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ORIGINAL ARTICLE

Projecting the Clinical and Economic Impacts of Changes to HIV Care Among Adolescents and Young Adults in the United States: Lessons From the COVID-19 Pandemic

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Background. During the COVID-19 pandemic, many US youth with HIV (YHIV) used telehealth services; others experienced disruptions in clinic and antiretroviral therapy (ART) access.

Methods. Using the Cost-effectiveness of Preventing AIDS Complications (CEPAC)-Adolescent HIV microsimulation model, we evaluated 3 scenarios: 1) *Clinic*: in-person care; 2) *Telehealth*: virtual visits, without CD4 or viral load monitoring for 12 months, followed by return to usual care; and 3) *Interruption*: complete care interruption with no ART access or laboratory monitoring for 6 months (maximum clinic closure time), followed by return to usual care for 80%. We assigned higher 1-year retention (87% vs 80%) and lower cost/visit ($49 vs $56) for *Telehealth* vs *Clinic*. We modeled 2 YHIV cohorts with non-perinatal (YNPHIV) and perinatal (YPHIV) HIV, which differed by mean age (22 vs 16 years), sex at birth (85% vs 47% male), starting CD4 count (527/μL vs 635/μL), ART, mortality, and HIV-related costs. We projected life months (LMs) and costs/100 YHIV over 10 years.

Results. Over 10 years, LMs in *Clinic* and *Telehealth* would be similar (YNPHIV: 11 350 vs 11 360 LMs; YPHIV: 11 680 LMs for both strategies); costs would be $0.3M (YNPHIV) and $0.4M (YPHIV) more for *Telehealth* than *Clinic*. *Interruption* would be less effective (YNPHIV: 11 230 LMs; YPHIV: 11 620 LMs) and less costly (YNPHIV: $1.3M less; YPHIV: $0.2M less) than *Clinic*. Higher retention in *Telehealth* led to increased ART use and thus higher costs.

Conclusions. Telehealth could be as effective as in-person care for some YHIV, at slightly increased cost. Short interruptions to ART and laboratory monitoring may have negative long-term clinical implications.

Key words. adolescents and young adults; COVID-19; HIV; telehealth; youth.

KEY POINTS

Using a microsimulation model, we found that telehealth has the potential to improve clinic-based care for some groups of youth with HIV, while even short, complete shutdowns could have adverse long-term implications.

INTRODUCTION

The early months of the COVID-19 pandemic disrupted care for many people with HIV in the United States [1]. Pandemic safety measures forced many clinics to close abruptly or reduce services, including laboratory testing and urgent visits [2]. Job losses, lack of insurance, and fear of contracting COVID-19 also posed barriers to accessing healthcare [3]. Rates of depression and anxiety increased, both of which are correlated with poor medication adherence [4, 5]. Data continue to emerge on the impact of these changes on youth with HIV (YHIV), a group that is less likely to be retained in care and to achieve virologic suppression than the general population of people with HIV [6].

Simultaneously, the pandemic spurred a rapid expansion of telehealth, creating a new avenue to retain YHIV in care. For some patients, telehealth access increases appointment scheduling and attendance [7, 8]. For others, telehealth may exacerbate existing inequities; for example, lack of phone or internet access or a private space and the inability of providers

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to conduct full physical examinations via telehealth may lead to wider disparities in care access by race/ethnicity, gender, and sexual orientation [2, 6, 9]. Youth with chronic conditions have used telehealth successfully [10, 11], and are more likely to take advantage of telehealth services than adults [12]. The US Department of Health and Human Services and the Infectious Disease Society of America endorse making telehealth available to people with HIV, including adolescents, regardless of age [13, 14]. While reimbursement for telehealth during the COVID-19 pandemic expanded greatly, policies continue to evolve, with some insurers becoming more restrictive over time [15].

Ensuring consistent access to HIV-related care is essential to keep YHIV healthy, maintain virologic suppression, and reduce the likelihood of onward HIV transmission. Previous modeling analyses have estimated the impact of the COVID-19 pandemic on HIV infections and HIV testing services [16–19], but did not consider changes to care among youth or among those already engaged in HIV care. The goal of this analysis was to project the clinical and economic impact of COVID-19-related disruptions in HIV care on YHIV who were in care at the start of the pandemic, and to consider the potential role for telehealth in keeping YHIV engaged in care and virologically suppressed.

METHODS

Analytic Overview

Using the Cost-effectiveness of Preventing AIDS Complications (CEPAC)-Adolescent model of HIV disease and treatment, we simulated 2 cohorts of YHIV, YHIV acquired non-perinatally (YNPHIV) and perinatally (YPHIV), aged 13–24 in care pre-pandemic. Cohort characteristics and key cost parameters were informed by data from the Adolescent Medicine Trials Network for HIV/AIDS Interventions (ATN) Cascade Monitoring sites and published sources (Table 1). We modeled 3 care strategies: *Clinic*: in-person care and laboratory monitoring; *Telehealth*: virtual visits, without laboratory (CD4 or viral load) monitoring for 12 months; and *Interruption*: complete care interruption, that is, no antiretroviral therapy (ART) or laboratory monitoring for 6 months, followed by return to usual care for 80% of the cohort. We chose to model a 6-month duration of this complete care interruption in the base case because this was likely to be the longest period a clinic may have been closed [2, 40]. We varied characteristics of these scenarios widely in additional analyses. We projected undiscounted clinical outcomes and costs over 10 years, including life expectancy in life months (LMs), rates of care engagement, and virologic suppression. We scaled the results to a hypothetical clinic serving 100 YHIV at the start of the COVID-19 pandemic.

Model Structure

The CEPAC-Adolescent model is a validated Monte Carlo state-transition model of HIV disease and treatment. Individuals are simulated throughout the modeled time horizon. The model sums clinical events at the end of the simulated period [41, 42].

Natural History and Treatment

Simulated YHIV enter the model in care and on ART, between ages 13 and 24 years. At model start, YHIV are assigned a CD4 count, HIV RNA setpoint, and ART adherence level. Without effective ART, CD4 count declines, and HIV RNA increases. Decreased adherence leads to lower probabilities of virologic suppression when starting ART and over time. When viremia occurs, modeled YHIV may have the opportunity to re-suppress on the same ART regimen before switching to a new regimen. The model tracks true virologic status, regardless of whether it is observed through laboratory monitoring. YHIV face a monthly probability of becoming lost to follow-up at any point. Those who become lost to follow-up then have a monthly probability of returning to care. To capture the disease trajectory and behavioral characteristics of adolescents, key model parameters are linked to age, including adherence to ART, engagement in care, CD4 count, CD4-stratified probabilities of opportunistic infections and HIV-related mortality, and non-HIV-related mortality.

Model Inputs

Cohort Characteristics

We modeled 2 populations of YHIV based on mode of acquisition, either YPHIV or YNPHIV, who are engaged in care and on ART at the start of the COVID-19 pandemic. Mean (standard deviation) age at model start is 21.8 (3.0) and 16.0 (3.8) years for YNPHIV and YPHIV, respectively (range 13–24 years; Table 1 [20]), and 85% and 47% are assigned male sex at birth. Mean (standard deviation) CD4 count at model start is 527 cells/μL (227) and 635 cells/μL (381) for YNPHIV and YPHIV, respectively [20]. Based on ATN data, cohort-level virologic suppression is 62% for both YPHIV and YNPHIV at the start of the simulation [22].

HIV Natural History and Treatment

From age 13 through 29 years, modeled individuals face adolescent and young adult-specific opportunistic infection incidence and HIV-related mortality, both stratified by CD4 count and ART use and derived from ATN and International Maternal Pediatric Adolescent AIDS Clinical Trials (IMPAACT) Network studies [20]. Beginning at age 30, opportunistic infection and HIV-related mortality probabilities were derived from the adult-focused Multicenter AIDS Cohort Study (MACS) as well as published studies (Supplementary Table 1). Opportunistic infection rates and mortality were derived separately for YPHIV and YNPHIV [20]. To reflect differing treatment history, we also modeled distinct ART regimens for the 2 cohorts (Table 1). All YHIV start the simulation prescribed integrase strand transfer inhibitor (INSTI)-based ART treatment, with efficacy varying based on adherence level [27–30]. Once suppressed on

Table 1. Select Model Input Parameters: Clinical and Economic Impact of COVID-19-related Care Interruptions

Parameter	Youth With Non-perinatal HIV	Youth With Perinatal HIV	Source
Cohort characteristics			
Age, mean (SD)	21.8 (3.0)	16.0 (3.8)	[20]
Male/female sex, %	85/15	47/53	[21]
CD4 at model start, cells/μL, mean (SD)	527 (227)	635 (381)	[20]
Cohort-level virologic suppression at model start	62%	62%	[22]
Loss to follow-up			
In-person care, annual, %	19.7	19.7	[23]
Telehealth, annual, %[a]	13.1	13.1	[24]
Interruption, initial %[a]	100	100	
Return to care, annual, %	16.6	16.6	[25]
Return to care, post-interruption, %	80	80	[23, 26]
ART adherence and virologic suppression			
Adherence to ART, age <25 years (% of cohort)			[27]
Adherence ≥90%	28%	43%	
Adherence <90%	72%	57%	
Adherence to ART, age ≥25 years (% of cohort)			[27]
Adherence ≥90%	66%	66%	
Adherence <90%	34%	34%	
Mean ART efficacy, >95% adherence, %[b]			
INSTI-based regimen	96%	80%	[28–30]
PI-based regimen	88%		[31]
NNRTI-based regimen	93%	93%	
Late virologic failure, mean monthly probability			
INSTI-based regimen	0.0033	0.0030	[32]
PI-based regimen	0.0059		[33]
NNRTI-based regimen	0.0059	0.0039	
Costs, 2020 USD			
CD4 cell count test	46.98	46.98	[34]
Viral load test	85.10	85.10	[34]
In-person clinic visit	56	56	[35]
Telehealth visit	49	49	[35]
Routine HIV care costs off-ART, stratified by CD4, range by age, monthly[c]			[34, 36–38]
>500 cells/μL	70–330	300–330	
351–500	110–410	410–760	
201–350	110–640	640–760	
101–200	630–1540	1250–4610	
51–100	630–1590	1590–4610	
<50	630–3040	3040–4610	
Routine HIV care costs on ART, stratified by CD4, range by age, monthly[c]			
>500 cells/μL	80–270	150–270	
351–500	120–560	300–560	
201–350	120–570	300–570	
101–200	670–1530	670–2260	
51–100	670–1530	1340–2260	
<50	670–1530	1220–2260	
ART, range by regimen, monthly	2630–2725	2630–2725	[39]

Abbreviations: ART, antiretroviral therapy; INSTI, integrase strand transfer inhibitor; NNRTI, non-nucleoside reverse transcriptase inhibitor; PI, protease inhibitor; SD, standard deviation.

[a]After the 6 months of *Interruption* and 12 months of *Telehealth*, the in-person loss to follow-up rate is applied to all individuals.

[b]HIV viral load <50 copies/mL at 48 weeks.

[c]Routine HIV care costs are calculated based on annual rates of outpatient visits, inpatient visits, and emergency room visits, stratified by age, ART use, and CD4 strata.

ART, all YHIV experience a monthly probability of subsequent virologic failure (range by adherence level: 0.30%–0.59%), resulting in regimen change upon detection [32]. Modeled YPHIV have fewer options for ART regimens after INSTI failure, since they may have previously been treated with older antiretroviral drugs (Supplementary Methods). Simulated individuals <25 years generally have poorer modeled medication adherence, higher rates of virologic failure, and higher rates of loss to follow-up than those >25 years, reflecting differences in adolescent vs adult data [41].

Table 2. Ten-year Model-projected Clinical and Cost Outcomes of a Model of COVID-related Care Interruptions at a Hypothetical Clinic of 100 Youth With HIV (Undiscounted)

	Total Life Months	Difference From Clinic	Additional HIV-related Deaths [a]	Total Costs Incurred, Million 2020 USD
Youth with non-perinatal HIV				
Clinic	11 348	Ref	Ref	24.4
Telehealth[b]	11 365	+17	0	24.7
Interruption[c]	11 226	−122	2	23.1
Youth with perinatal HIV				
Clinic	11 683	Ref	Ref	28.4
Telehealth[b]	11 678	−5	1	28.8
Interruption[c]	11 617	−66	1	28.2

Numbers may not sum due to rounding.

Abbreviation: USD, United States Dollars.

[a]Additional HIV-related deaths are projected based on how many of the 100 individuals alive at model start remain alive at year 10. Differences in total life months therefore arise not from additional deaths, but from deaths occurring at different time points of the 10-year modeled horizon.

[b]12 months of 3-monthly *Telehealth* visits without laboratory monitoring before returning to usual care. For YPHIV, we project fewer total life months in *Telehealth* compared with *Clinic*, while for YNPHIV we project higher total life months in *Telehealth* compared with *Clinic*. This difference is small and is due to HIV-related mortality inputs leading to a differential impact of missing detection of viremia (Supplementary Table 1).

[c]6-months without ART, visits or laboratory monitoring; 80% return to care at the end of the 6-month period.

Laboratory Monitoring and Care Engagement

In the base case, in the *Clinic* scenario, modeled YHIV receive in-person care, including visits with lab monitoring every 3 months. In the primary analyses, YHIV in the *Telehealth* scenario have telehealth visits every 3 months for 12 months, with no laboratory monitoring before returning to in-person care. There is no disruption to ART access in the *Clinic* or *Telehealth* scenarios. In the *Interruption* scenario, the clinic is closed for 6 months, during which time YHIV do not receive ART or laboratory monitoring. The model tracks true virologic status, regardless of whether it is observed through laboratory monitoring. Loss to follow-up is lower for *Telehealth* (13.1% compared with 19.7% for in-person care, annually [23, 24]). For those who are lost to follow-up, return to care (16.6%/year [23, 25]) is the same for *Clinic* and *Telehealth*. We assume that a lower proportion of the cohort would return to care following an interruption (~80%) than would remain in care in *Clinic* or *Telehealth* over the same 6-month time period (~90% and 94% [23, 26]).

HIV-related Costs

Routine HIV-related care costs were calculated based on rates of outpatient visits, emergency room visits, and inpatient days among YNPHIV and YPHIV in the HIV Research Network, and are stratified by age, ART use, and CD4 count [36]. Cost inputs are generally higher at older ages and lower CD4 counts. Higher monthly routine care costs for YPHIV compared with YNPHIV are driven by a higher rate of inpatient days per person-year (Table 1 [36]). ART costs are regimen-dependent [39]. Based on a time-driven activity-based costing study of in-person and telehealth visits during COVID-19, in-person clinic visits during the COVID-19 pandemic are modeled as being modestly more expensive than telehealth visits ($56 vs $49/visit; Table 1 [35]). This cost accounts for physician and staff labor only; it does not include costs such as technology licenses, facility fees, or travel.

Sensitivity Analyses and Additional Analyses

To understand the impact of different clinical scenarios, we varied the completion of lab testing, retention in care, and adherence to ART in the *Telehealth* scenario compared with *Clinic*. We also examined shorter *Interruption* scenarios with higher rates of return to care to understand the magnitude of difference in clinical impact compared with base case assumptions. Finally, we varied the routine HIV care costs by 0.5× and 2× base case values to better understand how total costs were impacted by these inputs.

RESULTS

Clinical Outcomes: Hypothetical Clinic of 100 YHIV Over 10 Years (Table 2)

Over the 10-year modeled time horizon for cohorts of 100 YHIV, *Clinic* and *Telehealth* led to similar projected LMs for YNPHIV (11 348 LMs and 11 365 LMs; +17 LMs with *Telehealth* compared with *Clinic*) and YPHIV (11 683 and 11 678 LMs; −5 LMs with *Telehealth* compared with *Clinic*). *Interruption* led to the lowest projected LMs: 11 226 LMs (−122 LMs compared with *Clinic*) for YNPHIV and 11 617 LMs (−66 LMs compared with *Clinic*) for YPHIV.

HIV Care Continuum Outcomes

One year after the start of the COVID-19-related care changes, for YNPHIV in or out of care, 58% of the cohort in *Clinic* were projected to remain virologically suppressed, compared with 54% in *Telehealth* and 48% in *Interruption* (Figure 1) which both lacked laboratory testing during the relevant timeframe. For YPHIV, 65% of the cohort in *Clinic* were projected to be suppressed at 1 year, compared with 54% in *Telehealth* and 48%

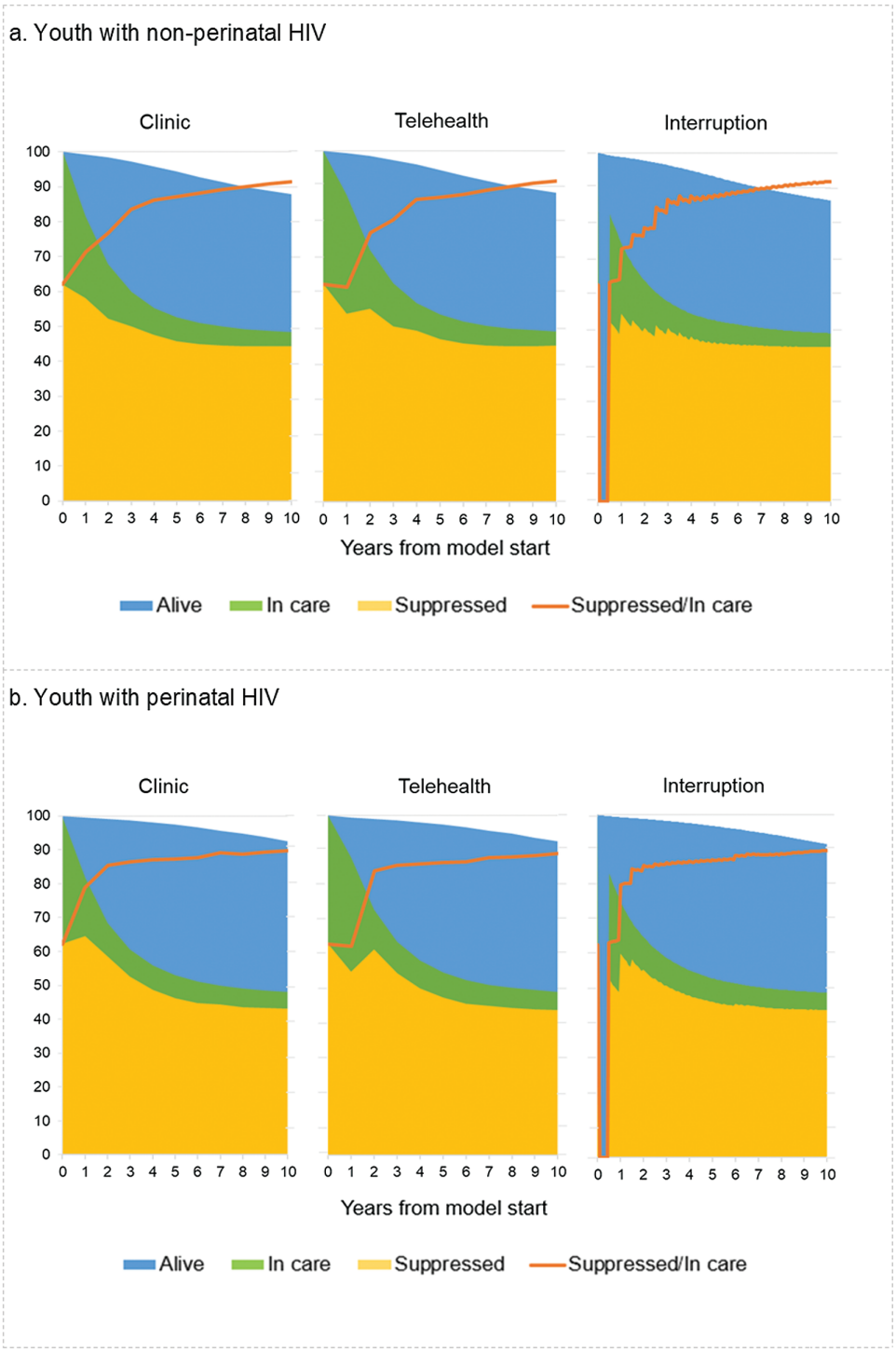

Figure 1. HIV care continuum outcomes of a model of COVID-related care changes. Each panel shows the proportion virologically suppressed, in care, and alive over time since model start among the hypothetical 100-person clinic cohort modeled. The line shows the proportion virologically suppressed among those in care over time. From left to right, the panels report results for the *Clinic*, *Telehealth,* and *Interruption* scenarios. In both cohorts (youth with non-perinatal HIV [a] and youth with perinatal HIV [b]), virologic suppression is initially decreased in the *Telehealth* scenario compared with the *Clinic* scenario, as individuals in the model miss CD4 and viral load testing for the first modeled year, so those with virologic failure miss the opportunity to detect and act on that failure. In the *Interruption* scenario, all modeled youth stop ART for a 6-month period, but on return, a substantial portion returning to care re-suppress on ART. Over 10 years, differences in care continuum outcomes between the strategies are small. Between the 2 cohorts, overall survival is similar but higher for youth with perinatal HIV compared with youth with non-perinatal HIV.

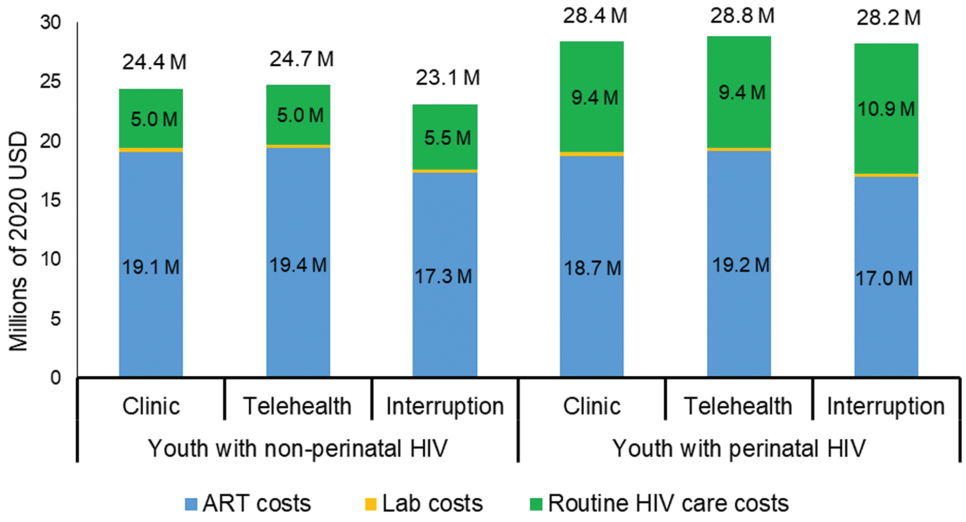

Figure 2. Total costs over 10 years, by cohort and scenario. Total costs over 10 years for 100 youth with HIV for each scenario: *Clinic, Telehealth*, and *Interruption*. Within each cohort (youth with non-perinatal HIV [left] and youth with perinatal HIV [right]), differences in costs between the scenarios are driven primarily by differences in ART costs, and to a lesser extent by differences in routine HIV care costs. Routine HIV care costs are calculated based on annual rates of outpatient visits, inpatient visits, and emergency room visits, stratified by age, ART use, and CD4 strata. Between the 2 cohorts, differences in costs are driven primarily by differences in routine HIV care costs, with youth with perinatal HIV incurring higher costs than youth with non-perinatal HIV. Costs in this figure may not add to the costs in Tables 2 and 3 due to rounding. Lab costs are $0.32 million for *Clinic*, $0.29 million for *Telehealth*, and $0.30 million for *Interruption* for both cohorts. ART, antiretroviral therapy; M, Million; USD, United States Dollars.

in *Interruption*. By 10 years after the start of the COVID-19-related care interruption, 44% of YNPHIV and 43% of YPHIV would be suppressed in all 3 scenarios.

HIV-related Costs Over 10 Years

Telehealth costs were somewhat higher than *Clinic*: for YNPHIV, projected costs were $24.4 million for *Clinic* and $24.7 million for *Telehealth*; for YPHIV, costs were $28.4 million for *Clinic* and $28.8 million for *Telehealth*. The additional costs in *Telehealth* were driven by higher retention in care leading to more individuals being prescribed ART (Figure 2: blue shading). *Interruption* resulted in lower projected costs compared with *Clinic* ($23.1 and $28.2 million for YNPHIV and YPHIV, respectively) due to the 6-month interruption of routine care and ART, and because only 80% of the modeled population returned to care when the clinic re-opened. Costs were higher for YPHIV compared with YNPHIV across scenarios, due primarily to higher routine HIV care costs.

Scenario/Sensitivity Analysis

We considered a scenario where YHIV missed only 1 CD4 and 1 HIV viral load test in *Telehealth* (instead of 3) to assess *Telehealth* clinical benefits if labs could be obtained: LMs were then 24 and 11 months greater and costs 1.1% and 0.5% greater for YNPHIV and YPHIV, respectively compared with *Clinic* (Table 3). We next considered a scenario where *Telehealth* improved not only retention in HIV care (as in the base case), but also ART adherence: when we doubled the odds of adherence in *Telehealth* compared with *Clinic*, LMs were then 68 and 31 months greater in YNPHIV and YPHIV, respectively, compared with *Clinic*, and costs were 0.9% and 1.3% lower, respectively. We also considered a scenario where *Telehealth* did not improve either retention or adherence compared with *Clinic*, to understand the potential clinical harms of a *Telehealth* scenario which differed from *Clinic* only in that lab tests were missed. In this scenario, LMs were then 14 and 22 months less and costs were decreased by 0.1% and increased by 1.2% for YNPHIV and YPHIV, respectively compared with *Clinic*. We also considered shorter duration *Interruption* scenarios with higher return to care: even with 90% of patients returning after a 3-month *Interruption*, LMs were then still lower, 57 and 29 months less, and costs lower by 1.9% and 0.1% for YNPHIV and YPHIV, respectively compared with *Clinic*. Finally, when routine HIV care costs were 0.5× the base case value, we projected total cost differences similar to that of the base case. However, when routine HIV care costs were 2.0× the base case value, the total cost of the *Interruption* scenario surpassed the total cost of *Clinic* for YPHIV because of higher care costs at lower CD4 counts (Supplementary Table 2).

DISCUSSION

Using an adolescent-focused HIV microsimulation model we projected the clinical impact and cost of COVID-19-related care changes for YHIV in the United States, including care interruptions and telehealth. We projected the impact of stopping ART and the risk that some YHIV may not promptly return to care and restart ART. While shorter interruptions were less

Table 3. Scenario Analyses of 10-year Model-projected Clinical and Cost Outcomes of a Model of COVID-related Care Interruptions (Undiscounted), Varying Parameters of Modeled Scenarios

	Life Months		Costs	
Scenario	Total	Change From *Clinic Base Case*[a]	Total, Million 2020 USD	Change From *Clinic Base Case, %*
Youth with non-perinatal HIV				
Clinic base case	*11 348*		*24.43*	
Telehealth base case	*11 365*	*+17*	*24.73*	*+1.2%*
Telehealth, 1 missed test (vs 3)	11 372	+24	24.71	+1.1%
Telehealth, 2× odds of adherence	11 416	+68	24.22	−0.9%
Telehealth, same retention as clinic	11 334	−14	24.41	−0.1%
Interruption base case	*11 226*	*−122*	*23.11*	*−5.4%*
3-month interruption, 90% return	11 291	−57	23.97	−1.9%
Youth with perinatal HIV				
Clinic base case	*11 683*		*28.43*	
Telehealth base case	*11 678*	*−5*	*28.81*	*+1.4%*
Telehealth, 1 missed test (vs 3)	11 694	+11	28.58	+0.5%
Telehealth, 2× odds of adherence	11 714	+31	28.07	-1.3%
Telehealth, same retention as clinic	11 661	−22	28.76	+1.2%
Interruption base case	*11 617*	*−66*	*28.21*	*−0.8%*
3-month interruption, 90% return	11 654	−29	28.40	−0.1%

Abbreviation: USD, United States Dollars.

Base case results are shown in italics.

[a]All results are a <1% change from the base case.

impactful than longer interruptions, even disruptions in clinic and ART access as short as 3 months could lead to additional deaths and time spent viremic. While few clinics nationwide experienced prolonged interruptions, some were forced to close completely in the early stages of the US COVID-19 pandemic and some patients did not or could not access care during that period even if their clinic remained open [2, 43, 44].

We projected that telehealth services mitigate the negative clinical outcomes of interruption scenarios by keeping YHIV engaged in care despite the absence of laboratory testing. We also found that telehealth led to similar clinical and cost outcomes as in-person clinic services, suggesting that telehealth may have benefits that apply even when there is no risk of care interruption. In both modeled cohorts, when YHIV experienced improved adherence to ART in the *Telehealth* scenario analyses, long-term outcomes improved relative to in-person care. This is consistent with previous studies of short-term adherence interventions [42], and is indicative of the potential short- and long-term benefits of telehealth for certain populations, including youth [40, 45]. Offering choice and hybrid approaches may be optimal for patients; while telehealth is ideal for some youth, for other YHIV who already struggle with engagement in care, a mandated switch to telehealth may make them feel deprioritized. Patient-provider relationships, which are particularly important for youth populations, may also be more difficult to foster via mobile platforms [2, 6].

As emergency policies related to telehealth reimbursement for COVID-19 expire, providers are concerned that they will not be reimbursed for these services [46]. Providers were permitted to practice across state lines via telehealth during the pandemic, but this allowance has expired; geographic limitations for telehealth providers may be particularly harmful for youth who are more likely to have temporary educational or job opportunities in other states [47]. Guidelines released by the Department of Health and Human Services and the Infectious Disease Society of America/HIV Medicine Association are generally supportive of telehealth but nonspecific about indications for telehealth use [13]. While this analysis projects short- and long-term benefits of telehealth that may apply to many YHIV, more data are needed to identify which populations may benefit most from these services and then how to design, prioritize, and offer these services. Low-income youth may struggle to make appointments due to a lack of internet connection or mobile data. While 96% of youth age 18–29 own a phone, only 77% of youth and 56% of those with incomes <$30 000/year subscribe to broadband internet and may have limited cellular data [46]. Youth, particularly those with unstable living situations, may also have difficulty finding private places for telehealth appointments. Conversely, telehealth appointments may give clinicians unique insights, providing information about factors at the patient's home and the environment that may impact an individual's health [6]. If telehealth improves retention by even a small amount compared with in-person care, it leads to similar health outcomes; if laboratory testing could be obtained, then telehealth may lead to better health outcomes than clinic care. A youth HIV clinic in Washington, DC that offered telehealth alongside rideshare services so that youth could complete laboratory testing offers a promising model for this care modality

[45]. If telehealth is not reimbursed equally to in-person visits, telehealth use may exacerbate existing health inequities; ensuring equitable access to a wide variety of care modalities should remain a priority for policymakers [9, 43].

We chose not to conduct a cost-effectiveness analysis given limited long-term telehealth use data and outcomes. In this analysis, however, the cost difference between *Telehealth* and *Clinic* was only $300–400 per patient per year; by comparison, the average monthly cost of ART is over $2600. Our analysis projects results based on a single simulation model; future studies are needed that explore the real-world clinical impact of telehealth and interruptions to care.

Future clinical studies and cost-effectiveness analyses of telehealth for HIV care should assess visit attendance, lab test completion, medication adherence, and virologic suppression. Additionally, understanding youth experiences with telehealth will be important to determine if there are additional quality-of-life considerations. Finally, enumerating the provider and patient costs associated with implementing and operating a hybrid telehealth and in-person clinic will be necessary to determine long-term cost-effectiveness.

This analysis has several limitations. First, while telehealth scale-up and outcomes following the implementation of lockdown measures have been described, clinic experiences and outcomes varied widely, and follow-up time is short to date [1, 2, 7–9, 40, 43, 45, 48]. Additionally, we had insufficient data to inform differences in the full panel of laboratory-based testing (such as testing for sexual transmitted infections, complete blood counts, and liver function tests) associated with in-person compared with telehealth visits and thus only modeled specific differences in routine CD4 and viral load tests between the clinical scenarios. Second, this analysis does not consider the impact of the pandemic on those diagnosed with HIV but not engaged in care. While previous modeling studies focused on HIV infections and testing [16–19], and ours considers youth engaged in HIV care, the experiences of youth and adults with HIV who were already out of care at the start of the COVID-19 pandemic have not been described. Finally, given the uncertainty of behaviors during the pandemic—some data suggest an increase in new HIV diagnoses, and other data suggest a decline [49]—this analysis did not consider the contribution of the viremia occurring among YHIV under each modeled strategy to onward HIV transmissions. Incorporating transmissions, and the clinical outcomes and costs of additional youth who newly acquire HIV as a result, would likely worsen both the clinical and economic impact of the modeled interruption scenarios.

In conclusion, clinic interruptions for YHIV may have substantial short- and long-term clinical and economic consequences, whether caused by the COVID-19 pandemic or other sources. In this model-based analysis, telehealth services led to improvements in clinical outcomes over clinic interruptions of any length and led to similar clinical and cost outcomes as in-person clinic services. Hybrid telehealth and in-person services, which offer patients choice, may lead to the best clinical outcomes for YHIV.

Supplementary Data

Supplementary materials are available at the *Journal of The Pediatric Infectious Diseases Society* online (http://jpids.oxfordjournals.org).

Notes

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Author Contributions

All authors contributed substantively to this manuscript in the following ways: study design (I. R. B., K. S., C. F. F., A. L. A., A. L. C., and A. M. N.), data analysis (I. R. B., C. F. F., and A. M. N.), interpretation of results (all authors), drafting the manuscript (I. R. B., C. F. F., and A. M. N.), critical revision of the manuscript (all authors), and final approval of submitted version (all authors).

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