Estimation of the potential effects of disruption to HIV programs in sub-Saharan Africa caused by COVID-19: results from multiple models

APPENDIX

Further modelling details

Optima HIV model

Estimation of the potential effects of disruption to HIV programs in sub-Saharan Africa caused by COVID-19: results from the Optima HIV model

Objective

To estimate the impact of a potential three- or six-month interruption of HIV services in 2020 due to the COVID-19 pandemic in 12 countries in sub-Saharan Africa examined over a one or five-year period.

Methods

The impact of a 3- and 6-month disruption in HIV services in 2020 were modeled using the Optima HIV model (1). The HIV-related mortality rate was applied to those on antiretroviral therapy (ART) who were removed from ART due to this disruption following empirical observations from the SMART Study Group (2). CD4 counts declined rapidly as a result, and gradually returned to pre-ART levels after interruption. Once ART coverage was resumed following the disruption, mortality rate for those on ART were reapplied. Numbers of circumcisions were held constant over the 6-month disruption period, as it was assumed no new voluntary male medical circumcisions would be performed during COVID-19 pandemic lockdown due to physical distancing concerns.

The impact on drug resistance as a result of this disruption, behavior change as a result of pandemic lockdown (e.g. reduced numbers of casual or commercial sexual acts and receptive needle sharing) and additional COVID-19-related deaths among people living with HIV (PLHIV) was not considered.

The aim of this study is to focus on excess deaths in 1 year due to a 3- or 6-month interruption of ART in 2020. The resulting impact on new HIV infections was also examined, as well as interruption of other HIV services including voluntary medical male circumcision (VMMC), HIV testing, prevention of mother-to-child transmission (PMTCT) programs, and viral load testing, enhanced adherence counselling and switches to other treatment regimens stopped.

Changes in sexual contacts due to the COVID-19 pandemic lockdown could be assumed as an increase in sexual acts between regular partners and a decrease between casual and commercial partners; however, there is uncertainty whether a common change should be applied across all countries modeled. Therefore, no changes to behaviour were modeled.

Results

VMMC

Suspension of VMMC services for 3- or 6-months in 2020 did not show any relative impact on HIV mortality or incidence in 2020 or over 5-years from 2020 to 2024 (table 1).

Condoms

Interruption of condom availability showed relatively no impact on HIV mortality, and the most impact in HIV incidence over the 1-year period in 2020.

HIV testing

Suspension of HIV testing for 3- or 6-months in 2020 showed a relatively small increase in HIV mortality and incidence over the same year or 2020 to 2024 (1.00 to 1.02).

No new ART initiation

No new ART initiation showed the most pronounces relative impact over the 1-year period in mortality over infections, compared with the 5-year period over 2020-2024.

PMTCT

Suspension of PMTCT for 6-months in 2020 showed a relative increase in HIV incidence of 1.09 in 2020, with decreased relative increase over the 5-year period (1.03).

Viral load monitoring

Suspension of viral load monitoring leading which would ordinarily lead to enhanced adherence counselling, and switches of treatment regimens showed the relatively largest impact on HIV mortality with 3- or 6-months service disruption in 2020 (1.11 and 1.23, respectively). The impact lessening over the longer 5-year period (table 1)

Table 1. Predicted average relative excess in HIV-related deaths and new HIV infections per year for 5 years over 2020-2024 in countries in sub-Saharan Africa that would result from 3- / 6-months disruption of specific HIV services.

	1-year over 2020		**5-years over 2020-2024**	
HIV service disruption	**HIV mortality**	**HIV incidence**	**HIV mortality**	**HIV incidence**
Suspension of VMMC services	1.00 / 1.00	1.00 / 1.00	1.00 / 1.00	1.00 / 1.00
Condom availability interrupted	1.00 / 1.00	1.07 / 1.11	1.00 / 1.00	1.02 / 1.03
Suspension of HIV testing	1.01 / 1.02	1.00 / 1.01	1.01 / 1.02	1.00 / 1.01
No new ART initiation	1.03 / 1.05	1.02 / 1.04	1.01 / 1.01	1.00 / 1.00
Suspension of PMTCT	1.06 / 1.12	1.03 / 1.09	1.03 / 1.06	1.01 / 1.02
Viral load monitoring, enhanced adherence counselling and drug regimen switches stopped	1.11 / 1.23	1.04 / 1.09	1.03 / 1.07	1.01 / 1.03
Break in supply of ARVs leading to ART interruption	1.35 (1.13 – 1.61) / 1.87 (1.20 – 2.49)	1.11 / 1.23	1.20 / 1.35	1.06 / 1.11

Values in brackets for HIV mortality over the 1-year period represent uncertainty bounds.

HIV mortality

Excess deaths in the 6-month ART interruption scenario showed the largest relative impact on HIV mortality and deaths, with baseline deaths from 2018 exceeded in countries with high baseline viral suppression (table 2 and figure 1). This is due to a higher rate of CD4 count regression in those with higher baseline CD4 counts, conforming with Grund et al. findings.

Table 2. Predicted excess HIV-related deaths in 2020 due to a 3- /6-month interruption of ART in 2020

Country	Estimated HIV-related deaths in 2018*	Excess HIV-related deaths from a 3-month interruption of ART in 2020	Excess HIV-related deaths from a 6-month interruption of ART in 2020
Botswana	4,800	1,300	9,500
Cameroon	17,000	11,000	15,000
Cote d'Ivoire	16,000	8,400	12,000
Eswatini	2,400	2,300	4,700
Kenya	25,000	27,000	38,000
Malawi	13,000	6,100	18,000
Mozambique	54,000	39,000	54,000
Nigeria	53,000	35,000	52,000
South Africa	71,000	55,000	84,000
Tanzania	25,000	17,000	24,000
Uganda	23,000	22,000	43,000
Zimbabwe	22,000	5,400	21,000
Eastern and Southern Africa	160,000	93,000	140,000
Western and Central Africa	310,000	210,000	380,000
Sub-Saharan Africa	470,000	300,000	520,000

*Source: AIDSinfo, accessed 30 April 2020

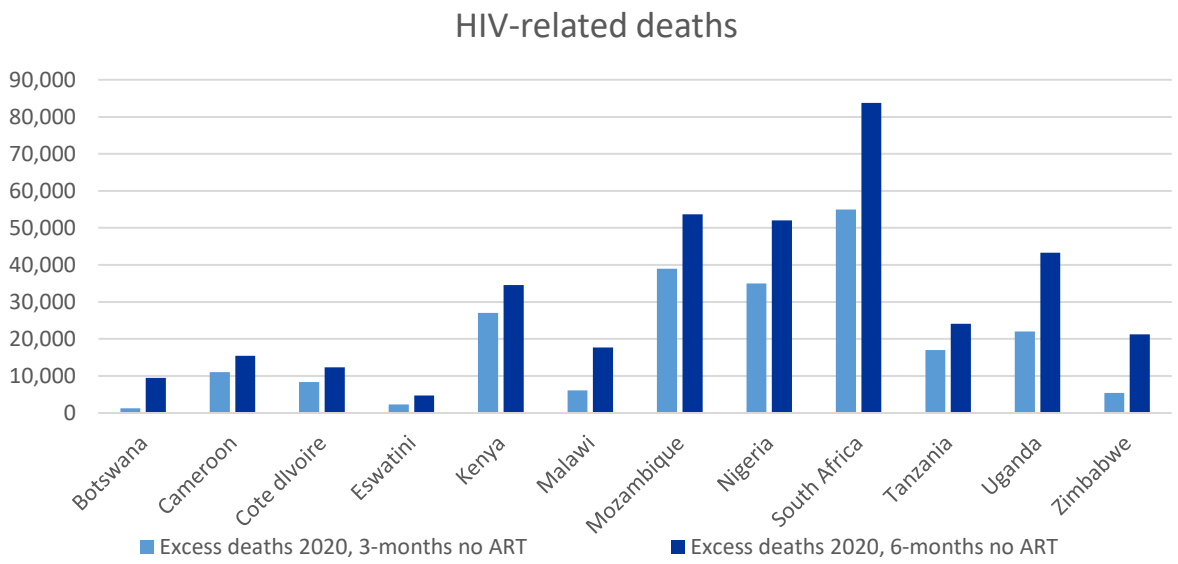


Figure 1. Excess HIV-related deaths from a 3-month and 6-month interruption of ART in 2020

Conclusion

Maintaining ART is vital to sustaining the response to the HIV epidemic. Interruption of ART causes CD4 counts in people living with HIV who were on treatment to drop dramatically, potentially resulting in a significant increase in deaths even over a one-year period. There are many limitations with this study, like with any modeling study; and additionally, the length and extent of disruptions due to COVID-19 remain uncertain. Secondary effects not modeled here include the potential loss to follow-up of people living with HIV that were in care before the disruption of services, and the significant effort that might be required to identify and re-integrate these people into care following the disruption. This could result in higher impacts due to a longer period of interruption in services, with a resulting increase in new HIV infections and deaths due to lower overall levels of viral suppression.

FURTHER DETAILS

1. CD4 count progression

CD4 progression used in the Optima HIV model are listed in Table A1.

Table A1. Average times in years to progress to the next CD4 stage used by the Optima HIV model

Stage	Average time to progress to next CD4 stage in years (low-high)
Acute to >500	0.24 (0.10-0.50)
>500 to 500	0.95 (0.62-1.16)
500 to >350	3.00 (2.83-3.16)
350 to >200	3.74 (3.48-4.00)
>200 to 50	1.50 (1.13-2.25)
200 to onset of AIDS	~2.00 (1.50-3.00)

See Optima HIV User Guide for supporting information

The figure below illustrates the PLHIV on ART and their subsequent CD4 count in the baseline versus the no ART for 6-month scenario in 2020 for an example country. For ART disruption, this is for the default “off ART” mortality rate, CD4 counts dropped even more dramatically following the parameter informed by the Grund et al. study, as used herein.

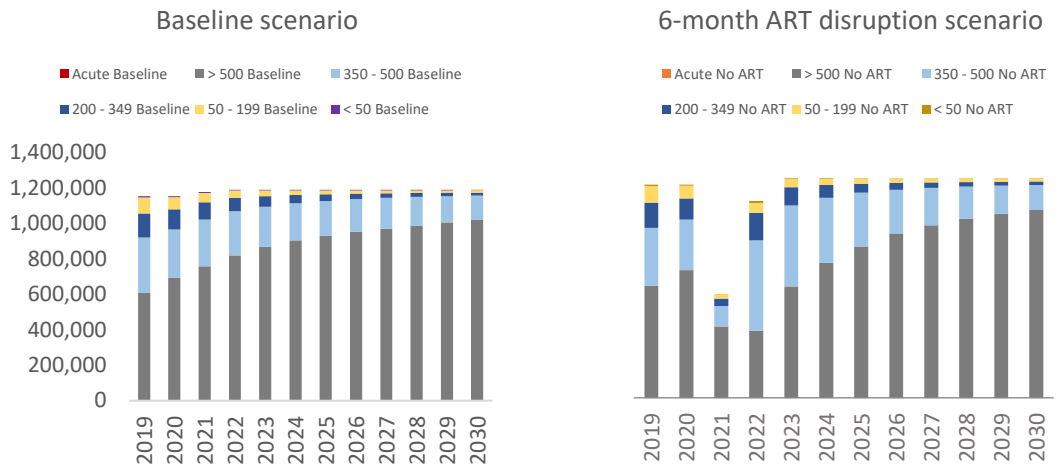


Figure A1. Distribution of CD4 count for people living with HIV both those on and off ART (baseline scenario) compared with a six-month complete of ART disruption scenario (default off ART mortality show here; mortality rate off ART used in the study followed Grund et al. findings, which would have showed even more dramatic CD4 reductions) in 2020 over 2019 to 2030

The example in figure A2 illustrates the difference in progression of CD4 count in PLHIV on ART and off ART for the Goals and Optima models for Malawi, illustrating proportional differences between the two.

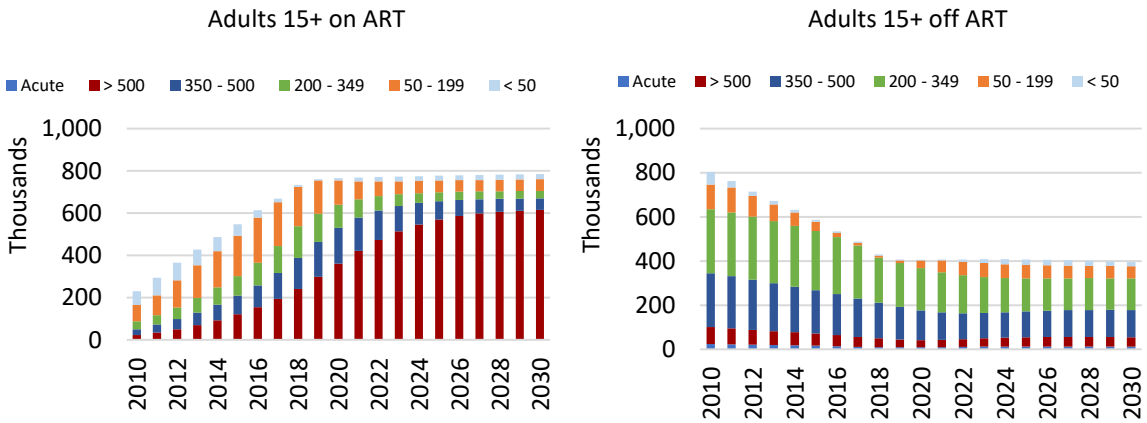


Figure A2. Distribution of CD4 count for estimated numbers of adults aged 15 and over who are living with HIV on and off ART for an example country

2. Mortality rates

The HIV-related death rate for people living with HIV who were on ART, but who stopped treatment due to potential disruption on the antiretroviral (ARV) drug supply as a result of the COVID-19 pandemic, was modeled to represent findings from Grund et al. 2006. This study, known as the SMART trial, showed that immune recovery during ARV therapy tended to be rapidly lost after interruption of treatment, with a median loss of 187 CD4 cells/mm^3 in 2 months and 25% of people experiencing a loss of > 317 cells/mm^3.

Table A2. HIV-related death rates (percent mortality per year with low and high bounds) by CD4 count or ART status used in the Optima HIV model

Stage or status	Best (low-high)
Acute infection	0.36% (0.29%-0.44%)
CD4 >500	0.36% (0.29%-0.44%)
CD4 350 to <500	0.58% (0.48%-0.71%)
CD4 200 to <350	0.88% (0.75%-1.01%)
CD4 50 to <200	5.90% (5.40%-7.90%)
CD4<50	32.30% (29.60%-43.20%)
Relative mortality rate on suppressive ART	23.00% (15.00%-30.00%)
Relative mortality rate on non-suppressive ART*	48.78% (28.35%-84.17%)

*With increased death rates for people on ART who stop ART as described above

See Optima HIV User Guide Vol. VI: Parameter Data Sources for supporting information

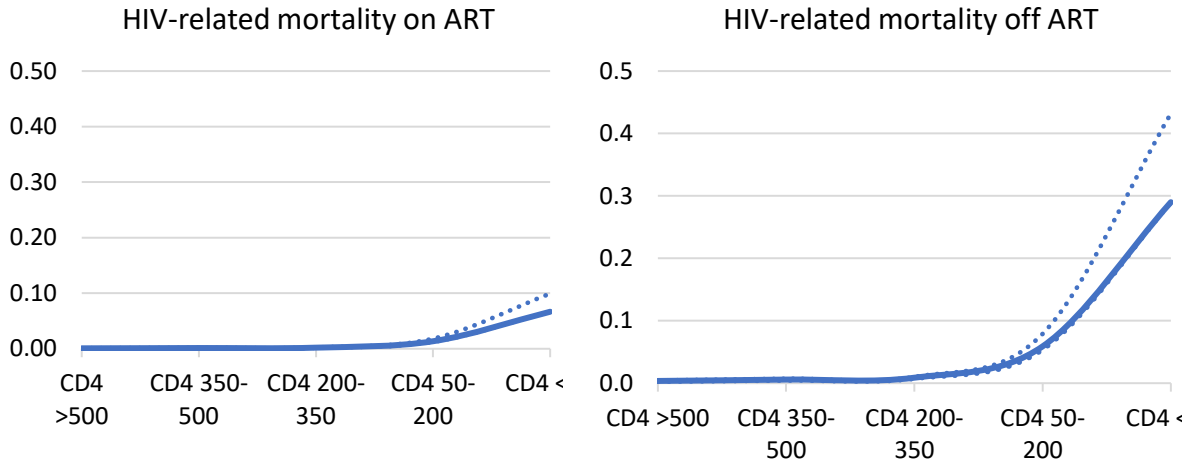


Figure A3. HIV-related mortality rates with bounds (area between dotted lines) by CD4 count for on and off ART used in the Optima HIV model

References

1. Kerr CC, Stuart RM, Gray RT, Shattock AJ, Fraser-Hurt N, Benedikt C, et al. Optima: A Model for HIV Epidemic Analysis, Program Prioritization, and Resource Optimization. Journal of acquired immune deficiency syndromes (1999). 2015;69(3):365-76.
2. Grund B for the SMART Study Group. Predictors of initial CD4 decline after antiretroviral treatment interruption in the SMART study. Abstract THPE0144. XVI International AIDS Conference, 13-18 August 2006.

HIV Synthesis Model

Supplementary Table 1. Description of setting scenarios at start of 2020 (n=1500).

Characteristic	**Model (2020)** (median, 90% range)	**Examples of observed data***
HIV prevalence (age 15-49)	14% (5% - 28%)	Zimbabwe 2016 13%, Tanzania 2017 5%, Uganda 2017 6%, Lesotho 2017 24%, Eswatini 2017 27%, Malawi 2016 10%, Namibia 2017 12%, Zambia 206 11%, Cameroon 2017 3.4%, Cote d'Ivoire 2017/18 2.5%, Mozambique 11%
HIV incidence age 15-49 (/100 person years)	1.09 (0.29 – 2.55)	Malawi 2016 0.37, Zambia 2016 0.66, Zimbabwe 2016 0.45, Lesotho 2017 1.55, Namibia 2016 0.40, Eswatini 2017 1.48, Tanzania 2017 0.27, Cameroon 2017 0.27
Proportion of men circumcised	0.32 (0.12 – 0.53)	Tanzania 2016 0.79 Lesotho 2016 0.68 South Africa 0.58 Uganda 2016 0.43 Namibia 2016 0.39 Eswatini 2016 0.30 Zambia 2016 0.28 Malawi 2016 0.25 Zimbabwe 2016 0.14
Percent of women that are sex workers	1.4% (0.3% -4.7%)	1.2% Zimbabwe (Fearon) 1%-4% Vandepitte et al.
Percent of people on PrEP	0.06% (0.01% - 0.24%)	
Proportion of HIV positive people diagnosed	91% (71% - 95%) (86% M, 93% W)	Malawi 2016 77%, Zambia 2016 67%, Zimbabwe 2016 74%, Namibia 2017 86%, Tanzania 2017 52%, Ethiopia 2018 72%, Cote d'Ivoire 2017/18 37%, Cameroon 2017 47%
Proportion of diagnosed HIV+ people on ART	90% (74% - 97%)	Lesotho 2016/17 92%, South Africa 2017 71%, Eswatini 2016/17 87%, Namibia 2017 96%, Zambia 2016 87%, Tanzania 2016/17 94%, Ethiopia 99%, Malawi 2016 91%, Uganda 2016/17 90%, Cameroon 2017 91%, Zimbabwe 2016 87%, Cote d'Ivoire 2017/18 88%, Cameroon 2017 91%.
Proportion of all HIV positive people with VL < 1000 copies/mL	65% (43% - 79%)	Zambia 2016 60%, Malawi 2016 68%, Zimbabwe 2016 60%, Eswatini 2017 73%, Lesotho 2017 68%, Tanzania 2017 52%, Uganda 2017 60%, Namibia 2017 77%, Ethiopia 2018 70%, Cote d'Ivoire 2017/18 40%, Cameroon 2017 47%.
Proportion of ART experienced people who have started 2^{nd}-line ART	15% (1% - 40%)	Malawi ~3%% (Malawi MoH Quarterly Reports)
Of people on ART, proportion with VL < 1000	86% (65% - 94%) (82% M, 88% W)	Zambia 2016 Men/Women 88%/90%, Malawi 2016 90%/92%, Zimbabwe 2016 84%/88%, Namibia 2017 92%/90%, Tanzania 2017 89%/83%, Ethiopia 2018 95%/87%, Cote d'Ivoire 2017/18 76%, Cameroon 2017 80%.
Of people on ART, proportion with CD4 < 500 / mm^3	45% (38% - 57%)	Eswatini 40% 2016/17, Malawi 52% 2016, Tanzania 2017/17 55%, Zambia 2016 59%.
Of people on ART, proportion with CD4 < 200 / mm^3	8% (4% - 17%)	

Of ART naïve ART initiators % with NNRTI resistance	12% (0% - 33%)	Angola 2012 14%, Botswana 2016 8%, South Africa 2017 14%, Zimbabwe 2015 10%, Namibia 9%, Uganda 2016 16%, Cameroon 8%. (HIV drug resistance report 2017)
Mother to child transmission rate	9% (0% - 25%)	(including breastfeeding period) Botswana 5%, South Africa 5%, Namibia 6%, Uganda 8%, Zimbabwe 7%, Malawi 9%, Tanzania 12%, Ethiopia 21%, Cote d'Ivoire 16%, Cameroon 15% (UNAIDS 2019)
Proportion of women age 15-65 giving birth per year	8% (3% - 18%)	South Africa 6%, Botswana 7%, Namibia 10%, Malawi 15%, Zimbabwe 12%, Uganda 18%, Tanzania 16%, Ethiopia 12%, , Cote d'Ivoire 15%, Cameroon 14%. (https://population.un.org/wpp/)

* all data from PHIA surveys (Population Health Impact Surveys. https://phia.icap.columbia.edu/), South Africa (HSRC survey), Botswana (BCPP 2013-15) unless stated.

Supplementary Table 2. Amongst setting scenarios with all ART stopped, relative increase in HIV deaths according to proportion of people with HIV with VL < 1000 copies/mL

Proportion of people with HIV with VL < 1000 copies/mL	**Mean relative increase in annual HIV-related deaths due to disruption (95% CI) over 1 year.**
< 0.5	2.3
0.50-	2.3
0.55-	2.4
0.60-	2.5
0.65-	2.7
0.70-	3.3
0.75-	3.9
0.80-	5.3

Supplementary Table 3. Predicted absolute number of excess HIV deaths in 1 year due to 6 months interruption of ART taking in example countries

Country	Number (age 15+) living with HIV*	Proportion of people with HIV with VL < 1000*	Assumed proportion of people with HIV with VL < 1000 in 2020	Number of HIV deaths in adults age 15+ in 2018*	Predicted number of excess HIV deaths in adults in one year from 2020.5 due to interruption of ART taking for 6 months due to disruption caused by COVID-19
Malawi	970,000	72%	70-75% (3.3 x)	10,500	24,100
Zimbabwe	1,220,000	60%**	60-65% (2.5x)	18,700	28,000
South Africa	7,500,000	54%	50-55% (2.3x)	66,000	83,800
Lesotho	320,000	56%	55-60% (2.4x)	5,400	7,600
Eswatini	192,000	83%	80-85% (5.3x)	2,130	9,200
Uganda	1,280,000	65%	65-70% (x2.7)	18,000	48,600
Mozambique	2,000,000	assume < 50%	< 50% (x2.3)	45,000	58,500
Kenya	1,440,000	assume 70-75%	70-75% (x 3.3)	20,100	46,200
Tanzania	1,460,000	63%	65-70% (x2.7)	18,600	31,600
Botswana	350,000	83%	80%-85% (x5.3)	4,500	19,350
Cameroon	500,000	assume < 50%	< 50% (x2.3)	14,300	18,600
Cote d'Ivoire	430,000	< 50%	< 50% (x2.3)	13,700	17,800
Nigeria	1,770,000	< 50%	< 50% (x2.3)	40,000	52,000
Western & Central Africa	5,000,000	39%	< 50% (x2.3)	160,000	208,000
Eastern & Southern Africa	20,600,000	58%	60-65% (x2.5)	310,000	465,000

* UNAIDS estimates; ** PHIA 2016

Reference

1. Phillips AN, et al. Updated assessment of risks and benefits of dolutegravir versus efavirenz in new antiretroviral treatment initiators in sub-Saharan Africa: modelling to inform treatment guidelines. Lancet HIV 2020. https://www.thelancet.com/journals/lanhiv/article/PIIS2352-3018(19)30400-X/fulltext

   Appendix: https://www.thelancet.com/cms/10.1016/S2352-3018(19)30400-X/attachment/3398d3d8-5988-4171-aa74-2f68ce877725/mmc1.pdf

Modelling of effects of interruption of ART in HIV Synthesis

This below is from the appendix to reference 1 describing the Viral load and CD4 count changes during ART interruption. https://www.thelancet.com/cms/10.1016/S2352-3018(19)30400-X/attachment/3398d3d8-5988-4171-aa74-2f68ce877725/mmc1.pdf Risk of AIDS death is related to the most recent CD4 count, viral load and age, as described in that appendix.

Viral load returns to previous maximum viral load (vmax) in 3 months and adopts natural history changes thereafter.

CD4 rate of decline returns to natural history changes (i.e. those in ART naïve patients) after 9 months, unless the count remains > 200 above the CD4 nadir

Rate of CD4 count decline depends on current viral load. c(t) is the CD4 count at time t, cmin(t) is the CD4 count nadir measured by time t and cc(t-1) is the change in CD4 count from t-1 to t.

if time off ART = 3 months or if time off ART > 3 months and CD4 in previous period is > 300 above the minimum CD4 count to date

v(t) = vmax(t-1)

if $v(t) \geq 5$	then cc(t-1) = Normal $(-200,10^2)$
if 4.5 <= v(t) < 5	then cc(t-1) = Normal $(-160,10^2)$
if v(t) < 4.5	then cc(t-1) = Normal $(-120,10^2)$

If this leads to c(t) < cmin(t) (CD4 nadir) then c(t) is set to cmin(t)

if time off ART = 6 months:-

if $v(t) \geq 5$	then cc(t-1) = Normal $(-100,10^2)$
if 4.5 <= v(t) < 5	then cc(t-1) = Normal $(-90,10^2)$
if v(t) < 4.5	then cc(t-1) = Normal $(-80,10^2)$

if time off ART = 9 months:-

if $v(t) \geq 5$	then cc(t-1) = Normal $(-80,10^2)$
if 4.5 <= v(t) < 5	then cc(t-1) = Normal $(-70,10^2)$
if v(t) < 4.5	then cc(t-1) = Normal $(-60,10^2)$

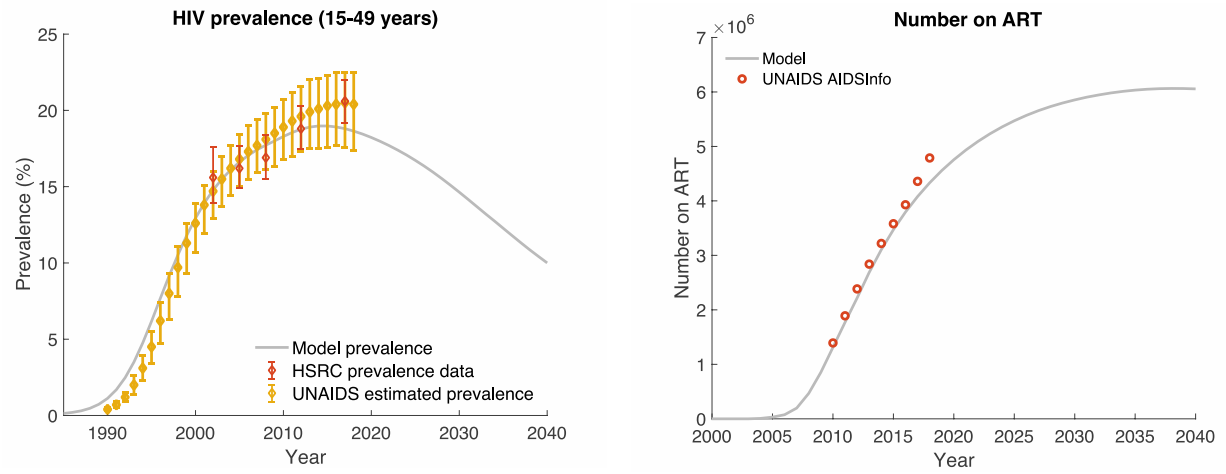
This is broadly based on evidence from a number of analyses of the effects of ART interruption (1-5 below)

1. d'Arminio Monforte A, Cozzi Lepri A, Phillips AN, et al. Interruption of HAART in HIV clinical practice. Results from the ICONA study. JAIDS 2005; 38: 407-416
2. Li X, Margolick JB, Conover CS, et al. Interruption and discontinuation of HART in the MACS. JAIDS 2005; 38: 3:320-328.
3. Mocroft A, Youle M, Moore A, et al. Reasons for modification and discontinuation of antiretrovirals: results from a single treatment centre. AIDS 2001; 15 (2): 185-194.
4. Wit FWNM, Blanckenberg DH, Brinkman K, et al. Safety of long-term interruption of successful antiretroviral therapy: the ATHENA cohort study. AIDS 2005; 19: 345-348.
5. Grund B for the SMART Study Group. Predictors of initial CD4 decline after antiretroviral treatment interruption in the SMART study. XVI International AIDS Conference. August 13-18, 2006. Toronto. Abstract THPE0144.

Imperial College London Model

The Imperial College London Model is a deterministic, compartmental model of HIV transmission and progression, and has been described previously [1,2]. Briefly, the model is stratified by age, sex, behavioural risk group (including partner change rate, condom use, and frequency of sex acts), and male circumcision status, with population growth in accordance with country-specific projections. HIV-infected individuals in the model progress through HIV infection based on stage of infection, CD4 count, and antiretroviral therapy (ART) status. Rates of transmission within the model are based on the risk group of both partners, infection stage and ART status of the HIV-positive partner, and the circumcision status of an HIV-negative male partner.

The model is calibrated over time to age and sex-specific HIV prevalence, number and proportion of HIV-infected individuals on ART, and male circumcision scale-up. Parameters fit in the calibration include the HIV transmission probability per sex act, sexual contact rates by behavioural risk group, proportion of the population in each risk group, rates of mixing between risk groups, and the start time of the epidemic. Analyses provided are for models calibrated for Malawi, South Africa, and Zimbabwe. The model's fit to adult HIV prevalence and proportion on ART in South Africa are shown in Supplementary Figure 1.



Supplementary Figure 1: Modelled HIV prevalence and number on ART in the Imperial College London South Africa model.

This analysis simulates the effect of 3- and 6-month interruptions of different HIV services starting mid-2020 as a result of the COVID-19 pandemic. In all scenarios of interruptions to HIV services, there is assumed to be no change to sexual contact rates, but a scenario of a 10% reduction in sexual contacts for all risk groups is modelled separately. Each type of disruption is assumed to occur independently so as to illustrate the individual effect of the respective disruption. However, in reality, multiple disruptions might occur simultaneously.

Results are most sensitive to the assumption about mortality for HIV-infected individuals who stop ART. Our results are therefore presented using three different estimates of mortality, with the central result using the 'medium' assumption in Supplementary Table 1.

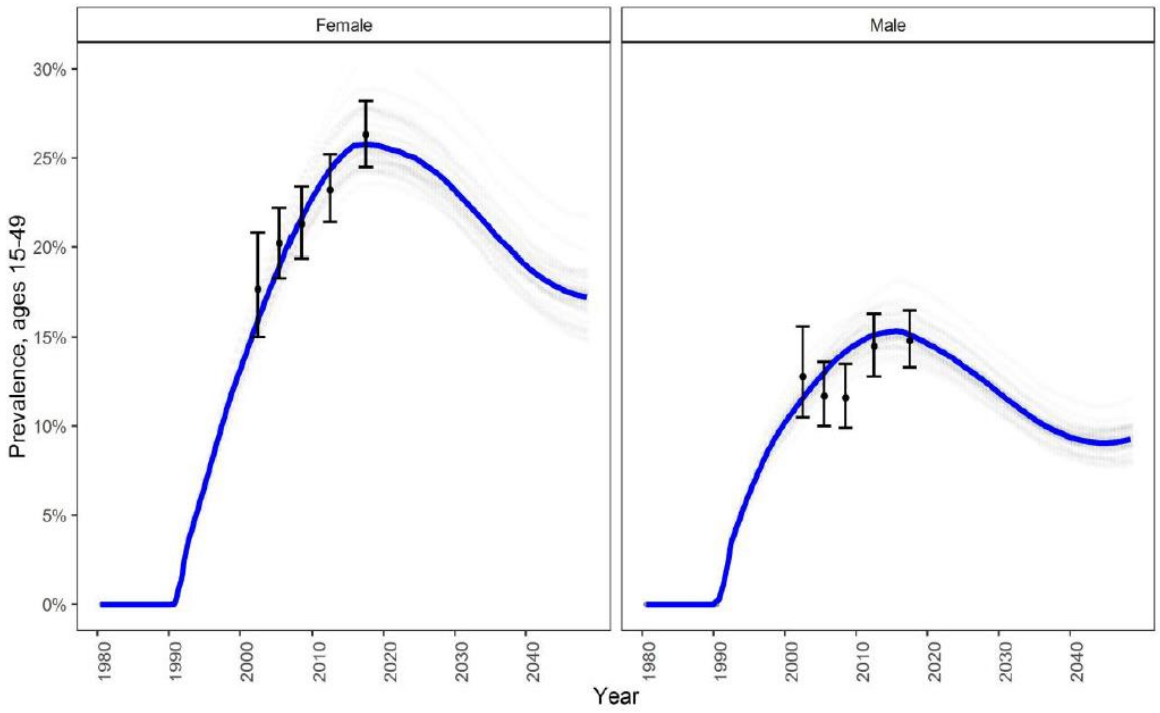
	Mean time to death	*Justification*
Lower Bound	32 years	The SMART trial found a 3% risk at 12 months of either death of an opportunistic infection for those with ART interrupted, which would give this mean survival time if that rate was maintained [3].
Medium	14 years	This is approximately the survival time for HIV-positive persons who have never been on ART [4].
Upper bound	7 years	This is a hypothetical worst-case scenario in which many persons deteriorate more rapidly.

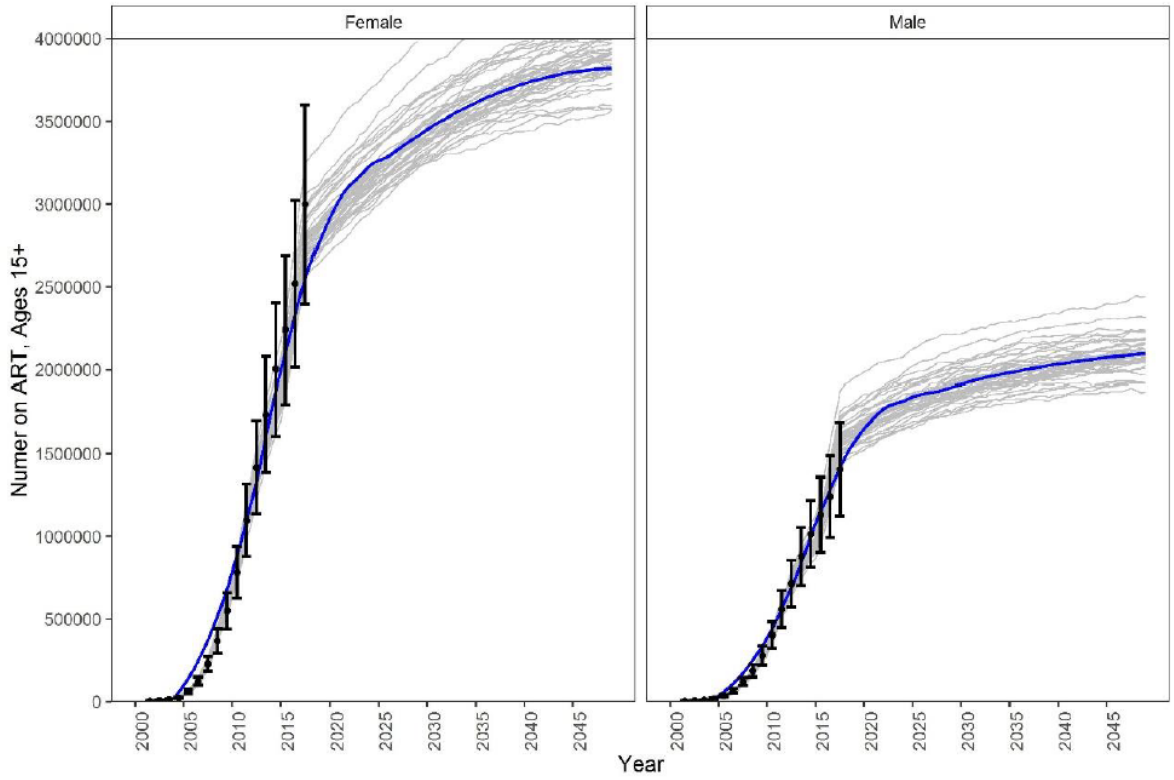
Supplementary Table 1: Alternative assumptions used for the risk of death experienced by those PLHIV for whom their ART supply is interrupted.

1. Cremin, I., et al., *The new role of antiretrovirals in combination HIV prevention: a mathematical modelling analysis.* AIDS, 2013. **27**(3): p. 447-458.
2. Smith, J.A., et al., *Maximising HIV prevention by balancing the opportunities of today with the promises of tomorrow: a modelling study.* The Lancet HIV, 2016. **3**(7): p. e289-e296.
3. The Strategies for Management of Antiretroviral Therapy (SMART) Study Group, *CD4+ Count–Guided Interruption of Antiretroviral Treatment.* New England Journal of Medicine, 2006. **355**(22): p. 2283-2296.
4. Todd, J., et al., *Time from HIV seroconversion to death: a collaborative analysis of eight studies in six low and middle-income countries before highly active antiretroviral therapy.* AIDS, 2007. **21**(Suppl 6): p. S55-63.

EMOD HIV Model

The EMOD model source code, parameter definitions and ranges, and description/documentation can be found at https://github.com/InstituteForDiseaseModeling/EMOD. Analyses are based upon a model calibrated to the HIV epidemic in South Africa and described elsewhere.[1-4] Briefly, the model is parameterized with epidemiologic data including population size, fertility, mortality, voluntary male circumcision coverage, health seeking and sexual behaviour. South Africa data on age and sex specific HIV prevalence, ART coverage, population size and HIV incidence were used to calibrate the model. Calibration was performed using a parallel simultaneous perturbation optimization (PSPO) algorithm. [5] Roulette resampling in proportion to the likelihood of each simulation was used to select 250 model parameter sets. The model's fit to adult HIV prevalence and number receiving ART are shown below (gray lines: individual simulations; blue line: average of 250 simulations; black dots/lines: data from HIV surveys).





To estimate the number of excess deaths in countries and regions throughout sub-Saharan Africa, we assumed that the number of deaths caused by a 6-month interruption in ART was proportional to the number of people virally suppressed on ART in a given country or region. A limitation of this assumption is that it does not take into account regional differences in the vulnerability of PLHIV with viral load suppression to death from an ART interruption, which could arise due to differences in the age distribution, CD4 count, health and nutritional status, and exposure to infections such as tuberculosis. Data used to estimate mortality by country and region are shown in Supplementary Table 1

Supplementary Table 1. Estimation of excess HIV deaths in 1 year due to 6 months interruption of ART.

Country	**Number of PLHIV[a]**		**Number of people receiving ART[a]**	**Percent of people on ART with Viral Load Suppression**	**Predicted number of <u>excess</u> HIV deaths in adults in one year from 2020.5 due to interruption of ART taking for 6 months due to disruption caused by COVID-19**
South Africa	7,700,000		4,788,000	54%	140,905
Malawi	1,000,000		814,000	69%	23,382
Mozambique	2,200,000		1,213,000	----	
Zimbabwe	1,300,000		1,155,251	85%[b]	33,394
Eswatini	210,000		177,000	81%	5,764
Lesotho	340,000		206,000	57%	6,567
Uganda	1,400,000		1,004,000	64%	30,363
Kenya	1,600,000		1,068,000	72%[c]	38,822
Botswana	370,000		307,000	81%	10,156
Tanzania	1,600,000		1,109,000	62%	33,617

East and Southern Africa	20,600,000		13,802,000	58%	404,889
Cameroon	540,000		281,000	79%[d]	14,530
Côte d'Ivoire	460,000		252,000	41%	6,391
Nigeria	1,900,000		1,016,000	42%	27,042
West and Central Africa	5,000,000		2,550,000	39%	66,081

[a] UNAIDS estimate for the most recent available year (2018 or 2019) obtained from http://aidsinfo.unaids.org/

[b] Estimate from the 2016 Zimbabwe Population HIV Impact Assessment (ZIMPHIA), https://phia.icap.columbia.edu/countries/zimbabwe/

[c] Estimate from the Preliminary Report of the 2018-19 Kenya Population HIV Impact Assessment (KENPHIA), https://phia.icap.columbia.edu/countries/kenya/

[d] Estimate from: Fokam, J., Sosso, S.M., Yagai, B. et al. Viral suppression in adults, adolescents and children receiving antiretroviral therapy in Cameroon: adolescents at high risk of virological failure in the era of "test and treat". AIDS Res Ther 16, 36 (2019). https://doi.org/10.1186/s12981-019-0252-0

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