nation. We focus on men who have sex with men (MSM), who represent 86% of people living with HIV/AIDS (PLWH) in SFC.[10] In March 2020, SFC began a SIP order that limited in-person social interactions. SFC disease surveillance reports documented a steep drop in sexual partnerships in mid-March which rebounded to pre-COVID levels only in 2021.[11] The SIP order also affected accessibility and use of HIV testing and treatment services and impacted pre-exposure prophylaxis (PrEP) uptake and retention even after the SIP order ended.[10–13] For instance, there was an 18% drop in the average monthly number of HIV tests that medical facilities performed, and the average monthly number of tests at community sites in 2021 was still 45% lower than in 2019.[10] Clinics have also reported increases in the odds of an HIV-positive patient having an unsuppressed viral load after COVID.[12] Similar trends have been documented for PrEP. Sexual health clinics showed PrEP initiations decreased by 62.2% during SIP and did not return to pre-COVID levels after SIP, and PrEP lapses for existing patients increased by 79% during SIP (reflected by reducing the proportion of MSM with high PrEP adherence in the model), and PrEP discontinuations increased by 21%.[13] SFC is an epicenter in the battle for control of the HIV epidemic, and how its reaction to COVID-19 changed HIV trajectories may provide a useful case study for understanding COVID-19 effects in other cities.

Quantifying COVID-19 effects on the HIV epidemic under different scenarios as service levels recover can aid policy decisions, particularly as new variants continue to challenge our health systems. Long-term HIV incidence trends may depend on the extent and durability of COVID-19–related changes. Previous work shows that the longer HIV care remains disrupted, the larger the impact on HIV incident cases or deaths.[14–16] Understanding the tradeoffs between resource allocation and future HIV burden may spur additional efforts to increase diagnosis, enrollment, and retention for antiretroviral therapy (ART) and PrEP. We sought to quantify these tradeoffs using a microsimulation model to project HIV burden under different COVID-19 recovery scenarios among MSM in SFC.

To the best of our knowledge, no previous work has assessed the impact of COVID-19 on the HIV epidemic in SFC using county-specific data. Although other studies have examined COVID-19 and HIV outcomes, many do not focus on SFC, despite its importance in the domestic HIV epidemic.[16,17] Notably, Fojo et al included SFC in their analysis,[15] but did not use county-specific input data and sampled the magnitude of COVID-19 effects from nationwide ranges. Instead, we draw COVID-19 effects from SFC-specific literature and surveillance reports, capturing location-specific trends for more realistic modeling outcomes. In addition, we examine how COVID-19 effects may impact Ending the HIV Epidemic (EHE) initiative goals set forth by the US federal government to better inform HIV policy decision-making.[18]

It is unclear how persistent and impactful COVID-19 effects will be on the HIV epidemic in SFC, nor how rapidly a return to pre-COVID service levels will occur. We therefore aim to quantify COVID-19–related effects on HIV diagnosis, incident cases, PrEP prescriptions, and number of individuals with viral load suppression (VLS) between now and 2035. To better understand the importance of the timing of return to pre-COVID HIV service levels, we assessed these outcomes under different durations of COVID-19 effects (COVID-19 effects on HIV services end in 2022 versus in 2025) for different types of services [those focused on outreach to new patients (HIV screening and PrEP uptake) versus retention of existing patients (achieving VLS and PrEP adherence)]. It is unclear when COVID-19 will no longer influence HIV services and whether service engagement will fully return to the same levels as pre-COVID because some peoples' behaviors may be altered by COVID-19 permanently. However, we chose to examine end dates in 2022 and 2025 for full return to pre-COVID service levels because these provide useful benchmarks for decision-making.

METHODS

Model Description

We adapted a previously published, discrete time microsimulation model of HIV among MSM, which tracks HIV disease progression and treatment dynamics according to characteristics of individual MSM on a yearly basis.[19,20] Specifically, the model determines the probability a susceptible individual becomes infected with HIV using the individual's demographic characteristics (age and race) and associated partnership preference pattern, number of partners, PrEP adherence, and ART adherence. See Appendix section, http://links.lww.com/QAI/C11 *Model Description and Parameters* for details. We set demographics of the initial cohort, and transition rates between health and treatment states, to reflect SFC trends. We also added COVID-19 effects on deaths, HIV diagnosis, achieving VLS, PrEP uptake, discontinuation, and adherence, and sexual transmission.

The model tracked each simulated individual's disease state, likelihood of acquiring HIV, PrEP usage, diagnosis, and VLS status of boys aged 15 years (assumed age of sexual debut), who entered the model at the beginning of each year. Their initial HIV infection and care engagement status reflected values estimated from the literature and empirical data. Subsequent evolution of each individual's status was simulated using conditional probabilities of PrEP uptake and adherence, diagnosis, ART adherence, disease progression, and mortality, given an individual's current status, age and race/ethnicity, and the prevalence of transmissible disease among likely sexual partners. The model assumed transmission was driven only by sexual partnerships, and that these were dependent only on age and race/ethnicity mixing patterns. Individuals exited the model when they died from HIV infection, COVID-19 infection, or other causes, and the model structure is described in detail in previous publications.[19,20] The code is implemented in MATLAB,[21] and the simulation code is available online at https://github.com/citina/microsimulation-sfc.

Model Inputs

To ensure that the model reflected trends in the SFC HIV epidemic, we drew inputs from the National HIV/AIDS

Strategy (NHAS),[22] SFC HIV Epidemiology report,[23] AIDSVu,[24] and previous published works (Table 1). The model began with 58,204 MSM in 2012[25] and was divided into 4 race/ethnicity groups (White, Black, Hispanic, and Other [consisting primarily of Asian Pacific Islanders and multiracial people]), with roughly 10% of MSM in the Other category.

To account for the high level of PrEP coverage in SFC, we updated the model with SFC-specific PrEP prescription data from AIDSVu[24] and calibrated the PrEP uptake rate to match empirically observed trends in SFC (see Appendix sections *Model Description and Parameters* and *Model Calibration and Validation,* Appendix Tables 1–4, and Appendix Figures 1–4, http://links.lww.com/QAI/C11).

Model Calibration

We calibrated our outcomes to match 15 calibration targets including the number of new diagnoses, AIDS deaths, PrEP use, number of diagnosed PLWH, and number of VLS over time, in aggregate and by age, race/ethnicity, and HIV stage. In the calibration process, we changed calibration parameters to ensure our outcomes matched the empirical data to mitigate the uncertainty in our model. Calibration parameters included the relative risk of HIV infection overall and by race/ethnicity, likelihood of death by age, and PrEP uptake probability over time. We used a hierarchical process to change these values to align model outputs with trends observed in the NHAS from 2012 to 2019, prioritizing aggregate calibration targets as opposed to those by age,

TABLE 1. Selected Transition Probabilities

Parameter	Value	Source
HIV prevention and care parameters		
PrEP use by PrEP adherence level		
Nondetectable	0.024	26
Low	0.108	26
High	0.867	26
Proportion of high ART adherence	0.95	19,20
PrEP uptake by year	Varies, see Appendix Table 3, http://links.lww.com/QAI/C11	Calculated and calibrated
PrEP discontinuation	0.17	26
Attaining viral suppression by race and age		
Black by age*	[0.08, 0.08, 0.21, 0.07]	19 ,20
Hispanic by age*	[0.11, 0.11, 0.21, 0.08]	19, 20
White by age*	[0.12, 0.12, 0.22, 0.08]	19, 20
Others by age*	[0.12, 0.12, 0.22, 0.08]	Assumption
COVID-19 parameters (ranges for sensitivity analysis in parenthesis)		
Initiation of care/prevention services		
Reduction in HIV testing	27.5% (13.8%, 55.0%)	Calculated
Reduction in PrEP uptake	56.1% (54.9%, 62.2%)	13
Prob. of PrEP uptake under COVID-19	0.018 (0.015, 0.018)	Calculated
Retention in care/prevention services		
Reduction in prob. of attaining VLS	21.3% (10.7%, 42.6%)	12
Reduction in prob. of PrEP continuation	20.6% (10.5%, 42.0%)	13
Reduction in proportion with high adherence to PrEP	11.4% (2.2%, 26.3%)	13
Prob. of PrEP discontinuation under COVID-19	0.206 (0.188, 0.241)	Calculated
PrEP adherence level under COVID-19		
Nondetectable	0.024	26
Low	0.223	Calculated
High	0.753	Calculated
Sexual behavior		
Reduction in sexual partners, 2020	25% (12.5%, 50.0%)	11
COVID-19 death		
Annual proportion, 2020	0.0299%	27
Annual proportion, 2021 and after	0.0495%	27
Relative risk (HIV+/HIV−)	1.278	28

PrEP, pre-exposure prophylaxis.
*Age: 15–29, 30–49, 50–69, 70–100 years.

race/ethnicity, or stage. Additional details are in the Supplemental Digital Content (see Appendix section, http://links.lww.com/QAI/C11 *Model Calibration and Validation*).

Model Validation

To ensure that the final model outputs reflected empirical trends, we validated our model by comparing the model outcomes with empirical data from SFC Epidemiology Annual reports (2013–2020), SFC HIV SEMI-Annual Surveillance reports, and the US national HIV surveillance data tables.[29] Validation measures included the numbers of new diagnoses by race/ethnicity and by age, diagnosed PLWH by race/ethnicity, proportion of PLWH with VLS, and PrEP counts.

COVID-19 Response Effects

To capture COVID-19 response effects on the HIV epidemic, we considered changes to 4 components of HIV care and disease dynamics: (1) HIV transmission (modeled as a 1-year reduction in sexual partners in 2020), (2) initiation of HIV care/prevention (modeled through reduced HIV screening and PrEP uptake), (3) retention in HIV care/prevention (through reduced VLS, PrEP continuation, and proportion of high PrEP adherence), and (4) new potential outcome of COVID-19–related death. Table 1 provides parameter reduction values; see Supplemental Digital Content (see Appendix section, http://links.lww.com/QAI/C11 *COVID-19–Related Effects*) for details. We also modeled a counterfactual scenario where COVID-19 never occurred, where none of these reductions were implemented, to provide a comparator for quantifying COVID-19 effects on the HIV epidemic.

To assess the combined impact of these changes, we examined 4 scenarios with different assumptions about when pre-COVID service levels will resume and compared them with the non-COVID counterfactual. In the first scenario, we assumed all COVID-19 response effects will stop by the end of 2022; although unlikely, this provides a useful benchmark. In the second scenario, we assumed they will all stop by the end of 2025. However, it is likely that some services may be able to return to pre-COVID service levels earlier than others. We therefore examined scenarios where retention efforts to existing patients (returning to pre-COVID retention levels for PrEP and achieving VLS) are prioritized between 2023 and 2025 (scenario 3), or, by contrast, outreach to new patients to initiate services (return to pre-COVID levels of new diagnoses, PrEP uptake) is prioritized during this period (scenario 4). In both scenarios, we assume prioritized services return to pre-COVID levels by the end of 2022 and all other services by the end of 2025. All scenarios are summarized in Table 2.

Sensitivity Analyses

Because the data on COVID-19 response effects on HIV care are limited, we performed sensitivity analyses to determine how uncertainty in these COVID-19–related parameters would change model outcomes. Specifically, we performed best- and worst-case scenario analyses (ranges in Table 1); worst-case here refers to greater reduction in HIV care and lower 1-year reduction in partnerships from 2020 to 2025 (and vice versa in the best case).

RESULTS

Calibration and Validation Results

The model calibrated well to empirical data, with less than 12% root mean squared error on all aggregate level metrics (see Appendix, Supplemental Digital Content, http://links.lww.com/QAI/C11 for details). Validation showed the model generally matched empirical external data; see all validation measures in the Supplemental Digital Content (see Appendix, *Model Calibration and Validation* section).

Impact of COVID-19 in SFC if COVID Effects End in 2022

Although partnership rates observed in empirical data returned to pre-COVID levels after 2020,[11] the reduction in sexual contacts because of SIP and continued reduced in-person social activities after SIP had a short-term positive

TABLE 2. Base Case Scenarios

	2020	2021–2022	2023–2025
Scenario 1: COVID-19 effects until the end of 2022			
Partner reduction	✓	×	×
HIV testing reduction	✓	✓	×
PrEP uptake reduction	✓	✓	×
PrEP continuation/high adherence reduction	✓	✓	×
VLS reduction	✓	✓	×
Scenario 2: COVID-19 effects until the end of 2025			
Partner reduction	✓	×	×
HIV Testing reduction	✓	✓	✓
PrEP uptake reduction	✓	✓	✓
PrEP continuation/high adherence reduction	✓	✓	✓
VLS reduction	✓	✓	✓
Scenario 3: prioritize retention of existing patients			
Partner reduction	✓	×	×
HIV testing reduction	✓	✓	✓
PrEP uptake reduction	✓	✓	✓
PrEP continuation/high adherence reduction	✓	✓	×
VLS reduction	✓	✓	×
Scenario 4: prioritize initiation of new patients			
Partner reduction	✓	×	×
HIV testing reduction	✓	✓	×
PrEP uptake reduction	✓	✓	×
PrEP continuation/high adherence reduction	✓	✓	✓
VLS reduction	✓	✓	✓

PrEP, pre-exposure prophylaxis.

effect on HIV burden, with the reduction in sexual partnerships offsetting the negative COVID-19–related effects on HIV care. In 2020, the number of incident cases is 24.6% (31 persons, 95% UI: 24.4%–24.6%) lower than in the non-COVID counterfactual. However, higher annual HIV incidence rates over the next 2 years because of reduced HIV service levels resulted in higher cumulative incidence rates by 2022 (see Appendix Figure 5, http://links.lww.com/QAI/C11).

If the services were restored to pre-COVID levels by the end of 2022, incidence levels would be statistically indistinguishable from non-COVID counterfactual levels by 2027, although there would be a 3.1% (50 persons, 95% UI: 1.3%–4.9%) increase in cumulative new cases because of COVID-19 effects over the 2020–2035 period. Similarly, the number of new diagnoses, MSM on PrEP, and virally suppressed PLWH all returned to non-COVID levels relatively quickly after service levels resumed after 2022, although the model results showed there were 2.4% (38 persons, 0.7%–4.2%) more diagnoses, with knowledge of HIV status stabilizing around 95%–97% after 2020. There were also 12% (13,240 person-years, 11.8%–12.2%) decrease in person-years on PrEP, 1.4% (1716 person-years, 1.1%–1.6%) decrease in person-years that are virally suppressed, and 1.3% (72 persons, 1%–1.5%) increase in deaths because of COVID-19 effects (see Fig. 2).

Impact of Timing When Returning to Pre-COVID Care Levels

However, if pre-COVID service levels only resumed after 2025 instead of 2022, then there was a 9.1% (146 persons, 95% UI: 7.4%–10.8%) increase in the number of cumulative new cases because of COVID-19 effects over the end of 2022–2035 period, with a 6.2% (97 persons, 4.5%–7.9%) increase in diagnoses, 23.3% (25,790 person-years, 23.2%–23.5%) decrease in person-years on PrEP, 2.5% (3168 person-years, 2.3%–2.8%) decrease in person-years virally suppressed, and 2.6% (150 persons, 2.3%–2.9%) more deaths because of the additional years of COVID-19 effects (Fig. 2).

Rapid return to pre-COVID care levels by the end of 2022, compared with 2025, would therefore be projected to avert 78 (1.4%, 95% UI: 76–79) deaths, avert 96 (6%, 94–98) new HIV cases, and increase 12,550 (11.3%, 12,515–12,584) person-years on PrEP, and increase 1452 (1.2%, 1399–1494) person-years of viral suppression.

Variation in Return to Pre-COVID Care Levels Across Services

We also examined scenarios where there was a partial return to pre-COVID HIV service levels between 2023 and

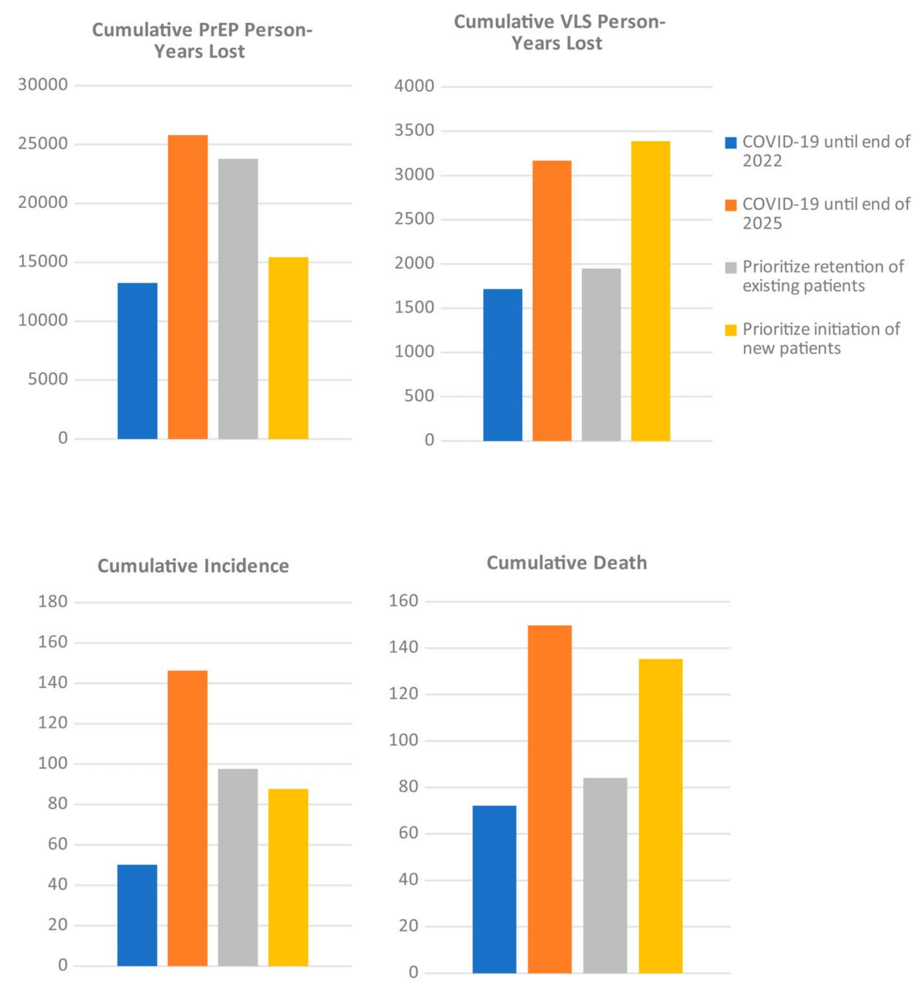

FIGURE 1. Cumulative differences in outcomes between the non-COVID counterfactual and 4 different COVID-19 scenarios by 2035. full color online

2025. As expected, the outcomes of these scenarios lay between those of the 2022 and 2025 return to pre-COVID care level scenarios (see Appendices Figures 5 and 6, and Table 5, Supplemental Digital Content, http://links.lww.com/QAI/C11).

Prioritizing resources for existing patients versus new patients made no significant difference on cumulative new diagnoses and incidence by 2035, but it did for cumulative person-years of VLS and on PrEP, and cumulative deaths. The average cumulative new diagnoses and new incident cases increased 3.6% and 5.8% compared with the non-COVID counterfactual.

The cumulative PrEP person-years was 8362 (7.6%, 95% UI: 8329–8390) higher in the scenario where resources were prioritized for initiation of new patients compared with where resources were prioritized for retention of existing patients. However, the cumulative VLS person-years was 1439 (2.7%, 1419–1456) lower, and there were 51 (2.4%, 50–53) more cumulative deaths in the case where resources were prioritized to new patients (Fig. 1).

Impact on EHE Goals

The model predicts that even under the non-COVID counterfactual, SFC would not have been able to reach the VLS, incidence, and new diagnoses goals for 2025 or 2030, and these targets would remain unmet under COVID-19 effects. However, model outcomes suggested that SFC would reach the knowledge of HIV status goal in 2025 or in 2030 under all scenarios, with 95%–97% of HIV-positive MSM aware of their HIV status.

However, the timing of returning to pre-COVID care levels and how resources are prioritized would impact whether the PrEP coverage goal is reached. The model predicts that the PrEP coverage goal in 2025 would be reached with 22% (95% UI: 21.9%–22.2%) in excess of the target under the non-COVID counterfactual, 10.7% (10.5%–11%) in excess of the target if COVID-19 effects stop in 2022, and 6.4% (6.2%–6.7%) in excess of the target if resources are prioritized to initiation of new patients. However, the PrEP coverage goal would not be reached if COVID-19 effects persisted until the end of 2025 or resources were prioritized for retention efforts (Table 3).

Results of Sensitivity Analysis

In comparing the scenarios where COVID-19 effects end in 2022 or 2025 under the best- and worst-case scenarios, the model suggested that a return to pre-COVID care levels earlier in 2022 would be more beneficial. Early return to pre-COVID care levels would avert 42 (95% UI: 41–43) deaths and 88 (87–89) incident cases under the best-case scenario and 185 (184–186) deaths and 153 (150–155) incident cases under the worst-case scenario; at the same time, it would increase 466 (444–481) VLS person-years and 11,569 (11,553–11,585) PrEP person-years under the best-case scenario and 2880 (2860–2931) VLS person-years and 15,254 (15,157–15,370) PrEP person-years under the worst-case scenario.

Figure 2 illustrates the outcomes associated with the best- and worst-case outcomes. Although the policy implications remain consistent, our sensitivity analyses showed that uncertainty in COVID-19 effects could generate substantial differences in the magnitude of HIV burden because of

TABLE 3. EHE Outcomes Under Different COVID-19 Scenarios*

	EHE Goals	Non-COVID Counterfactual	COVID-19 Effects Until 2022	COVID-19 Effects Until 2025	Prioritize Retention of Existing Patients	Prioritize Initiation of New Patients
2025 outcomes						
PrEP coverage	50%	72.0%	60.7%	37.2%	40.8%	56.4%
PrEP count	—	7112	5991	3670	4021	5565
Incidence reduction	75%	25.4%	20.7%	15.4%	18.3%	18.6%
Incident cases	45	108	116	124	117	120
Knowledge of HIV status	95%	96.8%	96.5%	95.8%	95.9%	96.4%
New diagnoses	61	104	117	109	109	119
VLS	95%	79.5%	78.6%	77.1%	79.0%	76.8%
2030 outcomes						
PrEP coverage	50%	74.4%	71.3%	64.2%	65.5%	70.2%
PrEP count	—	6976	6672	5992	6127	6566
Incidence reduction	75%	36.6%	35.3%	30.3%	31.0%	34.3%
Incident cases	18	92	95	102	99	97
Knowledge of HIV status	95%	96.9%	96.7%	96.4%	96.5%	96.6%
New diagnoses	24	88	93	100	94	97
VLS	95%	81.4%	81.0%	80.2%	80.8%	80.5%

PrEP, pre-exposure prophylaxis.
*See definitions of EHE goals at: https://ahead.hiv.gov/methods/target-values.

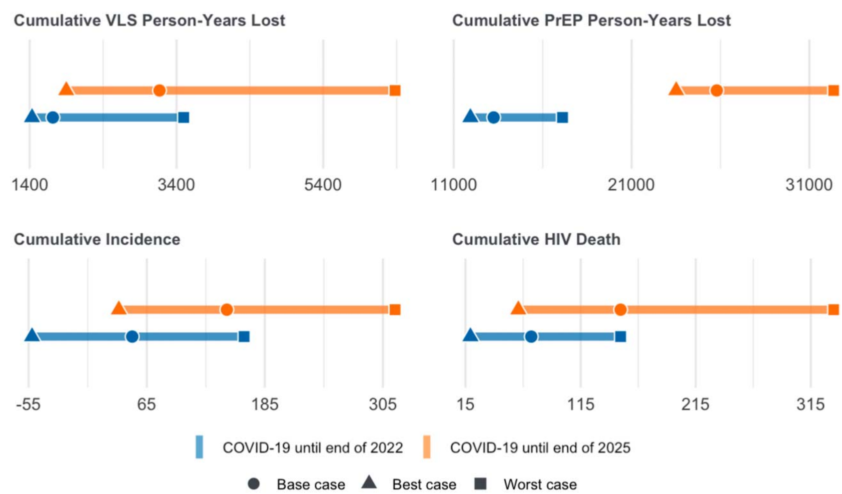

FIGURE 2. Difference between non-COVID counterfactual and base, best case, and worst case in scenarios 1 and 2 (COVID-19 effects until the end of 2022 or 2025). full color online

COVID-19. For instance, in the scenario where COVID-19 effects stopped in 2025, the worst case generated 17.1% more cumulative incident cases than the best-case scenario from 2020 to 2035, with 4.7% more deaths, 10.2% fewer PrEP person-years, and 3.7% fewer VLS person-years. See Figure 2, Supplemental Digital Content (see Appendix section *Supplemental Results*, and Appendix Table 6, http://links.lww.com/QAI/C11 for details).

DISCUSSION

Model outcomes confirmed that the COVID-19 response had a substantial impact on HIV burden in SFC among MSM. We estimated COVID-19 response changes to HIV prevention and care led to 150 more deaths, 146 more incident cases, 25,790 less person-years on PrEP, and 3168 less person-years with VLS from 2020 to 2035 if COVID-19 effects end in 2025 relative to the counterfactual where COVID-19 never occurred. This is consistent with previous studies that show that COVID-19 effects will likely lead to higher incident cases in SFC and more deaths.[15]

In addition, return to pre-COVID service levels 3 years sooner, by the end of 2022 versus 2025, would avert 6% these new HIV cases and avert 11.3% of these COVID-19–related person-years on PrEP by 2035. This supports general findings from previous work that show early return to pre-COVID in service levels can avert incidence.[15,16] The model suggests levels of incident cases would be indistinguishable whether resources are prioritized to new or existing patients from 2023 to 2025, but there would be some trade-offs between these 2 scenarios. Prioritizing resources to new patients will result in 8362 more PrEP person-years but 1439 less VLS person-years and 51 more deaths from 2020 to 2035. Although previous work has shown how testing can avert new infections,[17] our analysis additionally provides estimates of tradeoffs if only certain services can return to pre-COVID levels quickly.

We measured 5 EHE goals in our simulation. The model suggests that the 2025 and 2030 new diagnosis, incidence reduction, and VLS goals cannot be reached under any scenario, including those where COVID-19 changes never occurred. However, the 50% PrEP coverage goal will be reached if COVID-19 effects end in 2022 instead of in 2025, or resources are prioritized to new patients instead of existing patients in the intervening 3 years before full-service levels resume. The knowledge of status goal was reached at the beginning of the EHE initiative in 2017, and COVID-19 effects would not affect the achievement of this goal.

These results indicated that efforts to return HIV services in SFC to pre-COVID levels as soon as possible could mitigate the negative effects from COVID-19, and if resources are limited, policymakers will need to consider trade-offs and financial impact between prioritizing resources because faster return to pre-COVID levels in initiation versus retention in care/prevention services may impact some EHE goals. To reach EHE goals, the model outcomes indicate that SFC will need to invest more than pre-COVID levels of resources to reach all the 5 goals. For example, return to pre-COVID levels of PrEP enrollment before the end of 2025 may be critical for reaching the PrEP coverage EHE goal, and resources should be allocated accordingly.

We must acknowledge several limitations of this study. Our model assumes that service levels return immediately to pre-COVID levels after the end of 2022 or 2025; realistically, services would gradually increase. Our model uses a yearly cycle time, which required using average annual COVID-19 effects (instead of monthly or weekly values) to estimate outcomes. Although average values in model outcomes should generally be consistent with outcomes generated from a model with finer time cycles, we acknowledge that our results approximate COVID-19 effects. Previous works have used models with finer time cycles to assess COVID-19 effects in HIV burden,[15–17] and we find similar outcomes to those articles. In general, COVID-19 effects on service levels are very uncertain and may vary by demographic group (eg, age, race/ethnicity, and homelessness status). Because of data scarcity, we were unable to fully assess these demographic-specific differences. We account for the annual average number of sexual partners and age/race partner preference patterns but not patterns of condom use and serosorting. Although this omission is mitigated because the overall transmission rates in the model are scaled to reflect observed incidence (which indirectly accounts for levels of condom use and serosorting), the simulation omits age- and race/ethnicity-specific patterns in these behaviors. If these patterns are extremely different between groups, this could underestimate or overestimate the risk within a particular group. Model inputs were also taken from a variety of sources, some of which were not consistent in the literature (eg, the definition of PrEP coverage varies between 2 well-established sources, AIDSVu[24] and the America's HIV Epidemic Analysis Dashboard[30]). We do not distinguish between different types of PrEP dosing and consider PrEP in general; definitions of PrEP may vary between our input parameters. We therefore compare values in our validation table (see Appendix section, Supplemental Digital Content, http://links.lww.com/QAI/C11 *Model Calibration and Validation*) and document which values are used in the model (see Appendix section, Supplemental Digital Content, http://links.lww.com/QAI/C11 *Model Description and Parameters*).

Despite these limitations, we believe that the model outcomes are valuable for gaining insight into general trends around COVID-19 effects on the HIV burden of MSM in SFC. We find that rapid return to pre-COVID care levels is important, and although the model does not explicitly consider alternative services, our results support nontraditional service delivery systems (telemedicine, at-home diagnostics, etc.) and newly approved long-acting injectable PrEP if they can be a reliable substitute for or supplement to traditional services. We hope that this study helps inform future work in this area because more data on COVID-19 response effects on the HIV epidemic and service level impacts continue to be gathered.

REFERENCES

1. Centers for Disease Control and Prevention. *COVID Data Tracker*; 2022. Available at: https://covid.cdc.gov/covid-data-tracker/#datatracker-home. Accessed July 7, 2022.
2. Iuliano AD, Brunkard JM, Boehmer TK, et al. Trends in disease severity and health care utilization during the early Omicron variant period compared with previous SARS-CoV-2 high transmission periods—United States, December 2020–January 2022. *MMWR Morb Mortal Wkly Rep.* 2022;71:146–152.
3. Rio Cdel, Malani PN. COVID-19 in 2022—the beginning of the end or the end of the beginning? *JAMA*. 2022;327:2389–2390.
4. Moitra E, Tao J, Olsen J, et al. Impact of the COVID-19 pandemic on HIV testing rates across four geographically diverse urban centres in the United States: an observational study. *Lancet Reg Health Am.* 2022;7:100159.
5. del Amo J, Diaz A, Polo R. The impact of coronavirus disease 2019 on people with HIV. *Curr Opin Infect Dis.* 2022;35:9–14.
6. Krakower D, Solleveld P, Levine K, Mayer K. Impact of COVID-19 on HIV preexposure prophylaxis care at a Boston community health center. In: 23rd International AIDS Conference; 2020. Available at: https://programme.aids2020.org/Abstract/Abstract/11755. Accessed May 18, 2022.
7. Brown LB, Spinelli MA, Gandhi M. The interplay between HIV and COVID-19: summary of the data and responses to date. *Curr Opin HIV AIDS.* 2021;16:63–73.
8. Menza TW, Zlot AI, Garai J, et al. The impact of the SARS-CoV-2 pandemic on human immunodeficiency virus and bacterial sexually transmitted infection testing and diagnosis in Oregon. *Sex Transm Dis.* 2021;48:e59–e63.
9. Pinto RM, Park S. COVID-19 pandemic disrupts HIV continuum of care and prevention: implications for research and practice concerning community-based organizations and frontline providers. *AIDS Behav.* 20202020;2424:2486–2489.
10. San Francisco Department of Public Health Population Health Division. HIV Epidemiology annual report 2020. Available at: https://www.sfdph.org/dph/files/reports/RptsHIVAIDS/AnnualReport2020-Purple_20210817Web.pdf. Accessed May 18, 2022.
11. San Francisco Department of Public Health. San Francisco monthly STD report. Available at: https://www.sfdph.org/dph/files/reports/StudiesData/STD/STD122020.pdf. Accessed May 18, 2022.
12. Spinelli MA, Hickey MD, Glidden Dv, et al. Viral suppression rates in a safety-net HIV clinic in San Francisco destabilized during COVID-19. *AIDS*. 2020;34:2328–2331.
13. Broussard J, Moore K, Tourneau N, et al. HIV pre-exposure prophylaxis (PrEP) care in a LGBTQ community-based sexual health and wellness clinic after COVID-19 restrictions. In: IAS; 2021. Available at: https://theprogramme.ias2021.org/Abstract/Abstract/2052. Accessed May 5, 2022.
14. Jenness SM, le Guillou A, Chandra C, et al. Projected HIV and bacterial sexually transmitted infection incidence following COVID-19–related sexual distancing and clinical service interruption. *J Infect Dis.* 2021;223:1019.
15. Fojo A, Wallengren E, Schnure M, et al. Potential effects of the coronavirus disease 2019 (COVID-19) pandemic on human immunodeficiency virus (HIV) transmission: a modeling study in 32 US cities. *Clin Infect Dis.* 2022;75:e1145–e1153.
16. Mitchell KM, Dimitrov D, Silhol R, et al. The potential effect of COVID-19-related disruptions on HIV incidence and HIV-related mortality among men who have sex with men in the USA: a modelling study. *Lancet HIV.* 2021;8:e206–e215.
17. Zang X, Krebs E, Chen S, et al. The potential epidemiological impact of coronavirus disease 2019 (COVID-19) on the human immunodeficiency virus (HIV) epidemic and the cost-effectiveness of linked, opt-out HIV testing: a modeling study in 6 US cities. *Clin Infect Dis.* 2021;72:e828–e834.
18. Fauci AS, Redfield RR, Sigounas G, et al. Ending the HIV epidemic: a plan for the United States. *JAMA*. 2019;321:844–845.
19. Drabo E, Moucheraud C, Nguyen A, et al. Using microsimulation modeling to inform EHE implementation strategies in Los Angeles County. *J Acquir Immune Defic Syndr.* 2022;90:S167–S176.
20. Nguyen A, Drabo EF, Garland WH, et al. Are unequal policies in pre-exposure prophylaxis uptake needed to improve equality? An examination among men who have sex with men in los Angeles county. *AIDS Patient Care STDS.* 2022;36:300–312.
21. *MATLAB. Version 9.10.0.1710957 R2021a)*. Natick, MA: The Math Works, Inc; 2021a.
22. White House Office of National AIDS Policy. National HIV/AIDS Strategy for the United States; 2020. Available at: https://hivgov-prod-v3.s3.amazonaws.com/s3fs-public/nhas-update.pdf. Accessed June 19, 2022.
23. San Francisco Department of Public Health Population Health Division. *HIV Epidemiology Annual Report*; 2014. Available at: https://www.sfdph.org/dph/files/reports/RptsHIVAIDS/HIV-EpidemiologyAnnualReport-2014.pdf. Accessed May 28, 2022.
24. Emory University's Rollins School of Public Health in partnership with Gilead Sciences Inc, the Center for AIDS Research at Emory University (CFAR). *San Francisco County—AIDSVu*. Available at: https://aidsvu.org/. Accessed May 5, 2022.
25. Hughes AJ, Chen YH, Scheer S, Raymond HF. A novel modeling approach for estimating patterns of migration into and out of San Francisco by HIV status and race among men who have sex with men. *J Urban Health.* 2017;94:350–363.
26. Liu AY, Cohen SE, Vittinghoff E, et al. HIV pre-exposure prophylaxis integrated with municipal and community based sexual health services. *JAMA Intern Med.* 2016;176:75.
27. San Francisco Digital Services team Office of the City Administrator. COVID-19 cases and deaths in San Francisco. Available at: https://sf.gov/data/covid-19-cases-and-deaths. Accessed May 29, 2022.
28. Division of HIV and STD Programs Department of Public Health County of Los Angeles. HIV surveillance annual report 2020. Available at: http://www.publichealth.lacounty.gov/dhsp/Reports/HIV/2020AnnualHIVSurveillanceReportUpdated9-2021_f1f2update.pdf. Accessed May 5, 2022.
29. Centers for Disease Control and Prevention. *Core Indicators for Monitoring the Ending the HIV Epidemic Initiative (Preliminary Data): National HIV Surveillance System Data Reported through March 2022; and Preexposure Prophylaxis (PrEP) Data Reported through December 2021*; 2022. Available at: https://www.cdc.gov/hiv/library/reports/surveillance-data-tables/index.html. Accessed May 5, 2022.
30. U.S. Department of Health & Human Services. America's HIV epidemic analysis dashboard (AHEAD). Available at: https://ahead.hiv.gov/. Accessed May 5, 2022.