**Supplement A: Uncertainty analysis, scenario analysis considering alternate assumptions about COVID-19 pandemic effects in 2021**

**Background**

In this section we provide a detailed description of the scenario analysis we performed to obtain upper and lower bounds on several EHE indicators in our COVID-19 simulations. As discussed in the main body text, we assumed that the COVID-19 pandemic affected both individual behaviors (“behavioral effects”) and the provision of care (“HIV care effects”). In our model, the behavioral effects were modeled by changing the number of sexual partners during the COVID-19 period, while the care-related effects were modeled by changes in rates of HIV testing and diagnosis, initiation of ART, probability of dropping off ART and losing VLS. These effects are summarized in Table A1.

Note that the sources referenced for each COVID-19 effect are primarily based on data collected for the year 2020. There is significantly less information regarding to what extent these effects continued into 2021. We assumed in our base-case simulation that both the behavioral effects continued at 50% of their 2020 levels in 2021, and the care-related effects continued at 25% of their 2020 levels in 2021. While the results from this assumption suggest a good agreement with surveillance data, we performed a scenario analysis to better understand possible outcomes given different assumptions used given the lack of clear data about COVID-19 pandemic HIV care and behavioral effects in 2021.

In addition to the COVID-related uncertainty, there is also significant uncertainty arising from the inherent model parameterization. As discussed in the main text, we accounted for this uncertainty by running our model for both the pandemic and non-pandemic scenarios for 10 additional calibration sets.

**Methods**

We varied the behavioral and HIV care effects separately. Care effects refer to COVID-19-related changes to HIV testing and diagnosis, rates of ART initiation, rates of ART drop-off and loss of viral suppression. Behavioral effects refer to COVID-19-related changes to number of partnerships among MSM and heterosexuals with multiple risk factors. Given surveillance data suggesting that PrEP prescriptions rebounded strongly in 2021, we did not consider any additional COVID-19 effects on PrEP initiation and adherence, or mortality post-2020.1

Behavioral and HIV care effects were varied independently. We considered scenarios in which the HIV care effects in 2021 were 0%, 25%, and 50% of the 2020 effects, and in which the behavioral effects in 2021 were 0%, 50%, and 100% of the 2020 effects. Each combination of HIV care- and behavioral- effect levels were simulated (Table A2), resulting in eight additional simulations (note that Scenario 1 corresponds to our baseline scenario).

The choices for ranges of variation were motivated by availability of relevant data. Data suggested that COVID-19 effects on HIV care were highly likely to have been smaller in 2021 compared to 2020.2 However, given that behavioral data were less readily available, we considered a wider band of values and assumed that 2021 effects were not larger than 2020 effects.

All alternate scenarios were identical up to and including 2020. In 2022 and beyond, all scenarios had identical input values, assuming a return to pre-COVID-19 rates. Finally, to capture the joint sensitivity to both COVID-19 effects and parameter uncertainty, we performed the COVID-19 sensitivity analysis on each of the 10 calibration sets used for our uncertainty analysis.

**Results and Discussion**

The scenario analysis showed a range of variability consistent with the available HIV diagnosis data and incidence estimates for 2021, with the upper and lower bounds for 2021 overlapping with the surveillance data (Figure A1).Further, our uncertainty analysis showed consistent qualitative and quantitative behavior across of our calibration sets, with simulations in agreement with surveillance data for key model inputs (Figure A2, see also Table 2 in the main text).3 Further, both the qualitative and quantitative effects of COVID-19 are consistent across the different calibration sets. Note that, for ease of readability, results of COVID-19 sensitivity analyses are only plotted for the upper- and lower- limits of each quantity.

Figure A3 gives a summary of the results for the COVID-19 sensitivity analysis for our base calibration set. Results for other calibration sets were similar. Variability in 2021 incidence was large (ranging from 33,395 to 37,313) and was mostly determined by the level of behavioral effects in 2021, with the effects of HIV care disruptions less pronounced. Incidence among scenarios with the same level of behavioral effects, but differing care effects, differed by less than two percent. In contrast, scenarios with the same care effects but differing behavioral effects differed by as much as 12%. The level of care disruptions in 2021 had a larger effect on incidence levels in 2022 and beyond.

We found that behavioral effects had almost no impact on HIV diagnoses in 2021, with these determined almost entirely by HIV care effect. On average, scenarios with the same level of care disruption in 2021, differed by one percent in 2021 diagnoses, but by as much as 12% in 2021 incidence. This is consistent with the results in Fojo et al (2022), which indicated that 2021 diagnosis levels may not be an accurate indicator of underlying incidence.4 In 2022 and beyond, while we found the effect of 2021 behavioral effects on diagnoses was larger, HIV care effects remained significant.

The ranges reported in Tables 2 and 3 in the main text for different simulation outcomes were obtained from the upper and lower bounds of these simulations. As the findings in those tables and Figure 1 in the main text showed, the differences between the different scenarios narrowed over time for all observed outcomes.

Overall, this scenario analysis around 2021 COVID-19 effects showed that the effect on outcomes is largest in 2021 and become less pronounced from 2022 onward. The effect of 2021 behavioral changes on HIV incidence appears largely transient, with the effect essentially disappearing by 2022. In contrast, the effects of care disruptions appear more persistent for

both HIV incidence and diagnosis levels, which remain apparent for several years.

**References**

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4 Fojo A, Wallengren E, Schnure M, Dowdy DW, Shah M, Kasaie P. Potential Effects of the Coronavirus Disease 2019 (COVID-19) Pandemic on Human Immunodeficiency Virus (HIV) Transmission: A Modeling Study in 32 US Cities. *Clinical Infectious Diseases* 2022; published online Jan 7.

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**Figure A1:** Comparison between simulated (blue) and surveillance (black) for new HIV infections (left) and annual HIV diagnoses (right), over the years 2018-21. Upper and lower bounds for the simulated values were obtained through the sensitivity analysis to COVID-19 effects.



**Figure A2:** Results of the uncertainty analysis (COVID-19 simulation). The model was run using ten distinct calibration sets. We observe a similar COVID-19 effect in all cases, as evidenced by the profiles of each case shown. Results shown for the years 2021-24 also incorporate the additional COVID-19 sensitivity analysis in addition to the uncertainty analysis; for ease of plotting, however, these are not plotted for all cases. The aggregate mean of all simulations is depicted in a dashed black line.



**Figure A3:** Results of the scenario analysis, using the base calibration set. We see that the short and long-term implications of behavioral and care disruptions differ. Scenarios with the same level of behavioral disruption are presented with the same line color (blue for 50%, orange for 0%, yellow for 100%) and the same level of care disruption are presented with the same marker shape and line style (inverted triangle and dashed for 25%, square and dotted for 0%, circle and dot-dash for 50%).Differences in incidence in 2021 depend mostly on the magnitude of COVID-19 behavioral disruption, however, care disruptions have a larger effect on incidence in 2022 and beyond. Care disruptions are also more important in determining HIV diagnosis levels in 2021, with incidence differences showing almost no effect; differences in incidence in 2021 show a larger influence in diagnoses after 2022, but continuum of care disruptions remain significant.



**Table A1:** Summary of the COVID-19 effects changed in the sensitivity analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Behavior change  | Testing+diagnosis rate | ART initiation rate | ART dropoff rate + loss of VLS rate |
| 2020 | 20% decrease from 2019 in partnerships among MSM, and HET with multiple risk factors5 | 18% decrease from 2019 rates6 | 4·5% decrease from 2019 rate7  | Increases in rates to match 2·5% drop in use of ART7  |
| 2021 | 10% decrease from 2019 in partners among high-risk MSM, HET (50% of 2020 effect) | 4·5% decrease from 2019 rates (25% of 2020 effect) | 1·125% decrease from 2019 rate(25% of 2020 effect)  | 25% of increases from 2020 (25% of 2020 effect) |

**Table A2:** Summary of the different scenarios considered in the scenario analysis. Percentages refer to the magnitude of the 2021 COVID-19 effect in relation to its 2020 value. Note that “care-related changes” encompass the effects to testing and diagnosis, ART initiation rate, ART dropoff and loss of VLS rates (shown in Table A1). Note scenario 1 corresponds to the base-case pandemic scenario.

|  |  |  |
| --- | --- | --- |
| Scenario | Behavior change, 2021  | Care-related change, 2021 |
| **1** | **50%**  | **25%**  |
| 2 | 50%  | 0%  |
| 3 | 50%  | 50%  |
| 4 | 0%  | 25%  |
| 5 | 0%  | 0%  |
| 6 | 0%  | 50%  |
| 7 | 100%  | 25%  |
| 8 | 100%  | 0%  |
| 9 | 100%  | 50%  |