Home HIV testing and counseling for reducing HIV incidence in a generalized epidemic setting: a mathematical modeling analysis

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Summary

Background—Home HIV testing and counseling (HTC) achieves high levels of HIV testing and linkage to care. Periodic home HTC, particularly targeted to those with high HIV viral load, may facilitate expanding antiretroviral therapy (ART) coverage. We used a mathematical model to assess the impact of periodic home HTC programs on HIV incidence in KwaZulu-Natal, South Africa.

Methods—We developed a dynamic HIV transmission model with parameters, primary cost data, and measures of viral suppression collected from a prospective study of home HTC in KwaZulu-Natal. We assumed five-yearly home HTC with ART initiation for persons with CD4 350 cells/μL. For individuals with CD4>350 cells/μL, we compared increasing ART

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coverage for those who have CD4 counts 350–500 cells/μL with those who have viral loads >10,000 copies/mL.

Findings—Maintaining the current level of 36% viral suppression among HIV-positive persons, HIV incidence decreases by 34% over 10 years. Five-yearly home HTC and linkage to care with ART initiation at CD4 350 cells/μL reduces HIV incidence by 57% over 10 years. Expanding ART to persons with CD4>350 cells/μL who also have VL>10,000 copies/mL decreases HIV incidence by 68%, and was the most cost-effective strategy for preventing HIV infections at $2,960 per infection averted. Expanding ART eligibility to persons with CD4 350–500 cells/μL is cost-effective at $900 per QALY gained. Following health economic guidelines, expanding ART use to those who have VL>10,000 copies/mL among those with CD4>350 cells/μL was cost-effective to reduce HIV-related morbidity.

Interpretation—In KwaZulu-Natal, five-yearly province-wide home HTC can cost-effectively increase ART coverage and reduce HIV burden. ART initiation criteria based on VL>10,000 copies/mL for those with CD4>350 cells/μL is also an efficient strategy for HIV prevention.

Keywords

home testing and counseling; mathematical modeling; ART; HIV prevention

Introduction

The global response to the HIV epidemic is currently at a crossroads where maintaining the status quo is insufficient for reducing the HIV burden. A multi-disciplinary approach that increases HIV testing and linkage to antiretroviral therapy (ART) is critical to curbing the epidemic. Initiatives such as the UNAIDS 90-90-90, which aims to identify 90% of HIV-positive persons through testing, link 90% of them to ART, and achieve viral suppression in 90% of those on ART, focus on delivering services and interventions to patients, namely ART, which is estimated to contribute to the majority of reductions in HIV infections by 2030. Increasing ART coverage also has public health benefits by lowering HIV incidence through reductions in HIV RNA viral load. In KwaZulu-Natal, South Africa, a province with 28% adult HIV prevalence, expanding HIV testing and treatment may curb the epidemic. Encouragingly, an observational community-based study in KwaZulu-Natal from 2004 to 2011 supports the hypothesis that ART coverage can reduce HIV incidence; the authors found a 14% (95% Confidence Interval [CI]: 9–19%) reduced risk of HIV acquisition with every 10% increase in ART coverage.

In 2013, the World Health Organization (WHO) revised its ART guidelines to recommend ART initiation for persons with CD4 500 cells/μL, which South Africa recently adopted. Maximizing the potential benefits of the new guidelines will require improvements to the HIV care continuum, from testing to ongoing engagement in care. Current HIV testing coverage in South Africa is low (49% ever tested), and the CD4 count at HIV diagnosis is low (median 159 cells/μL, interquartile range: 65–299 cells/μL), suggesting that few asymptomatic persons seek care. In addition, retention in HIV care prior to ART initiation is low with an estimated 18% of people being retained in care from HIV diagnosis to ART eligibility. Recently, strategies that simplify HIV testing and counseling (HTC) by

decentralizing HIV testing, ART initiation, and follow-up care, such as home-based HTC, have shown success. A recent meta-analysis of home HTC estimated 70% population coverage (95% CI: 58%–79%) across 37 studies, and studies of home HTC with facilitated linkage to care demonstrated high HIV testing coverage (>90%), linkage to care (>90%), ART uptake (>70%), and viral suppression (40% and 50% at baseline in two studies and increasing to 70% and 65% at month 12, respectively), indicating that home HTC can be an effective large-scale strategy.

With a focus on viral load testing and expected reductions in the price of point-of-care viral load tests, home HTC also presents the opportunity to target ART to persons with high viral load who are likely to transmit HIV, in addition to those with lower CD4 counts. This strategy is being tested in the Botswana Combination Prevention Project (BCPP), an ongoing cluster-randomized trial of combination HIV prevention in Botswana, which assesses the impact on community HIV incidence of home HTC plus ART initiation in addition to their national ART eligibility guidelines persons with CD4 350 cells/μL. For persons with CD4>350 cells/μL, ART is initiated if viral load is >10,000 copies/mL. This approach may decrease HIV incidence by targeting persons with the highest risk of onward transmission. We used a mathematical model of HIV transmission in KwaZulu-Natal, South Africa, to estimate the effectiveness and cost-effectiveness of expanding ART initiation either by CD4 count alone or in combination with a viral load criterion.

Methods

Model Design

We constructed a dynamic, population-based, compartmental model of HIV transmission in rural KwaZulu-Natal, South Africa, stratified by age, gender, and sexual activity. The model proceeds in 3-month time steps and captures the natural history of HIV infection over time through five stages each of CD4 count and HIV viral load (Table 1). Individuals have, at every time point, a CD4 count and an HIV viral load. Starting at the time of infection, these values progress such that the average duration in each category is as estimated in Table 1. The model was calibrated to HIV prevalence data from South Africa (1990 to 2000), KwaZulu-Natal (2001 to 2010), and a home HTC study conducted by our research group (2012), with particular emphasis on the latter data point as that setting was the source of our parameterization data. The parameters for HIV transmission probability were based on previous studies in the literature, and estimated by the number of coital acts per year and the probability of HIV transmission per coital act. The parameters for sexual partnership rates and degree of sexual mixing were based on participant self-reported sexual behavior (the current and last three sexual partners, multiple partners, and condom) and further optimized using least-squares regression to fit the HIV prevalence in KwaZulu-Natal. (See Supplementary Appendix page 9.)

Rates of CD4 progression are dependent on viral load, and vice versa, and were based on data from cohorts of ART-naïve HIV-positive persons in the Partners in Prevention HSV/HIV Transmission Study and Partners PrEP Study, and validated with cross-sectional CD4 and viral load distributions from our home HTC study in South Africa (Supplementary Appendix page 3). Individuals progress through categories of decreasing CD4 count and

increasing viral load at different rates, accounting for the age and gender specific HIV-associated and other all-cause mortality, as well as allowing for heterogeneity in set-point viral loads. Further model details are described in the Supplementary Appendix.

Data sources

The model was parameterized using data from a prospective study of home HTC in KwaZulu-Natal which we conducted between September 2011 and May 2013, and other estimates from the literature which are summarized in Table 1. KwaZulu-Natal, South Africa, has an adult HIV prevalence of 28%, with the specific region of the study having an HIV prevalence of 32%. Of the 1,295 adults in the community where home HTC was conducted, 70% had been tested for HIV before, and similarly, 71% of HIV-positive persons knew their HIV status. Overall baseline self-reported ART coverage in the study was 40% of all HIV-positive persons. We estimated the effectiveness of home HTC as the change in the proportion of all HIV-positive persons with viral suppression (VL 40 copies/mL), which increased from 36% at baseline to 48% of HIV-positive persons at 12 months.

Primary cost data for home HTC and its associated program of linkage to care were collected in KwaZulu- Natal between November and December 2013, adopting a programmatic perspective that assumes home HTC would be implemented by the government. Assuming government salaries for community care workers, task shifting of clinical activities to nurse counselors, and removing ART and research costs, home HTC cost $28·06 per HIV-positive person tested and $8·22 per HIV-negative person tested (Table 1). This cost encompasses all aspects of the home HTC program, including staff training, HIV testing, and follow-up visits by counselors. Additional costs for ART medication, counseling, and retention in care; hospitalization with and without ART; and a semi-quantitative point-of-care viral load test were included (See Supplementary Appendix page 12).

Statistical Analysis

ART coverage scenarios were modeled with baseline ART eligibility (CD4 350 cells/μL), home HTC, and home HTC with expanded ART eligibility guidelines (Table 2). In each scenario, ART coverage is assumed to increase exponentially from 0% in 2004 to 36% for all HIV-positive persons in 2015, and reach a steady-state coverage of 42% viral suppression in 2025. Although ART guidelines in South Africa call for treatment initiation at CD4 500 cells/μL, median CD4 count at start of ART is low (160 cells/μL). Therefore we model several scenarios of ART initiation (CD4 350 cells/μL and CD4 500 cells/μL) to assess the impact of ART initiation by viral load is >10,000 copies/mL compared to various realistic scenarios of ART coverage.

The first scenario (Baseline) simulated the impact of 36% of all HIV-positive persons successfully linking to ART and achieving viral suppression, encompassing 60%, 40%, and 10% viral suppression for persons with CD4 200 cells/μL, 200–350 cells/μL, and 350–500 cells/μL, respectively. The second scenario (Home HTC and linkage) simulates viral suppression for 48% of HIV-positive persons encompassing 90%, 60%, and 20% viral suppression for persons with CD4 200 cells/μL, 200–350, and 350–500 cells/μL,

respectively, as observed in a study of home HTC. Two additional scenarios were then modeled to assess ART expansion to persons with CD4>350 cells/μL following home HTC. First, "Home HTC+High Viral Load" simulated individuals with CD4>350 cells/μL and VL>10,000 copies/mL initiating ART with 60% uptake. Second, "Home HTC+CD4" simulates individuals with CD4 350–500 cells/μL initiating ART with 60% uptake, which represents the new South African guidelines. In these two scenarios, ART coverage for those with CD4>350 cells/μL is assumed to be equal to those with CD4 200–350 cells/μL due to the lack of data on ART coverage at high thresholds. We simulated ART enrollment in home HTC as province-wide year-long programs that occur every five years beginning in 2015. For all scenarios, we assumed baseline ART enrollment occurring between home HTC programs and a 6% annual ART dropout rate from ART care.

To evaluate the health and economic impact of the simulated home HTC scenarios, we calculated the incremental cost-effectiveness ratio (ICER) per HIV infection averted, HIV-associated death averted, and quality-adjusted life-year (QALY) gained. QALY weights are described in the Supplementary Appendix page 12. An intervention was considered very cost-effective if the cost per QALY gained was less than the per capita GDP of South Africa ($6,618), and cost-effective if it was less than three times the per capita GDP ($19,854). We calculated the ICER at 10 years, and all costs and health outcomes were discounted by 3% annually.

We conducted one-way sensitivity analyses to determine the influence of uncertain parameters on the ICER of ART eligibility at CD4 500 cells/μL. We varied the annual per-person cost of home HTC and pre- and post-ART initiation hospitalizations (one-half to four times the base case) and ART ($100 to $1,000, base case: $682). We also varied our estimate for the annual ART drop-out rate from 0% to 10% (base case: 6%), the HIV transmission factor for persons with acute HIV infection from 1 to 50 (base case: 26), and the annual cost discount rate from 0% to 10% (base case: 3%).

A multivariate sensitivity analysis was also conducted to assess the cost-effectiveness of home HTC under pessimistic and optimistic scenarios. We varied simultaneously the cost of ART care ($100 to $1,000), the per-person cost of home HTC (one-half to four times the base case), the per-person cost of pre- and post-ART initiation hospitalization (one-half to four times the base case), and the annual rate of ART dropout (0% to 10%). The pessimistic scenario assumed high costs and ART dropout, whereas the optimistic scenario assumed low costs and ART dropout.

Role of the funding source

The sponsor of the study had no role in the 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

The model was validated using independent HIV incidence and prevalence estimates from South Africa (1990 to 2000) and KwaZulu-Natal (2001 to 2012) (Figures 1a and 1b).

Estimated disease progression parameters were also validated with data from South Africa (See Supplementary Appendix page 3).

Figures 1c and 1d show the impact of home HTC on HIV prevalence and HIV incidence, respectively, until yeah 2030, with five-yearly campaigns. Table 3 shows the estimated impact of home HTC on the HIV burden with varying ART initiation guidelines in year 2025.

If ART coverage remains at the baseline level (36% viral suppression for all HIV-positive persons), HIV incidence is expected to remain at approximately 3·0% per year. With additional home HTC under current ART initiation guidelines (CD4 350 cells/μL) increasing viral suppression to 48% for all HIV-positive persons, then in 10 years, HIV incidence is expected to decrease to 2·0%, averting 152,000 additional infections. Home HTC with current ART guidelines cost-effectively reduces HIV-related deaths at $3,290 per death averted and increases QALY's at $860 per QALY gained. Home HTC with additional ART for those with high viral load is the most cost-effective strategy for preventing HIV infections and for increasing QALYs.

Both ART expansion scenarios resulted in additional HIV transmissions averted. If ART eligibility were increased without a viral load criterion to CD4 500 cells/μL, 16,000 additional individuals will initiate ART during the first testing program, resulting in 31,000 fewer HIV infections per year over 10 years. This strategy is more expensive than using a viral load criterion for preventing HIV infections ($3,320 per infection averted) but cost-effectively increases QALYs ($900 per QALY gained) and reduces HIV-related deaths ($4,070 per death averted). If ART eligibility is expanded to persons with CD4>350 cells/μL and VL>10,000 copies/mL, 40,000 additional individuals will initiate ART, averting 43,000 additional HIV infections at $2,960 per infection averted. In this scenario, viral load tests account for 1% of the total costs over 10 years. In all scenarios, approximately 81% of the costs are attributable to ART, whereas hospitalizations and home HTC contribute approximately 15% and 3% of total costs, respectively.

The frequency of home HTC also drives the impact and cost-effectiveness of home HTC. For home HTC without revised ART initiation guidelines (CD4 350 cells/μL), a higher frequency of home HTC increases the program's total cost and effectiveness, with the total proportion of costs attributable to home HTC increasing from 2% with seven-yearly programs to 7·4% with annual programs. The impact on HIV incidence increases as well from a 36% reduction with seven-yearly programs to a 58% reduction with annual programs. Over 10 years, the cost-effectiveness of home HTC does not vary much with frequency because the majority of costs are incurred by ART treatment and care, whereas a small proportion is attributable to home HTC. The cost per QALY gained and HIV infection averted range from $780 and $11,000, respectively, with seven-yearly programs to $1,280 and $4,600, respectively, with annual programs (See Supplementary Appendix page 18).

In one-way sensitivity analyses for the cost per QALY gained over 10 years (Figure 2), we found that home HTC with an ART initiation criterion of CD4 500 cells/μL remained very cost-effective (ICER per QALY less than or equal to South Africa's per capita GDP) over all

assumption ranges, and was cost-saving over 10 years only when costs are discounted at 9% or greater.

The ICER was most sensitive to the cost of ART medication and care, with the ICER per QALY gained varying from $155 to $1,941 if annual ART medication and care cost were $100 and $1,000, respectively. The ICER was also sensitive to the annual discount rate, being cost saving at high discount rates and costing $1,161 per QALY gained when costs are undiscounted. The ICER showed little variation with the per-patient cost of home HTC due to the small proportion of costs attributable to home HTC programs, and also varied little with the cost of hospitalization because the interventions increase ART coverage for patients early in infection when the cost of hospitalization is low. In a multivariate sensitivity analysis, the most pessimistic scenario resulted in an ICER of $1,680 per QALY gained, whereas the most optimistic scenario resulted in an ICER of $170 per QALY gained.

Discussion

We constructed and validated a mathematical model of HIV transmission using observed parameters and costs from a prospective study of home HTC, and evaluated the impact of using periodic home HTC to target ART, based on CD4 count and viral load, in KwaZulu-Natal, South Africa. We found that home HTC is a cost-effective strategy to increase QALYs and reduce HIV incidence, and using home HTC to expand ART coverage to persons with CD4>350 cells/μL and high viral load cost-effectively reduces the HIV burden relative to home HTC without increased ART coverage. In univariate and multivariate sensitivity analyses, home HTC remained very cost-effective in increasing QALYs over a wide range of uncertainty, but was most sensitive to the costs of ART care and viral load tests.

Previous mathematical models have similarly found that expanding ART coverage can be very effective, but that the effect size depends on assumptions of ART coverage, and prevalence of circumcision and condom use. Walensky *et al.* evaluated the impact of one-time, five-yearly, and annual testing in South Africa with 47% of people linking to care, and found that the ICER for annual testing is $1,720 per QALY gained, and is robust to changes in linkage rate. Waters *et al.* also evaluated the impact of varying the testing frequency with different levels of background HIV incidence. They estimated that annual testing in a region with 1.3% annual HIV incidence, similar to South Africa, has an ICER of $2,650 per QALY gained, and that testing with intervals longer than five years is not cost-effective. Finally, an independently-developed model that uses an agent-based structure to evaluate this home HTC program produced similar results, with estimated ICERs of $342 per DALY averted and $2,780 per HIV infection averted with an ART criterion of CD4 500 cells/μL compared to the estimates found here of $900 and $3,320, respectively, despite using different model structure and modeling a community rather than the entire province.

Despite the estimated cost-effectiveness of home HTC in KwaZulu-Natal, two factors that may be barriers to "Universal Test and Treat" are transmissions from acutely infected individuals and from individuals who drop out of ART care. Our model estimates that at baseline, 27% of incident infections come from acutely infected partners (estimates from other analyses vary from 2% to 38·4% [95% CI: 18·6% to 52·3%]), whereas ART scale-up

to CD4 500 cells/μL increases the contribution of incident infections from acutely infected persons to 52%. Although there has been considerable debate over the contribution of HIV transmissions from acutely infected individuals, our sensitivity analyses suggest cost-effectiveness under both scenarios. ART drop-out and poor retention in care are also large barriers to long-term viral suppression. With an annual ART drop-out rate of 6%, our model estimates that these individuals transmit 12% of incident infections under current ART coverage, but that with ART scale-up to CD4 500 cells/μL, the proportion increases to 20%. Patients often identify logistical barriers to ART being the main reason for loss to follow-up, suggesting that increasing the efficiency of ART provision with home HTC may increase retention in care.

A recent analysis by Tanser *et al.* found that in KwaZulu-Natal, HIV incidence is reduced by 1·4% for every 1% increase in ART coverage; similarly our model estimates a 1·6% reduction in HIV incidence for every 1% increase in ART coverage. The difference in our estimates may be attributed to how ART coverage was measured. Whereas Tanser *et al.* measured ART coverage as receipt of ART, our analysis estimated ART coverage using levels of virologic suppression. Thus, we expect our estimates to show a greater effect of ART coverage. The TEMPRANO study also found significant reductions in severe HIV morbidity (all-cause mortality, any AIDS-defining event, severe bacterial diseases, and non-AIDS cancers) with early ART initiation (ART for all HIV-positive persons versus using WHO guidelines), finding a 44% reduction. Similarly, our model estimates a 26% increase in QALYs, with the lower estimate being attributable to the low QALY weight for HIV-positive persons with high CD4 counts.

This analysis estimated the impact of increased ART uptake and HIV care due to home HTC, but may be influenced by several limitations. First, ART eligibility guidelines have recently increased to persons with CD4 500 cells/μL, but because our home HTC study was conducted under previous eligibility guidelines of CD4 350 cells/μL, we lack data on the effectiveness of home HTC under revised guidelines. Given the expected lag between guideline changes and implementation, however, we assumed ART uptake for newly eligible individuals to be similar to those with CD4 200 to 350 cells/μL, Additionally, home HTC presents the opportunity to increase uptake of other HIV prevention methods such as male circumcision and pre-exposure prophylaxis, but this modeling analysis only looks at the impact of increased ART uptake, given that ART is expected to drive HIV prevention in the future. Furthermore, parameterization of the model depends on data from various sources which may be from different regions. However, parameters were selected to be either representative of KwaZulu-Natal, if possible, or to be from robust studies if the parameter is assumed to have little variation by region. (Further details can be found in the Supplementary Appendix page 9.) Finally, the coverage, acceptability, and overall effectiveness of these interventions vary by region. Given the unusually high HIV prevalence in KwaZulu-Natal, the cost-effectiveness results may not be generalizable across settings, although implementation of home HTC in a Ugandan community with lower HIV prevalence (11%) saw similarly high increases of viral suppression after home HTC (47% to 59%).

ART for HIV prevention requires high levels of HIV testing, linkage to care, retention in care, and viral suppression—a multi-step pathway that requires widespread knowledge of HIV status and efficient strategies for linkages to care. Our analyses suggest that home HTC is a potentially cost-effective platform for increasing QALYs and averting HIV infections and deaths in KwaZulu-Natal. Additionally, the decentralization and integration of HIV care into primary care settings is likely to improve retention in care and health outcomes. To reduce the global HIV burden, effective and efficient methods to increase uptake of and adherence to HIV prevention methods are urgently needed. The next step for community-based HIV testing and linkage strategies is to assess how these strategies can be scaled up and integrated into existing health care programs to reduce HIV incidence.

Research in Context

Evidence before this study

Mathematical modeling can be used to estimate the cost-effectiveness of HIV testing and counseling (HTC) strategies that reach large communities and have population-level impacts on the HIV epidemic. We searched PubMed and EMBASE for economic mathematical modeling analyses of HTC strategies in sub-Saharan Africa published between January 1, 2000, and September 5, 2015, using the terms "HIV" AND "Africa South of the Sahara" AND "cost" AND "modeling" AND ("testing" OR "counseling" OR "screening"). We identified 110 abstracts, of which five met our inclusion criteria of estimating the cost-effectiveness of HTC strategies in sub-Saharan Africa with health-related outcomes. The strategies analyzed include various frequencies of voluntary and routine HTC, couples' HTC, self-testing, and an independently developed model using the same home HTC data. Incremental cost-effectiveness ratios (ICERs) ranged from $1,360 to $2,650 per life-year using community-wide HTC, with cost assumptions ranging from $8.17 to $9.85 per person tested. Alternative strategies include treatment as prevention, which was estimated to have an ICER of over $5,000 per HIV infection averted relative to couples' HTC, and self-testing, with an ICER of $3,286 per DALY gained relative to routine care. Averaging across the community HTC strategies yields an estimate of $1,910 per life-year, using an average estimate of $8.91 per HIV-negative person tested. Although many modeling studies have estimated the cost-effectiveness of increasing ART coverage, few have incorporated the changing costs of scaling up HTC strategies.

Added value of this study

To our knowledge, this is the first analysis to incorporate both micro-costing scale-up and population-level heterogeneity in viral load progression to estimate the cost-effectiveness of a home HTC program with varying criteria for ART initiation. The results show that given the currently low levels of ART initiation, introducing a criterion of viral load greater than 10,000 copies/mL for ART initiation is cost-effective for increasing life-years, and preventing HIV-related deaths and HIV infections in a ten-year period. Furthermore, the greatest driver of cost is ART; thus, reducing the cost of medication is critical to expanding access to care.

Implications of all the available evidence

Our findings suggest that home HTC, even when scaled to the population-level, can be a cost-effective strategy to reduce HIV-related morbidity and mortality. Recently expanded ART initiation criteria will improve the effectiveness of home HTC in reaching individuals eligible for ART and reduce the possibility for individuals being lost from HIV care. The existing evidence for community-based strategies indicate high acceptability and linkage to care, and this study adds to other economic modeling analyses to suggest that community-based strategies may be cost-effective for increasing the scale of HTC programs. More economic modeling analyses of community-based HTC are needed to strengthen the evidence for implementing large-scale HTC programs. Regardless of ART initiation criteria, efforts must be made to increase coverage, given the low levels of people living with HIV who are on ART.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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(a)

Baseline HIV Prevalence

(b)

Baseline HIV Incidence

+ SA Data   O KZN Data   ▬ Baseline

(c)

HIV Prevalence with ART Expansion

(d)

HIV Incidence with ART Expansion

▬ Baseline   ▬ HTC+CD4 500
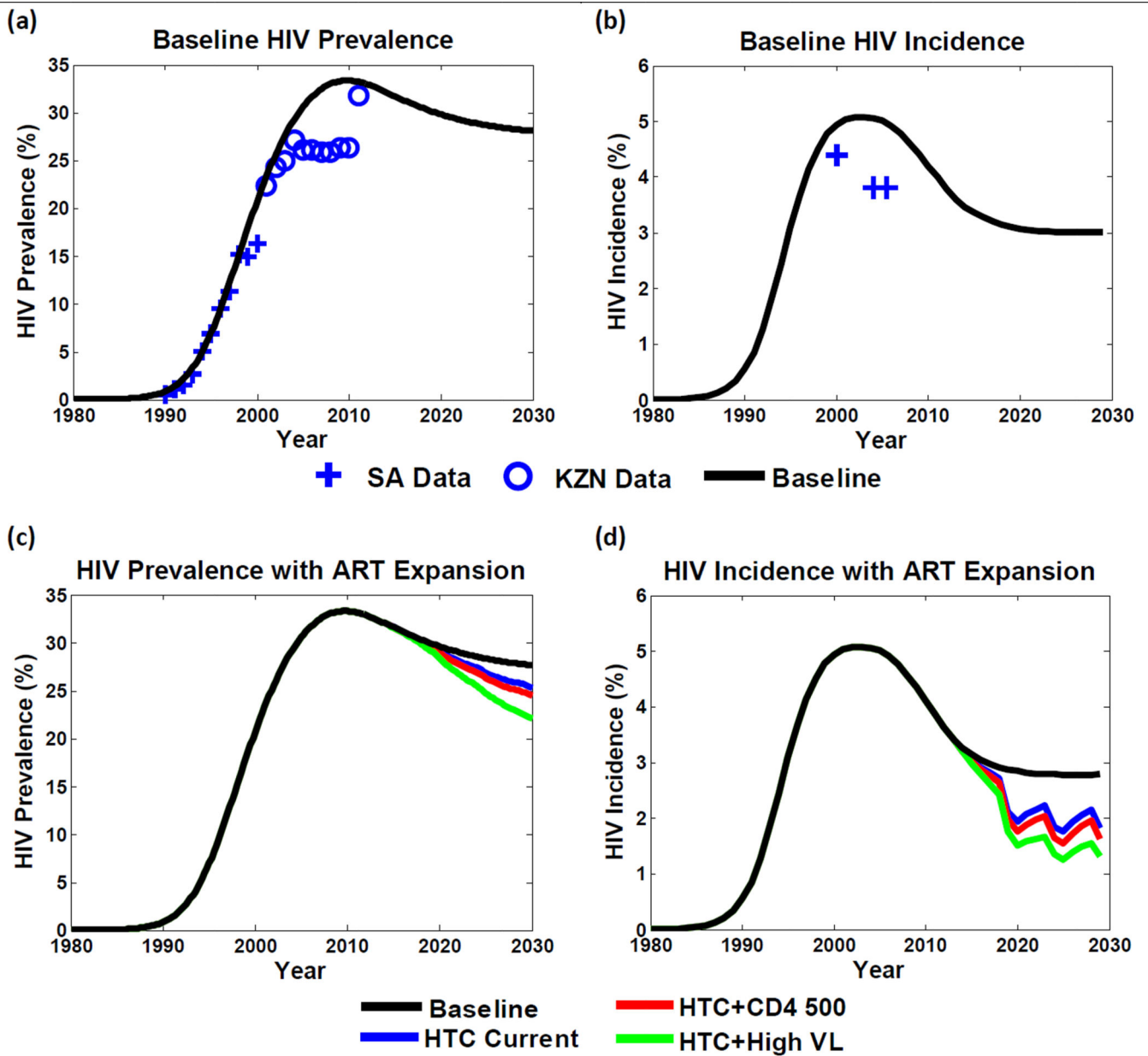▬ HTC Current   ▬ HTC+High VL

Figure 1. Model output for HIV prevalence and incidence
Model HIV prevalence (a) is similar to observed prevalence in KZN, and model HIV incidence (b) is similar to the average HIV incidence observed in KZN. Model output for prevalence (c) and incidence (d) for various intervention scenarios are shown with Baseline ART coverage of 36% for all HIV-positive persons (red). Home HTC with ART initiation at CD4 350 cells/μL is shown in blue, home HTC with ART for persons with CD4>350 cells/μL and viral load>10,000 copies/mL is shown in green, and home HTC with ART initiation at CD4 500 cells/μL is shown in purple.
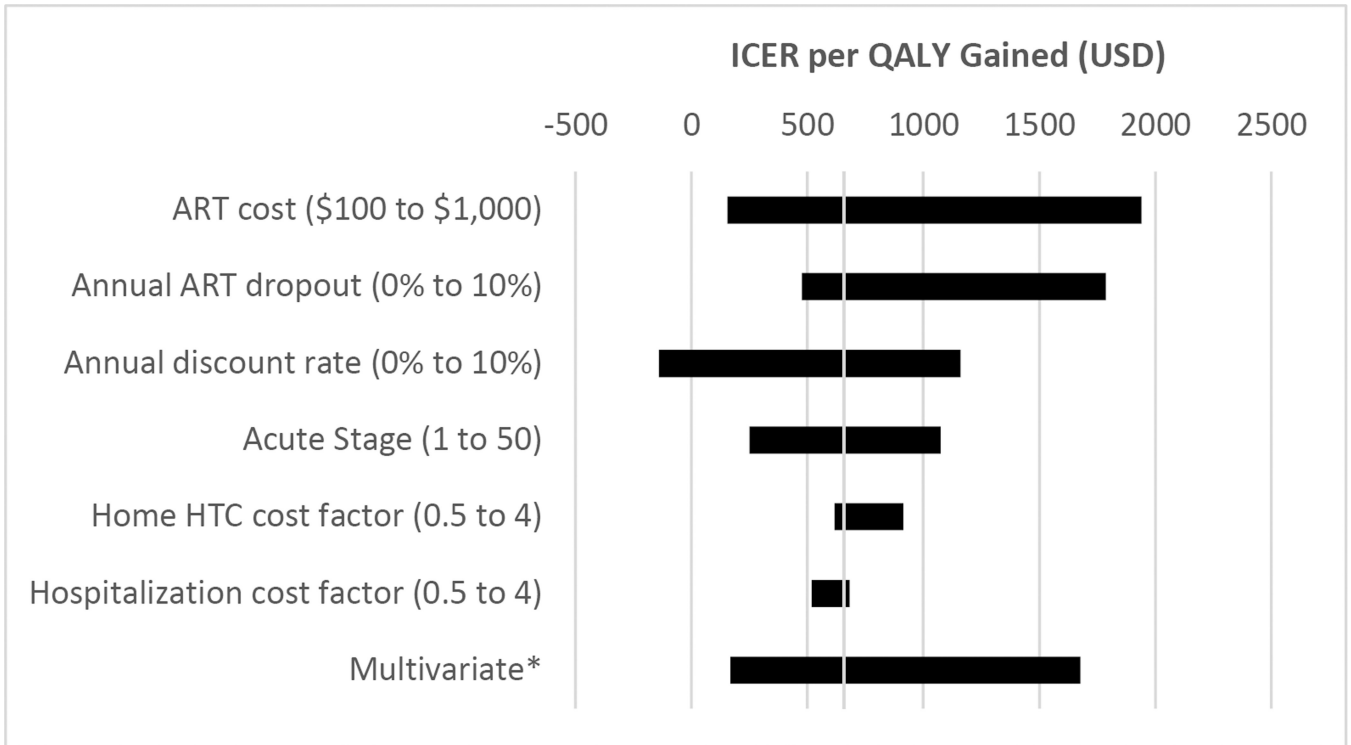
Figure 2. Tornado diagram of one-way sensitivity analyses

We varied individual parameters one at a time while maintaining baseline values for other parameters in order to estimate their impact on the 10-year ICER per QALY gained of home HTC with ART initiation at CD4 500 cells/μL. The Base Case ICER is $659 per QALY gained.

*Multivariate analyses include variations in the cost of ART, cost of hospitalization, cost of Home HTC, and dropout from ART.

Table 1

Key parameters used in model

The parameters were based on the Home HTC study and other literature. For parameters with varying estimates, we chose values that best fit our data.

Model Parameter	Value [Range]	Reference
Duration of Disease		
By CD4 Count		
Acute	0·25 year [0·2, 0·25]	Johnson *et al.*
>500 cells/µL	1·88 years	Celum *et al.*, Baeten *et al.*·
500 to 350 cells/µL	1·22 years	Celum *et al.*, Baeten *et al.*·
350 to 200 cells/µL	5·90 years	Celum *et al.*, Baeten *et al.*·
200 cells/µL	1·96 years (95% CI: 3·0–4·3 years)	Badri *et al.*
By HIV Viral Load		
Acute	0·25 year	Johnson *et al.*
<1,000 copies/mL	3·13 years	Celum *et al.*, Baeten *et al.*·
1,000–10,000 copies/mL	1·99 years	Celum *et al.*, Baeten *et al.*·
10,000–50,000 copies/mL	4·40 years	Celum *et al.*, Baeten *et al.*·
>50,000 copies/mL	1·44 years	Estimated
Costs		
Annual Home HTC with	HIV-positive: $28·06 per person	Smith *et al.*
Community Care Workers	HIV-negative: $8·22 per person	

Table 2

Home HTC programmatic assumptions

The scenarios used in model to evaluate home HTC are based on an observational study of home HTC in KwaZulu-Natal from March 2011 to March 2013. The percentage represents the percentage of people living with HIV with a given CD4 count and viral load who are initiated on ART after one year of an HTC campaign.

CD4 Category	Scenario 1: Baseline[a]	Scenario 2: Home HTC	Scenario 3: Home HTC +High VL	Scenario 4: Home HTC +CD4
CD4 200	60%	90%	90%	90%
200–350	40%	60%	60%	60%
Additional ART Coverage	**Scenario 1**	**Scenario 2**	**Scenario 3**	**Scenario 4**
	All VL	**All VL**	**>10,000**	**All VL**
350–500	10%	20%	60%	60%
>500	0%	0%	60%	0%

[a]Baseline represents continuing current ART coverage

Table 3

Effectiveness and Cost-effectiveness of ART Uptake from Home HTC

Results are shown for a ten-year time horizon relative to year 2015 with 6% annual drop-out from ART care. Costs and effectiveness are discounted by 3% annually.

Scenario	Change in HIV incidence[a]	Change in HIV prevalence[a]	ICER per Infection Averted	ICER per Death Averted	ICER per QALY Gained
Baseline: ART for 36% of all HIV-positive	--	--	--	--	--
Home HTC: ART for 48% of all HIV-positive	−33·8%	−4·7%	Dominated[b]	$3,290	$860
Home HTC + CD4: Additional ART for CD4 350–500 cells/μL	−40·6%	−6·7%	Dominated[b]	$4,070	$900
Home HTC + High Viral Load: Additional ART for VL>10,000 copies/mL	−51·6%	−12·1%	$2,960	$5,020	$1,710

[a]Relative to a No ART counterfactual.

[b]A dominated strategy is more costly and less effective or more costly and less cost-effective than a combination of other interventions.