# The potential epidemiological impact of COVID-19 on the HIV/AIDS epidemic and the cost-effectiveness of linked, opt-out HIV testing: A modeling study in six US cities

Xiao Zang, PhD[1], Emanuel Krebs, MA[2], Siyuan Chen, MSc[3], Micah Piske, MSc[2], Wendy S Armstrong, MD[4], Czarina N Behrends, PhD[5], Carlos Del Rio, MD[4], Daniel J Feaster, PhD[6], Brandon DL Marshall, PhD[1], Shruti H Mehta, PhD[7], Jonathan Mermin, MD[8], Lisa R Metsch, PhD[9], Bruce R Schackman, PhD[5], Steffanie A Strathdee, PhD[10], Bohdan Nosyk, PhD[2,3], **on behalf of the Localized HIV Modeling Study Group**

**1. Department of Epidemiology, School of Public Health, Brown University**
121 South Main St.,
Providence, RI
02903, USA

**2. British Columbia Centre for Excellence in HIV/AIDS**
608-1081 Burrard St.,
Vancouver, BC
V6Z 1Y6, Canada

**3. Faculty of Health Sciences, Simon Fraser University**
Blusson Hall, Room 11300
8888 University Dr.,
Burnaby, BC
V5A 1S6, Canada

**4. Division of Infectious Diseases, Department of Medicine, Emory University**
1518 Clifton Rd.,
Atlanta, GA
30322, USA

**5. Department of Healthcare Policy and Research, Weill Cornell Medical College**
402 East 67th St.,
New York, NY
10065, USA

**6. Department of Public Health Sciences, Leonard M Miller School of Medicine, University of Miami**
1120 NW 14th St., CRB 919
Miami, FL
33136, USA

**7. Department of Epidemiology, Bloomberg School of Public Health, Johns Hopkins**

**University**
615 N. Wolfe St.,
Baltimore, MD
21205, USA
**8. National Center for HIV/AIDS, Viral Hepatitis, STD, and TB Prevention, Centers for Disease Control and Prevention**
1600 Clifton Road,
Atlanta, GA
30329, USA
**9. Department of Sociomedical Sciences, Mailman School of Public Health, Columbia University**
722 West 168th St.,
New York, NY
10032, USA
**10. School of Medicine, University of California San Diego**
9500 Gilman Dr.,
La Jolla, CA
92093, USA

**Corresponding Author**:
Bohdan Nosyk, PhD
BC Centre for Excellence in HIV/AIDS
St. Paul's Hospital
613-1081 Burrard St.
Vancouver, BC, Canada V6Z 1Y6
E: bnosyk@cfenet.ubc.ca
T: 604-806-8649

**Research in context**

Evidence before this study:

The ongoing COVID-19 pandemic presents multifaced challenges to health providers in delivering HIV-related prevention and treatment services, as well as to people living with HIV (PLHIV). We searched the PubMed database for literature published up to June 15, 2020, with the terms ("HIV" [Title/Abstract]) AND ("COVID-19" OR "SARS-CoV-2" OR "coronaviruses" [Title/Abstract]) AND ("USA" OR "United States" OR "US"). We identified several observational studies and commentaries on how the COVID-19 pandemic has disrupted the HIV continuum of care and prevention. One survey study examined impacts of the disruptions caused by COVID-19 on sexual partnering and access to HIV prevention and treatment services among U.S. men who have sex with men. Another study conducted in Chicago, IL, also found declining HIV care engagement among PLHIV given the financial stressors and changes in healthcare delivery. However, none of the reviewed papers provided any direct evidence of the epidemiological impact of the COVID-19 pandemic on HIV incidence. In a recent editorial, we argued that SARS-CoV-2 testing and contact tracing may provide a unique opportunity to also conduct widespread opt-out (i.e. routine offer which the client may decline) HIV testing. The potential public health benefit and cost-effectiveness of this hypothetical strategy is not known.

Added value of this study:

Using a dynamic compartmental HIV transmission model calibrated for six US cities, this modeling study is the first, to our knowledge, to directly estimate the potential epidemiological impact of COVID-19 on the incidence of HIV under a range of possible levels of temporary service disruptions and behavioural changes due to COVID-19. We extend this analysis to determine the number of HIV infections that would be averted with the addition of linked opt-out HIV testing at various implementation levels and the cost-effectiveness of such a strategy, accounting for the effects of service disruptions and changes in risk behaviour. Despite requiring an up-front investment, implementing this one-time HIV testing campaign that is linked with SARS-CoV-2 testing would be cost-saving in the long term across all cities.

Implication of all the available evidence:

Linking HIV testing to SARS-CoV2 testing might reduce HIV incidence through linking individuals who test positive to HIV care and mitigate racial/ethnic disparities in HIV incidence and access to HIV treatment that have been highlighted and exacerbated by COVID-19 in the US. Although scarcity of healthcare resources, including labour force shortages, may present challenges, this strategy might have substantial public health benefits with relatively small incremental upfront investments.

## Abstract

**Background:** Widespread viral and serological testing for SARS-CoV-2 may present a unique opportunity to also test for HIV infection. We estimated the potential impact of adding linked, opt-out HIV testing alongside SARS-CoV-2 testing on HIV incidence and the cost-effectiveness of this strategy in six US cities.

**Methods:** We calibrated a dynamic compartmental HIV transmission model to match the epidemiological characteristics of six US cities (Atlanta, Baltimore, Los Angeles, Miami, New York City, Seattle). For each city, we constructed three sets of scenarios: (1) sustained current levels of HIV-related treatment and prevention services (status quo); (2) temporary disruptions in health services and changes in sexual and injection risk behaviours at discrete levels between 0%-50%; and (3) linked HIV and SARS-CoV-2 testing offered to 10%-90% of the adult population in addition to scenario (2). We estimated cumulative HIV infections between 2020-2025, as well as incremental costs, quality-adjusted life years, and incremental cost-effectiveness ratios of linked HIV testing over 20 years.

**Findings:** In the absence of linked, opt-out HIV testing, we estimated a best-case scenario (50% reduction in risk behaviours and no service disruptions) of 6,733 fewer HIV infections between 2020-2025 (16.5% decrease), and a worst-case scenario (no behavioural change and 50% reduction in service access) of 3,669 additional HIV infections (9.0% increase) across cities. If HIV testing could be offered to 10%-90% of the adult population, we estimated that a total of 576-7,225 (1.6%-17.2%) new infections could be averted. The intervention would require an initial investment of $20M-$218M across cities; however, the intervention would ultimately result in savings in health care costs in each city.

**Interpretation:** Although COVID-19-related disruptions in HIV-related services may increase or decrease HIV incidence, a campaign in which HIV testing is linked with SARS-CoV-2 testing could substantially reduce HIV incidence and reduce direct and indirect health care costs attributable to HIV.


**Funding:** US NIH-NIDA Grant No. R01-DA041747

## Introduction

The COVID-19 global pandemic is placing an increased burden on the health care system while creating widespread challenges and disrupting the delivery of routine medical services. In major urban centers of the United States, COVID-19 might exacerbate the burden of HIV in disproportionately affected populations with existing health challenges, especially Black and Latinx Americans.[1, 2] The reported reductions in access to health services due to the COVID-19 pandemic such as routine HIV testing, initiation or continuation of antiretroviral therapy (ART) for people living with HIV (PLHIV), pre-exposure prophylaxis (PrEP) for men who have sex with men at high-risk of HIV infection, medications, and harm reduction services for people who inject drugs (PWID)[3-7] may prompt increases in HIV transmissions, further challenging national efforts toward the 'Ending the HIV Epidemic' goals.[8]

At present, there is limited evidence on the clinical relationship between SARS-CoV-2 and HIV. Several studies have suggested no increased risk of COVID-19 disease among those stably engaged in HIV care.[9-14] Furthermore, COVID-19 physical distancing recommendations may also decrease sexual and drug injection risk behaviour, thus reducing the risk of HIV transmission.[6] However, if hospitals and clinics reach their capacity, disadvantaged populations such as PWID may experience even greater barriers to medical care for COVID-19.[15] Self-quarantine, physical distancing and other public health measures, the economic repercussions of the epidemic, and mental distress have disrupted access to syringe services programs, access to pharmacotherapies including medication for opioid use disorder (MOUD), and other support needed by people with opioid use disorder (OUD),[16] potentially putting this already disproportionately affected population at higher risk for HIV infection and drug overdose mortality. Likewise, disruptions in social services such as housing, food, and social counselling could complicate risk behaviour management and medical care provision for all PLHIV.

In a recent editorial, we argued for opt-out HIV testing to be linked to SARS-CoV2 testing and contact tracing efforts that have been proposed as a central component of a COVID-19 public health strategy in the United States.[17] Although recommendations from the US CDC and the US Preventive Services Task Force currently recommend opt-out HIV testing for adults in all healthcare settings[18, 19] to assist with reaching the goal of universal one-time testing of adults, population-level testing remains low;[20, 21] and even before the COVID-19 pandemic began, an estimated 14% of PLHIV in the US had undiagnosed HIV.[22] With evidence that HIV testing interventions are often cost-saving,[23-27] increasing HIV testing has been shown to provide great value on its own. Pairing SARS-CoV-2 viral and serological testing with testing for HIV (and potentially other sexually transmitted and blood-borne infections like hepatitis C virus) not only has the potential to provide profound health benefits, but may in part offset the immense costs of such an approach in the long-term.

We aimed to estimate the potential impact of widespread, linked, opt-out HIV testing combined with SARS-CoV2 testing on the HIV/AIDS epidemics in six US cities, as well as the cost-effectiveness of such a strategy, accounting for a variety of hypothesized effects of COVID-19 on HIV risk behaviours and access to HIV treatment and prevention services.

## Methods

*Model description*

We used a dynamic, deterministic compartmental HIV transmission model to replicate the city-level HIV microepidemics in Atlanta, Baltimore, Los Angeles, Miami (Dade County), New York City, and Seattle (King County). A detailed account of the underlying evidence synthesis, calibration, and validation are available in prior publications.[28, 29]

The model tracked HIV-susceptible individuals through infection, diagnosis, treatment with ART, and ART dropout. In each city, the adult population (aged 15-64 years) was grouped by biological sex (male, female), HIV transmission risk group (MSM, PWID, MSM-PWID, and heterosexual persons), race/ethnicity (Black/African American [Black], Hispanic/Latinx [Hispanic], and non-Hispanic White/others [White]), and sexual risk behaviour level (high-risk vs. low-risk). The model captured heterogeneity in the risk of HIV transmission, aging (via differential maturation and mortality rates for PLHIV and the general population across cities), and observed racial/ethnic disparities in access to health and prevention services, including HIV testing, ART, syringe service programs (SSP), MOUD, and targeted PrEP for high-risk MSM.

Racial/ethnic- and risk-behaviour-specific linkages to HIV care and use of PrEP, SSP, and MOUD were drawn from local, state and national surveillance sources.[28] We estimated stratified, regional ART initiation and persistence rates through separate analysis of HIV Research Network data.[30] In the absence of comprehensive city-level HIV testing data,[28] we back-calculated HIV testing rates from high quality race/ethnicity- and risk behaviour-specific surveillance data for new diagnoses published by local public health departments.[29] We accounted for in-migration of PLHIV and overall population growth, also stratified by race/ethnicity.[28]

*Hypothetical scenarios on changes in risk behaviours and reductions in access to services*

We estimated the potential impact of the COVID-19 pandemic on number of HIV infections in comparison to the status quo scenario for each city between 2020-2025. The status quo scenario was defined as maintaining all access to care constant at 2015 levels, with PrEP at 2017 levels and no changes to sexual or injection risk behaviours over time.[31]

In alternative scenarios, we assessed a range of possible health service disruptions levels due to COVID-19, defined as 0%, 25%, and 50% reductions in access to all forms of HIV care, treatment and prevention services, including HIV testing, ART initiation, ART engagement, PrEP uptake, SSP, and MOUD.[7] We also considered possible reductions of 0%, 25% and 50% in the number of sexual partners and the number of shared injections due to physical distancing recommendations, and estimated the potential impact of all combinations of these discrete levels of health service disruption and change in risk behaviours. These conditions were assumed for a 12-month period from March 1st 2020 to February 28th 2021, with conditions returning to pre-COVID-19 levels thereafter. These timeframes were chosen with the assumption that an effective vaccine will be developed and ready for use in early 2021.

*Linked HIV and SARS-CoV-2 testing*

We also estimated the preventive benefits of linked opt-out HIV testing compared with the aforementioned COVID-19 scenario with possible disrupted health services and changes in sexual and injection risk behaviours. We assumed that the SARS-CoV-2 testing would be offered to 10%, 25%, 50%, 75%, and 90% of the adult population in each city between June 1st and February 28th 2021, and that of those, 65.9% would accept opt-out HIV testing, consistent with acceptance rates reported in a randomized clinical trial set in the emergency department of an urban teaching hospital and regional trauma center.[32]

To maximize its potential reach, we assumed linked HIV testing could be offered alongside viral, antigen, or antibody testing for SARS-CoV-2, using oral swab or fingerstick point-of-care HIV testing, oral specimen or dried blood spot sample collection for remote laboratory testing, or phlebotomy for serological laboratory testing. We applied the costs of the highest-cost testing technology (oral swab point-of-care test: $17.63 for a non-reactive test, and $102.16 for a reactive test [**Appendix Tables A1-A3**]) to generate a conservative estimate for the cost-effectiveness of the strategy. The HIV testing cost included personnel time and material costs using fourth-generation HIV assays and equipment.[33] These costs were adapted from the estimated costs for HIV testing in emergency department settings.[34] We assumed reactive results would be reported to public health authorities for follow-up, and we did not include the cost of these follow-up activities.

*Cost-effectiveness analysis*

Model-projected outcomes included quality-adjusted life-years (QALYs), total costs (in 2018 US$), and new HIV infections. We described and compared the cumulative number of HIV infections for each city between 2020 and 2025, matching the timeframe for the first target of the US' Ending the HIV/AIDS Epidemic's strategy, and the cost-effectiveness analysis considered outcomes until 2040 to capture long-term individual health benefits (i.e. delayed morbidity, mortality due to ART engagement) and second-order transmission effects. We estimated incremental cost-effectiveness ratios (ICERs) as the incremental cost per QALY gained for the widespread HIV testing efforts compared with the hypothesized COVID-19 impact scenarios. Costs included those for HIV testing, ART, PrEP, and MOUD, other medical costs, and SSP costs.

In accordance with best practice guidelines of the Second Panel on Cost-Effectiveness in Health and Medicine, the cost-effectiveness analysis was conducted from the health-care sector perspective, including government, employer-paid, and out-of-pocket health-care expenditures. Both costs and QALYs were reported with a 3% annual discount rate.[35]

*Role of the funding source*

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

## Results

Compared to the status quo of holding service levels constant, we estimated that the best-case hypothetical scenario of 50% reductions in sexual and drug injection risk behaviours and no disruptions in health service provision due to the onset of COVID-19 could result in a total of 6,733 fewer HIV infections between 2020-2025 for all six cities, a 16.5% decrease in cumulative incidence. Across cities, the relative reductions for this hypothesized scenario range from 14.3% in Los Angeles (1,683 fewer infections) to 20.4% in Miami (2,383 fewer infections) (**Figure 1, Appendix Table A4**).

In contrast, the worst-case scenario of no behavioural change and 50% reductions in health service provision could lead to a total of 3,669 additional HIV infections between 2020-2025 for all six cities, a 9.0% increase in cumulative incidence compared to the status quo. The relative increases ranged from 7.0% in Miami (821 more infections) to 15.7% in New York City (945 more infections). Similarly, we estimated relative increases in HIV infections in all cities resulting from no behavioural change and 25% health service reduction, ranging from 3.4% in Atlanta to 7.5% in New York City. Comparing the change in HIV infections in the face of both behavioural change and health service reduction due to COVID-19, we found the results were relatively more sensitive to changes in HIV risk behaviours than disruptions in HIV-related services (**Figure 1, Appendix Table A4**).

We estimated that linked, opt-out HIV testing alongside SARS-CoV2 testing and contact tracing could reduce HIV infections between 2020-2025 in all six cities, ranging from 576-696 (1.6%-1.7%) fewer infections with 10% offered HIV testing (16.5% accepting a test), up to 5,840-7,225 (16.3%-17.2%) fewer infections with 90% offered testing (59.3% accepting a test) (**Figure 2, Appendix Table A4**).

At the city level, the smallest relative reduction in cumulative infections from linked opt-out testing would be 1.0-1.2% (52-83 fewer infections) in New York City with 10% offered an HIV test, and the largest reduction would be 25.9%-28.9% (609-719 fewer infections) in Baltimore with 90% offered an HIV test. The relative reduction in HIV infections due to linked HIV testing was greatest compared to the best-case scenario (50% reduction in risk behaviours and no health service reduction) at all levels of testing intervention in Atlanta, Baltimore, and Miami, while Los Angeles and New York City benefitted most compared to the worst-case scenario (no behavioural change and 50% health service reduction). In terms of the range for the absolute number of infections averted by the testing efforts, 10% testing would result in 19-23 (2.3%-2.4%) fewer infections in Seattle at various levels of behavioural change and service reduction, while the impact of 90% testing in Los Angeles would result in 1,601-2,070 (15.8%-16.1%) fewer infections (**Figure 2, Appendix Table A4**).

The linked opt-out HIV testing was estimated to produce gains of between 136-157 QALYs in Seattle with 10% offered an HIV test and up to 9,154-11,513 QALYs in Los Angeles with 90% offered an HIV test. At an estimated up-front cost ranging from $1.4M-$14.8M in Seattle to $6.7M-$70.2M in Los Angeles (with 10%-90% offered HIV tests), in addition to SARS-CoV2 testing costs alone, we found the linked opt-out HIV testing strategies were likely to be cost-saving over a period of 20 years for all cities at all testing levels compared to any comparator scenario for changes in risk behaviours and service access (**Appendix Table A5**).

## Discussion

This study demonstrated that, in six US cities, if the COVID-19 pandemic adversely impacts HIV health service provision, increased numbers of HIV infections will likely occur, even if HIV risk behaviors decline temporarily due to physical distancing recommendations. Furthermore, implementing linked HIV testing alongside SARS-CoV-2 testing has the potential to reduce the number of HIV infections by up to 17% over 5 years if 90% are offered HIV tests across all cities. In addition, offering HIV testing with a SARS-CoV-2 vaccine, rather than with SARS-CoV-2 testing (which could be implemented sooner because of the current lack of a vaccine), could be equally effective. This HIV testing strategy would require a $20M-$218M incremental upfront investment but would be cost-saving in the long term across all cities.

HIV testing has long been found to be an effective and cost-effective intervention in preventing HIV transmissions and linking more PLHIV to HIV treatment.[36] Given its low unit cost, our estimated cost-effectiveness for this proposed HIV testing intervention is consistent with our previous analysis[23] and other prior studies.[37] Population-level SARS-CoV-2 viral and serological testing may provide a unique opportunity to conduct HIV testing, among other health promotion activities. Our analysis shows that this HIV testing strategy averted a relatively greater percentage of HIV infections in Atlanta (which has low estimated HIV testing rates), Seattle, and Baltimore (cities with higher levels of HIV treatment engagement). This finding demonstrates the potential to enhance existing testing programs and the importance of subsequent HIV care and treatment services to maximize the benefits after individuals receive a diagnosis.

The US CDC conducted over 3 million HIV tests annually, many as part of the 'Expanded Testing Initiative',[38] and CDC-supported testing programs are associated with about one third of all HIV diagnoses in the nation annually.[39] Assembling and organizing the labor force to address COVID-19 has taken an all-encompassing effort in the six participating cities, but limited additional training is required to include an offer for an HIV test.[34] Offering linked HIV testing may add relatively little time to each contact, but implementation of HIV testing in practice may depend on local public health initiatives. For instance, sample collection with a self-administered oral swab would allow physical distancing, similar to how SARS-CoV-2 viral testing is currently being conducted, and point-of-care HIV testing would provide immediate results (albeit with slightly lower sensitivity) that may better facilitate subsequent linkage to care. Point-of-care HIV testing could also be delivered with a fingerstick, which would require interactions with public health personnel. While phlebotomy sample collection for HIV testing alongside serological SARS-CoV-2 testing would involve direct contact with patients and specimen handling, this option would allow for the inclusion of other testing initiatives that may provide great public health benefits (e.g., HCV, HbA1c); however, laboratory and personnel capacity for follow-up would need to be confirmed, as these inputs are likely to compete with resources needed for SARS-CoV2 testing, case investigation, and contact tracing efforts. Specific combination implementation strategies may therefore differ according to context, available resources and the needs of the communities served; we have only considered one such strategy in this analysis. Finally, whether linked HIV testing - offered alone or in combination with other health promotion activities - would reduce SARS-CoV-2 test acceptance rates is also unknown and would require meaningful engagement with public health personnel and the community throughout the process.

If these obstacles can be overcome, implementing widespread HIV testing in the SARS-CoV-2 testing and vaccine response can help address the disproportionate impact of COVID-19 and HIV on racial and ethnic minority and other disproportionately affected populations. A recent analysis documented that counties where the majority of residents were Black experienced three times the COVID-19 infection rate and nearly six times the death rate seen in counties where the majority of residents were White.[40] Driven by long-standing systemic health and social inequities, including the direct and downstream effects of systemic racism, lack of public health and economic investment in minority communities, and mass incarceration, similar racial/ethnic disparities are observed in HIV disease burden in the United States.[41, 42] We recently concluded that even with tailored HIV treatment and prevention strategies implemented at ideal levels for each city, racial/ethnic disparities in HIV incidence will persist without addressing existing inequities in access to healthcare.[43] Incorporating HIV testing and linkage to care within SARS-CoV-2 viral and serological testing, when done responsibly and with input from the most affected communities, could be a promising approach to addressing these overlapping racial/ethnic health disparities in the United States.

This study features several limitations in the structure of the model and the underlying evidence base that we have described in prior publications.[23, 28, 29, 31] In addition, specific to this analysis, the potential duration of the COVID-19 pandemic is unknown, and there is limited evidence of its impact on the PLHIV population and level of HIV health service interruption in the US. If the level of disruption in services is higher and lasts longer and/or the uptake of HIV testing does not achieve the ambitious levels we have proposed, the estimated additional number of HIV cases that could occur would be even greater. Second, in the cost-effectiveness analysis, we only captured the increased cost of providing more HIV tests and subsequent treatment, and did not consider additional costs that might be associated with implementing the linked HIV testing intervention, such as potential costs for training personnel and other public health expenses for linkage to care. In addition, many HIV and STD-focused staff in health departments have been reassigned to support the COVID-19 response, and there may be limited human resources to add HIV testing. However, we assumed the upper bound of possible incremental cost for linked HIV testing, so our results are likely to be conservative, potentially offsetting some of the additional costs and logistical obstacles. Furthermore, our results showed that the intervention was found to be cost-saving across all cities and analyzed scenarios, further emphasizing its public health value. Third, at present there are limited data on how the COVID-19 pandemic has affected risk behaviours and delivery of HIV-related services to parameterize our model. To address this, we simulated a range of possible levels of service disruptions and behavioural changes to better capture the potential epidemiological impact of COVID-19 and benefits of adding the linked HIV testing. Given the inherent uncertainty and exploratory nature of our results, we chose not to conduct further deterministic or probabilistic sensitivity analyses.

Securing funding and ensuring successful implementation of SARS-CoV-2 testing are key hurdles to cross; however, linking HIV testing to SARS-CoV-2 viral and serological testing efforts could substantially reduce HIV incidence and the upfront costs of doing so would be offset over the long-term. Furthermore, the linkage in testing would provide an opportunity for the US to remain focused on its ambitious plan to end the HIV epidemic by 2030 and address racial/ethnic disparities in HIV incidence at a time when HIV prevention and treatment services have been disrupted.

## *Acknowledgments*

This study was funded by the National Institutes on Drug Abuse (NIDA grant no. R01DA041747). The findings and conclusions in this report are those of the authors and do not necessarily represent the official position of the Centers for Disease Control and Prevention.


## *Contributors*

XZ and BN conceptualized the study. XZ, EK and MP wrote the first draft of the article. EK, XZ, MP and SC assisted with analyses and contributed to manuscript development. WSA, CNB, CDR, DJF, BDLM, SHM, JM, LRM, BRS, SAS and BN aided in the interpretation of results and provided critical revisions to the manuscript. BN secured funding for the study. All authors approved the final draft.

## *Declaration of interests*

XZ, EK, SC, MP, WSA, CNB, CDR, DJF, BDLM, SHM, JM, LRM, BRS, SAS and BN declare no competing interests.

## *The Localized HIV Modeling Study Group is composed of*


Czarina N Behrends, PhD, Department of Healthcare Policy and Research, Weill Cornell Medical College

Carlos Del Rio, MD, Hubert Department of Global Health, Emory Center for AIDS Research, Rollins School of Public Health, Emory University

Julia C Dombrowski, MD, Department of Medicine, Division of Allergy & Infectious Disease, adjunct in Epidemiology, University of Washington and Deputy Director, HIV/STD Program, Public Health – Seattle & King County

Daniel J Feaster, PhD, Department of Public Health Sciences, Leonard M. Miller School of Medicine, University of Miami

Kelly A Gebo, MD, Bloomberg School of Public Health, Johns Hopkins University

Matthew Golden, MD, primary with Department of Medicine, Division of Allergy & Infectious Disease, University of Washington. Director, HIV/STD Program, Public Health – Seattle & King County.

Gregory Kirk, MD, Bloomberg School of Public Health, Johns Hopkins University

Brandon DL Marshall, PhD, Department of Epidemiology, Brown School of Public Health, Rhode Island, United States

Shruti H Mehta, PhD, Bloomberg School of Public Health, Johns Hopkins University

Lisa R Metsch, PhD, Department of Sociomedical Sciences, Mailman School of Public Health, Columbia University

Julio Montaner, MD, BC Centre for Excellence in HIV/AIDS; Faculty of Medicine, University of British Columbia

Bohdan Nosyk, PhD, BC Centre for Excellence in HIV/AIDS; Faculty of Health Sciences, Simon Fraser University

Ankur Pandya, PhD, T.H. Chan School of Public Health, Harvard University

Bruce R Schackman, PhD, Department of Healthcare Policy and Research, Weill Cornell Medical College

Steven Shoptaw, PhD, Centre for HIV Identification, Prevention and Treatment Services, School of Medicine, University of California Los Angeles

Steffanie A Strathdee, PhD, School of Medicine, University of California San Diego

**Figure 1. Potential impact of COVID-19-related disruptions in HIV services and changes in risk behaviour on cumulative HIV infections between 2020-2025 in six US cities**

**Figure 2. Impact of linked opt-out HIV testing alongside SARS-CoV2 testing on averting HIV infections between 2020 and 2025 in six US cities**

# References

1. Shiau S, Krause KD, Valera P, Swaminathan S, Halkitis PN. The Burden of COVID-19 in People Living with HIV: A Syndemic Perspective. (AIDS Behav. 2020 Apr 18: 1–6. 1573-3254.).
2. Kim S, Bostwick W. Social Vulnerability and Racial Inequality in COVID-19 Deaths in Chicago. *Health Education & Behavior: the Official Publication of the Society for Public Health Education* 2020: 1090198120929677-.
3. Jiang H, Zhou Y, Tang W. Maintaining HIV care during the COVID-19 pandemic. *The Lancet HIV* 2020.
4. The Lancet HIV. When pandemics collide. *The Lancet HIV* 2020.
5. 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 and behavior* 2020: 1-4.
6. Sanchez TH, Zlotorzynska M, Rai M, Baral SD. Characterizing the Impact of COVID-19 on men who have sex with men across the United States in April, 2020. *AIDS and Behavior* 2020: 1.
7. Glick SN, Prohaska SM, LaKosky PA, Juarez AM, Corcorran MA, Des Jarlais DC. The Impact of COVID-19 on Syringe Services Programs in the United States. *AIDS and Behavior* 2020.
8. Fauci AS, Redfield RR, Sigounas G, Weahkee MD, Giroir BP. Ending the HIV epidemic: a plan for the United States. *Jama* 2019; **321**(9): 844-5.
9. Haerter G, Spinner CD, Roider J, et al. COVID-19 in people living with human immunodeficiency virus: a case series of 33 patients. *Infection* 2020: 1.
10. Suwanwongse K, Shabarek N. Clinical features and outcome of HIV/SARS-CoV-2 co-infected patients in the Bronx, New York City. *Journal of Medical Virology* 2020.
11. Vizcarra P, Pérez-Elías MJ, Quereda C, et al. Description of COVID-19 in HIV-infected individuals: a single-centre, prospective cohort. *The Lancet HIV* 2020.
12. Blanco JL, Ambrosioni J, Garcia F, et al. COVID-19 in patients with HIV: clinical case series. *The Lancet HIV* 2020; **7**(5): e314-e6.
13. Gervasoni C, Meraviglia P, Riva A, et al. Clinical features and outcomes of HIV patients with coronavirus disease 2019. *Clinical Infectious Diseases* 2020.
14. Shalev N, Scherer M, LaSota ED, et al. Clinical characteristics and outcomes in people living with HIV hospitalized for COVID-19. *Clinical Infectious Diseases* 2020.
15. Volkow ND. Collision of the COVID-19 and Addiction Epidemics. *Annals of Internal Medicine* 2020.
16. Chang J, Agliata J, Guarinieri M. COVID-19-Enacting a 'new normal'for people who use drugs. *International Journal of Drug Policy* 2020: 102832.
17. Nosyk B, Armstrong WS, del Rio C. Contact tracing for COVID-19: An opportunity to reduce health disparities and End the HIV/AIDS Epidemic in the US. *Clinical Infectious Diseases* 2020.
18. Branson BM, Handsfield HH, Lampe MA, et al. Revised recommendations for HIV testing of adults, adolescents, and pregnant women in health-care settings. *Morbidity and Mortality Weekly Report: Recommendations and Reports* 2006; **55**(14): 1-CE-4.
19. Moyer VA. Screening for HIV: US preventive services task force recommendation statement. *Annals of internal medicine* 2013; **159**(1): 51-60.
20. Dietz PM, Van Handel M, Wang H, et al. HIV testing among outpatients with Medicaid and commercial insurance. *PloS one* 2015; **10**(12): e0144965.

21. Rui P, Kang K. National Hospital Ambulatory Medical Care Survey: Emergency Department Summary Tables. US Department of Health and Human Services, National Center for Health …; 2015.

22. Centers for Disease Control and Prevention. Estimated HIV incidence and prevalence in the United States, 2014–2018. HIV Surveillance Supplemental Report 2020.; 2020.

23. Krebs E, Zang X, Enns B, et al. The impact of localized implementation: determining the cost-effectiveness of HIV prevention and care interventions across six U.S. cities. *AIDS* 2020; **34**(3): 447-58.

24. Sanders GD, Bayoumi AM, Sundaram V, et al. Cost-effectiveness of screening for HIV in the era of highly active antiretroviral therapy. *New England Journal of Medicine* 2005; **352**(6): 570-85.

25. Paltiel AD, Weinstein MC, Kimmel AD, et al. Expanded screening for HIV in the United States—an analysis of cost-effectiveness. *New England Journal of Medicine* 2005; **352**(6): 586-95.

26. Lasry A, Sansom SL, Hicks KA, Uzunangelov V. Allocating HIV prevention funds in the United States: recommendations from an optimization model. *PloS one* 2012; **7**(6): e37545.

27. Hutchinson AB, Farnham PG, Sansom SL, Yaylali E, Mermin JH. Cost-effectiveness of frequent HIV testing of high-risk populations in the United States. *Journal of acquired immune deficiency syndromes (1999)* 2016; **71**(3): 323.

28. Krebs E, Enns B, Wang L, et al. Developing a dynamic HIV transmission model for 6 U.S. cities: An evidence synthesis. *PLOS ONE* 2019; **14**(5): e0217559.

29. Zang X, Jalal H, Krebs E, et al. Prioritizing additional data collection to reduce decision uncertainty in the HIV/AIDS response in 6 US cities: a value of information analysis. *Value in Health* 2020; **R&R**.

30. Wang L, Krebs E, Min JE, et al. Combined estimation of disease progression and retention on antiretroviral therapy among treated individuals with HIV in the USA: a modelling study. *The Lancet HIV* 2019; **6**(8): e531-e9.

31. Nosyk B, Zang X, Krebs E, et al. Ending the Epidemic in America Will Not Happen if the Status Quo Continues: Modeled Projections for Human Immunodeficiency Virus Incidence in 6 US Cities. *Clin Infect Dis* 2019; **69**(12): 2195-8.

32. Montoy JCC, Dow WH, Kaplan BC. Patient choice in opt-in, active choice, and opt-out HIV screening: randomized clinical trial. *bmj* 2016; **352**: h6895.

33. Branson BM, Michele OS, Wesolowski LG, et al. Laboratory testing for the diagnosis of HIV infection: updated recommendations. *Centers for Disease Control and Prevention* 2014.

34. Schackman BR, Eggman AA, Leff JA, et al. Costs of Expanded Rapid HIV Testing in Four Emergency Departments. *Public Health Rep* 2016; **1**: 71-81.

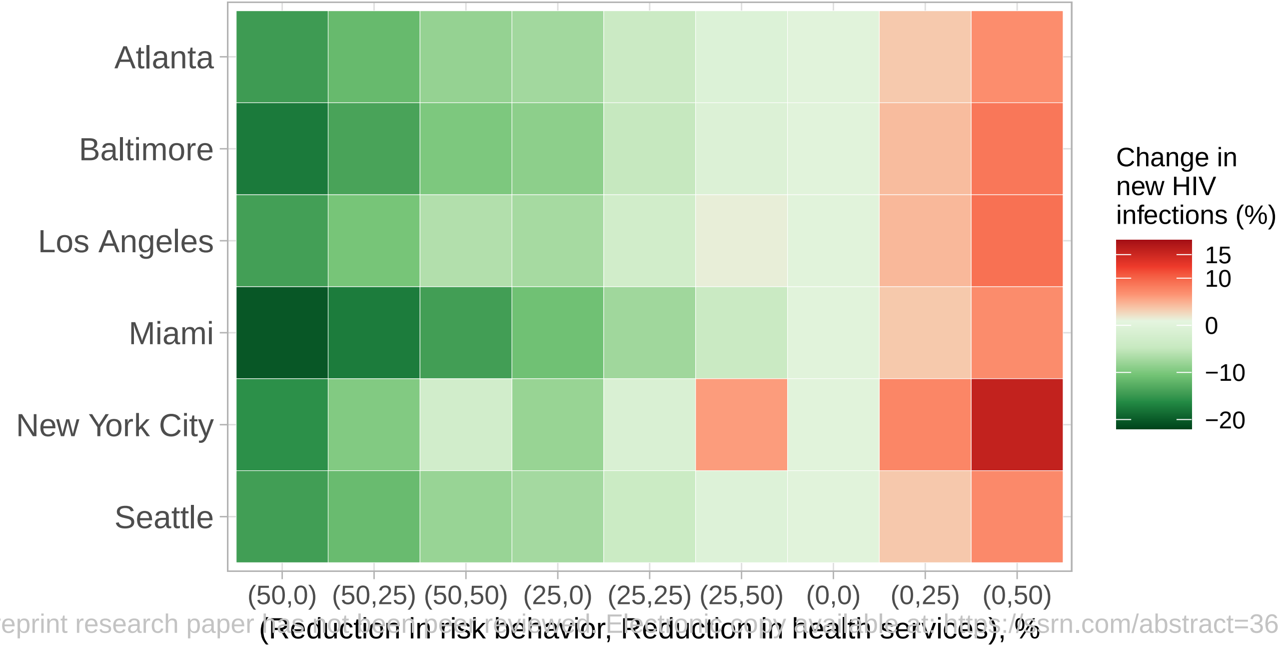
35. Sanders GD, Neumann PJ, Basu A, et al. Recommendations for conduct, methodological practices, and reporting of cost-effectiveness analyses: Second Panel on Cost-Effectiveness in Health and Medicine. *Jama* 2016; **316**(10): 1093.

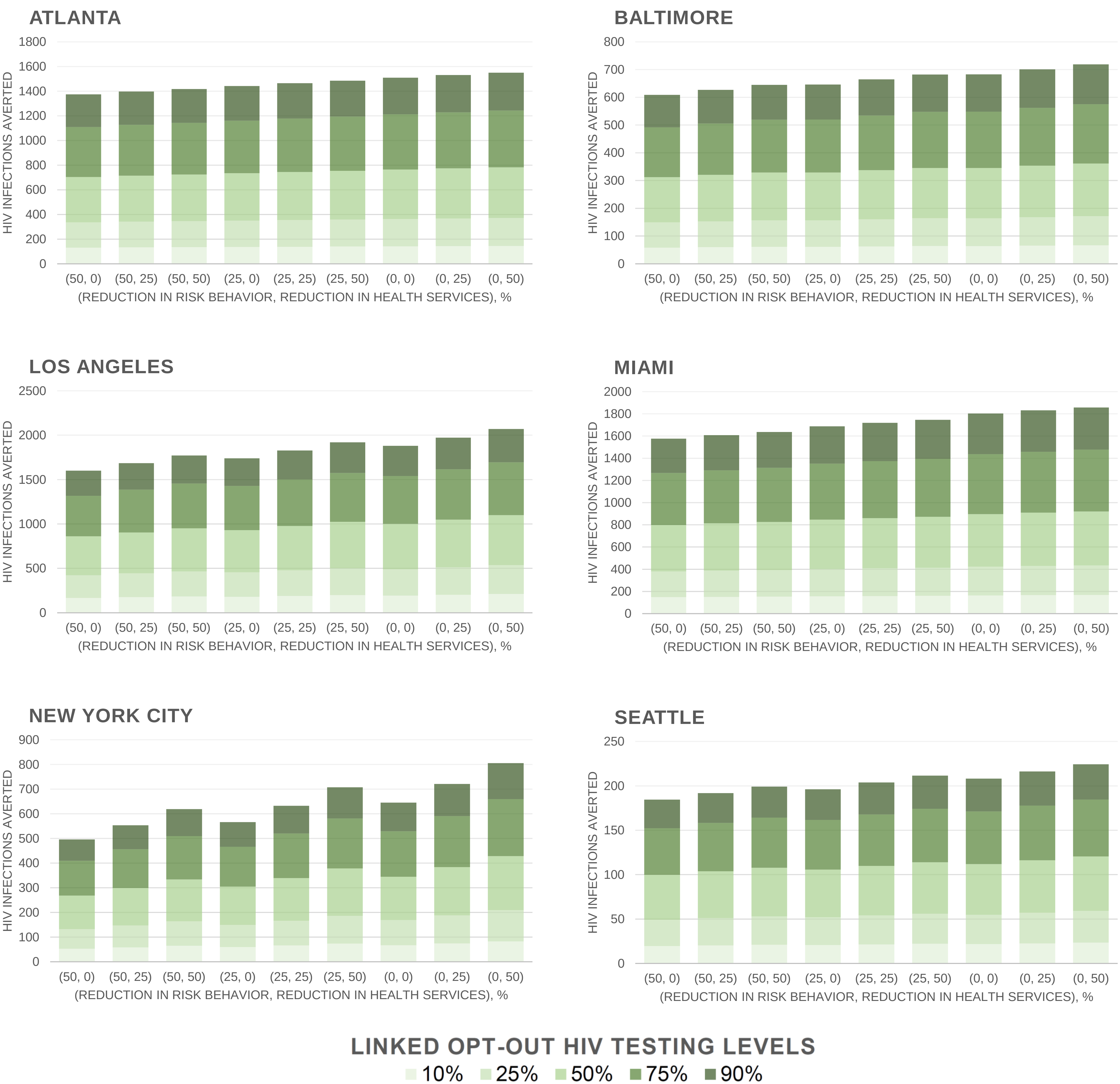
36. Walensky RP, Freedberg KA, Weinstein MC, Paltiel AD. Cost-effectiveness of HIV testing and treatment in the United States. *Clin Infect Dis* 2007; **45 Suppl 4**: S248-54.

37. Li XC, Kusi L, Marak T, Bertrand T, Chan PA, Galárraga O. The cost and cost-utility of three public health HIV case-finding strategies: evidence from Rhode Island, 2012–2014. *AIDS and behavior* 2018; **22**(11): 3726-33.

38. Centers for Disease Control and Prevention. CDC: Preventing New Infections. CDC is America's lead agency in the fight to prevent new HIV infections. https://www.cdc.gov/nchhstp/budget/infographics/preventing-new-hiv.html.

39. Centers for Disease Control and Prevention. More people with HIV have the virus under control. 2017. https://www.cdc.gov/nchhstp/newsroom/2017/2017-HIV-Continuum-Press-Release.html (accessed April 25 2020).
40. Thebault R, Williams V, Ba Tran A. The coronavirus is infecting and killing black Americans
at an alarmingly high rate. Washington Post 2020 Apr 7. https://www.washingtonpost.com/nation/2020/04/07/coronavirus-is-infecting-killing-black-americans-an-alarminglyhigh-rate-post-analysis-shows.
41. Chowkwanyun M, Reed Jr AL. Racial health disparities and Covid-19—caution and context. *New England Journal of Medicine* 2020.
42. Millett GA, Jones AT, Benkeser D, et al. Assessing differential impacts of COVID-19 on Black communities. *Annals of Epidemiology* 2020.
43. Nosyk B, Krebs E, Zang X, et al. ‘Ending the Epidemic’ will not happen without addressing racial/ethnic disparities in the US HIV epidemic. *Clinical Infectious Diseases* 2020.


Atlanta
Baltimore
Los Angeles
Miami
New York City
Seattle
(50,0)
(50,25)
(50,50)
(25,0)
(25,25)
(25,50)
(0,0)
(0,25)
(0,50)
(Reduction in risk behavior, Reduction in health services), %
Change in new HIV infections (%)
15
10
0
−10
−20


ATLANTA
BALTIMORE
LOS ANGELES
MIAMI
NEW YORK CITY
SEATTLE
HIV INFECTIONS AVERTED
(50, 0)
(50, 25)
(50, 50)
(25, 0)
(25, 25)
(25, 50)
(0, 0)
(0, 25)
(0, 50)
(REDUCTION IN RISK BEHAVIOR, REDUCTION IN HEALTH SERVICES), %
LINKED OPT-OUT HIV TESTING LEVELS
10%
25%
50%
75%
90%