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MAJOR ARTICLE

# Cost-effectiveness of a Medical Care Coordination Program for People With HIV in Los Angeles County

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***Background.*** The Los Angeles County (LAC) Division of HIV and STD Programs implemented a medical care coordination (MCC) program to address the medical and psychosocial service needs of people with HIV (PWH) at risk for poor health outcomes.

***Methods.*** Our objective was to evaluate the impact and cost-effectiveness of the MCC program. Using the CEPAC-US model populated with clinical characteristics and costs observed from the MCC program, we projected lifetime clinical and economic outcomes for a cohort of high-risk PWH under 2 strategies: (1) No MCC and (2) a 2-year MCC program. The cohort was stratified by acuity using social and clinical characteristics. Baseline viral suppression was 33% in both strategies; 2-year suppression was 33% with No MCC and 57% with MCC. The program cost $2700/person/year. Model outcomes included quality-adjusted life expectancy, lifetime medical costs, and cost-effectiveness. The cost-effectiveness threshold for the incremental cost-effectiveness ratio (ICER) was $100 000/quality-adjusted life-year (QALY).

***Results.*** With MCC, life expectancy increased from 10.07 to 10.94 QALYs, and costs increased from $311 300 to $335 100 compared with No MCC (ICER, $27 400/QALY). ICERs for high/severe, moderate, and low acuity were $30 500/QALY, $25 200/QALY, and $77 400/QALY. In sensitivity analysis, MCC remained cost-effective if 2-year viral suppression was ≥39% even if MCC costs increased 3-fold.

***Conclusions.*** The LAC MCC program improved survival and was cost-effective. Similar programs should be considered in other settings to improve outcomes for high-risk PWH.

**Keywords.** HIV; coordinated care; simulation modeling; cost-effectiveness; Ryan White.

People with HIV (PWH) may face a variety of medical and psychosocial needs that frequently go unmet due to individual-level barriers to care and systems-level access problems [1, 2]. These challenges can lead to reduced engagement in HIV care, poor medication or visit adherence, and suboptimal health outcomes [3–5]. In contrast, PWH who have access to care and consistently adhere to antiretroviral therapy (ART) can now expect a near normal life expectancy and quality of life [6, 7].

HIV care coordination is a form of medical case management that addresses patients' unmet medical and nonmedical needs and supports continuous engagement in care. Care coordination models have improved outcomes for numerous chronic diseases, including diabetes, heart failure, asthma, liver disease, and HIV [8–12]. Consistent with recommendations in the US National HIV/AIDS Strategy [13], HIV medical care coordination (MCC) programs have been implemented in New York City, Baton Rouge, and statewide in Indiana and Oregon, although cost and cost-effectiveness data are scarce [14–21].

Los Angeles County (LAC) reported a population of 46 000 PWH in 2012, more than any other county in California; only half were virally suppressed (defined as ≤200 copies/mL) [22, 23]. A large subset experienced important social challenges, including homelessness, substance use disorder, and serious mental illness [1]. To improve outcomes for these patients, the LAC Department of Public Health Division of HIV and STD Programs developed an MCC program in 2013 at 35 HIV clinics supported by Ryan White Comprehensive AIDS Resources Emergency Act funds and designated as medical homes [24]. This multidisciplinary program integrates medical and nonmedical case management models (eg, social and

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public assistance services) to improve engagement in care (ie, linkage, retention, and adherence) [25].

Initial results indicate that the LAC MCC program nearly doubled viral suppression and substantially increased retention in care at 2 years. Our objective was to project the long-term clinical impact, cost-effectiveness, and health care system costs of the LAC MCC program.

## METHODS

### MCC Program Overview

The LAC MCC program utilized a multidisciplinary team (a social worker, a registered nurse, and a case worker) based at Ryan White–supported clinics to address patient needs related to health status, linkage to and retention in care, adherence to ART, HIV-related risk behavior reduction, and psychosocial issues [26]. Key patient-centered activities included delivery of brief interventions around medication adherence and engagement in care, case conferences, and referrals to mental health and addiction treatment services. The primary outcomes of interest for program effectiveness were viral suppression (HIV RNA <200 copies/mL) and retention in care, defined as any combination of 2 or more HIV RNA, CD4 count, and/or genotype tests at least 90 days apart during the last 12-month observation period of the MCC program. Data for viral suppression and retention in care at baseline and 2 years postenrollment, as well as costs, were based on surveillance and programmatic data from the LAC Department of Health [26, 27].

Patients who enrolled in MCC met general eligibility criteria for Ryan White Care Act–supported services [22]. They were identified to be at risk for poor health outcomes at the time of enrollment by 1 or more of the following criteria: recent viral load >200 copies/mL, not currently receiving ART, no HIV medical appointment in the prior 7 months (including those newly diagnosed in the prior 6 months), sexually transmitted infection (STI) diagnosis within the prior 6 months, incarceration within the prior 6 months, or direct provider referral to MCC based on provider-perceived need for services. Patients who did not meet these criteria were considered appropriate for self-management without MCC.

At MCC enrollment, patients were assessed for their level of need for HIV medical and support services. This assessment was used to calculate patients' acuity level (ie, severe, high, moderate, and low), which determined the type and intensity of MCC services provided. Additional details of the LAC MCC assessment and protocol are described elsewhere [26].

### Analytic Overview

We used the Cost-Effectiveness of Preventing AIDS Complications (CEPAC)–US model, a validated microsimulation of HIV disease and treatment [28, 29], to project the clinical and economic outcomes of high-risk PWH in LAC under 2 strategies: (1) No MCC (standard of care) and (2) MCC, in which patients receive tailored services that improve retention in HIV care and viral suppression. We derived model input parameters for the MCC strategy, including viral suppression and retention in care at 2 years, from patients enrolled in the LAC MCC program (January–December 2013) and followed through December 2015. Baseline characteristics of the No MCC cohort were identical to the MCC cohort but with an assumption of stable rates of retention in care and viral suppression over 2 years [30]. All simulated patients initiated ART upon entering care (if not already on ART) and were eligible to switch to a new ART regimen upon virologic failure [31]. In addition to the full cohort analysis, we conducted separate analyses for acuity level–stratified subgroups.

We projected clinical and economic outcomes over the lifetime of each patient, including quality-adjusted life expectancy and mean per-person lifetime medical costs. We used the lifetime projections of quality-adjusted life-years (QALYs) and costs, both discounted at 3% per year [32], to calculate incremental cost-effectiveness ratios (ICERs) for MCC compared with No MCC from the health care sector perspective. We defined the cost-effectiveness threshold as an ICER <$100 000/QALY [33]. We also projected HIV transmissions from the prevalent cohort over 10 years and estimated the health care system costs of the 2 strategies over 2- and 5-year time horizons.

### The CEPAC-US Model

Simulated patients enter the model individually with characteristics drawn randomly from defined distributions of age, sex, CD4 count, and HIV RNA level. A clinical course is simulated for each patient using specified probabilities, which determine monthly transitions between health states. Patients not on ART experience a decline in CD4 count, leading to a greater risk of opportunistic diseases and HIV-associated mortality. (Additional model detail is available at https://www.massgeneral.org/medicine/mpec/research/cpac-model.)

All simulated patients are eligible to initiate ART, regardless of CD4 count, in accordance with current US DHHS guidelines [31]. Firstline ART is an integrase inhibitor–based regimen, and ART efficacy depends on a patient's level of adherence. Highly adherent patients experience greater rates of viral suppression at 12 weeks with rising CD4 cell counts. Patients who suppress on ART are subject to a monthly, regimen-specific probability of virologic failure. For those who remain in care, virologic failure is detected by routine viral load testing with a switch to a fully active ART regimen. Patients in care have a monthly probability of disengaging from care; for those who fall out of care, there is a monthly probability of returning to care, where ART is restarted.

To estimate HIV transmission rates under both strategies, we linked published estimates of viral load–specific transmission rates to simulated patient viral load distributions from the CEPAC model on a monthly basis. In the model, each simulated

patient's viral load depends on the patient's HIV RNA setpoint and whether the patient is acutely or chronically infected, on or off ART, virally suppressed or not, or at an advanced stage of disease (CD4 count ≤200 cells/μL).

### Input Parameters for the Model

#### *Cohort Characteristics*

Cohort characteristics reflected PWH enrolled in the LAC MCC program in 2013 across the 25 Ryan White clinics that reported data. Inputs were from the LAC Division of HIV and STD Program's Ryan White Data Reporting System (Casewatch) and matched HIV surveillance data [34, 35]. The cohort was 13% female with mean age (SD) of 40 (11) years, minimum age of 16 years, and mean CD4 count at ART initiation (SD) of 429/μL (293/μL) (Table 1). The MCC cohort contained 1204 patients in total: 362 high/severe acuity, 621 moderate acuity, and 221 low acuity. Mean age did not substantially differ by acuity level. Mean CD4 count (SD) was 377/μL (268/μL) for high/severe-acuity patients, 392/μL (288/μL) for moderate-acuity patients, and 620/μL (272/μL) for low-acuity patients.

#### *ART Adherence, Viral Suppression, and Retention in Care*

In MCC, simulated patients were more likely to improve their adherence, which resulted in higher likelihood of viral suppression and retention in care compared with No MCC ("MCC program effectiveness"). We calibrated the mean adherence of simulated patients in No MCC to achieve 33% viral suppression and 59% retention in care at 2 years; for patients in the MCC program, we calibrated adherence during the program to achieve 57% suppression and 72% retention in care at 2 years, as reported in the MCC program data (Table 1). For acuity-stratified analyses, we also performed these calibrations to MCC program data at 2 years. As the program's long-term effects are unknown, we made the conservative assumption in the base case that the beneficial effects of the MCC program on viral suppression and retention in care end after 2 years and revert to baseline levels; we varied this assumption in sensitivity analysis.

#### *Intervention Costs*

Total costs per patient were obtained from financial records for the 25 sites that reported MCC program data in 2013 [27]. These include salary and benefit costs for full-time and part-time employees, consultant/staffing agency costs, and site overhead costs. We assigned costs to acuity levels using weights derived from the proportion of total hours that care managers at each site allocated to patients in each of the acuity levels. Additional labor costs incurred by the Division of HIV and STD Programs for supervision and monitoring, as well as mileage costs for site visits, were allocated across all patients served in each year. Mean overall costs per patient per year were $2700; by acuity, per-patient costs were $3800 for high/severe, $2900 for moderate, and $2200 for low. Detailed derivations of MCC program cost inputs are available in the Supplementary Data.

#### *ART and Routine Medical Care Costs*

ART costs were based on average wholesale prices [36]. Branded dolutegravir/abacavir/lamivudine (DTG/ABC/3TC) was $28 800, after applying a 23% estimated Medicaid cost reduction on branded drugs [37]. Costs of routine medical care were stratified by CD4 count [39]. All costs were adjusted to and reported in 2017 US dollars [40].

#### *HIV Transmission Rates*

Viral load–specific transmission rates were from the published literature (Table 1). To calculate the rate of first-generation transmissions per 100 person-years over a 10-year horizon for each strategy's prevalent cohort, we used the cumulative viral load estimated by the model for all patients based on the viral load of each simulated patient [38].

### Sensitivity Analyses

In 1-way sensitivity analyses, we examined multiple parameters, including patient demographics (age, sex, initial CD4 count), 2-year MCC viral suppression, and annual MCC program costs (Table 1). Because ART costs comprise the largest proportion of annual "in care" costs, we assessed the impact of reduced ART costs.

We examined the cost-effectiveness of extending the duration of MCC beyond 2 years. In an "optimistic" scenario, we assumed that the benefits of MCC might persist past the duration of the program (ie, clinical benefits last 4 years, whereas the program costs end at 2 years). In a "pessimistic" scenario, we examined the impact of the clinical benefits ending after 2 years with the program and its costs lasting for 4 years.

We investigated the interplay of the most influential parameters in multiway sensitivity analyses, including a less intensive MCC strategy in which the program cost less but also achieved less of an improvement in viral suppression.

### Health Care System Costs

We used model outcomes to project the health care system costs of implementing MCC compared with No MCC in LAC. For ease of comparison with other settings, we projected the total undiscounted costs of care over 2-year and 5-year time horizons per 1000 patients with characteristics similar to MCC patients. We included the costs of the MCC program, routine HIV care, CD4 count, and HIV RNA testing, ART, and hospitalizations.

## RESULTS

### Base Case

For the overall population, discounted life expectancy increased from 10.07 QALYs with No MCC to 10.94 QALYs with MCC (Table 2). Per-person discounted lifetime medical

**Table 1. Key Input Parameters for an Analysis of the Los Angeles County Medical Care Coordination Program**

| Parameter | Base Case | [Range] | Reference |
|---|---|---|---|
| Female sex, % | | | [24] |
| Overall | 13 | [0–50] | |
| High/severe acuity | 10 | [0–50] | |
| Moderate acuity | 14 | [0–50] | |
| Low acuity | 15 | [0–50] | |
| Mean age (SD), y | | | [24] |
| Overall | 40 (11) | [30–50 (11)] | |
| High/severe acuity | 40 (11) | [30–50 (11)] | |
| Moderate acuity | 41 (12) | [30–50 (12)] | |
| Low acuity | 40 (12) | [30–50 (12)] | |
| Mean CD4 (SD), cells/μL | | | [24] |
| Overall | 429 (293) | [215–644 (293)] | |
| High/severe acuity | 377 (268) | [189–566 (268)] | |
| Moderate acuity | 392 (288) | [196–588 (288)] | |
| Low acuity | 620 (272) | [310–930 (272)] | |

| Parameter | Base Case | [Range] | Reference |
|---|---|---|---|
| Suppressed at baseline, % | | | [24] |
| Overall | 33 | | |
| High/severe acuity | 22 | | |
| Moderate acuity | 28 | | |
| Low acuity | 64 | | |
| Retained in care at baseline, % | | | [24] |
| Overall | 59 | | |
| High/severe acuity | 56 | | |
| Moderate acuity | 57 | | |
| Low acuity | 71 | | |

| Parameter | Base Case | | [Range] | Reference |
|---|---|---|---|---|
| | No MCC (SOC) | MCC | | |
| Viral suppression at 2 y, %[a] | | | | [24] |
| Overall | 33 | 57 | [34–90] | |
| High/severe acuity | 22 | 46 | [24–90] | |
| Moderate acuity | 28 | 59 | [29–90] | |
| Low acuity | 64 | 67 | [65–90] | |
| Retained in care at 2 y, % | | | | [24] |
| Overall | 59 | 72 | | |
| High/severe acuity | 56 | 71 | | |
| Moderate acuity | 57 | 72 | | |
| Low acuity | 71 | 71 | | |
| Cost of the MCC program per patient, per year, mean USD[a,b] | | | | Adapted from [24, 27] |
| Overall | | 2700 | [900–8100] | |
| High/severe acuity | | 3800 | [1300–11 400] | |
| Moderate acuity | | 2900 | [1000–8700] | |
| Low acuity | | 2200 | [700–6600] | |
| Cost of ART (DTG/ABC/3TC) per year per patient, USD | 28 800 | | [14 400–57 600] | [36, 37] |

| Parameter | Base Case | [Range] | Reference |
|---|---|---|---|
| Transmission rates by disease stage and viral load, per 100 PY | | | [38] |
| Late-stage disease (CD4 ≤200/μL) | 9.03 | [3.87–21.09] | |
| HIV RNA viral load, copies/mL | | | |
| >100 000 | 9.03 | [3.87–21.09] | |
| 10 001–100 000 | 8.12 | [2.78–23.77] | |
| 3001–10 000 | 4.17 | [0.84–20.65] | |
| 501–3000 | 2.06 | [0.57–7.47] | |
| 21–500 | 0.16 | [0.02–1.13] | |
| ≤20 | 0.16 | [0.02–1.13] | |

Abbreviations: 3TC, lamivudine; ABC, abacavir; ART, antiretroviral therapy; DTG, dolutegravir; LAC, Los Angeles County; MCC, medical care coordination program; PY, person-years; SOC, standard of care.

[a]Table range was used to perform sensitivity analysis on MCC strategy only.

[b]Overhead costs were derived for the 14 sites from which these were available. Primary data from LAC were analyzed to derive these parameters.

**Table 2. Projected Clinical Impact and Cost-effectiveness of a Medical Care Coordination Program in Los Angeles County**

| Acuity: Strategy | QALY pp[b] | Cost pp, USD[b] | ICER, USD/QALY[b] | Transmissions/100 PY[c] |
|---|---|---|---|---|
| Overall[a] | | | | |
| No MCC | 10.07 | 311 300 | — | 3.28 |
| MCC | 10.94 | 335 100 | 27 400 | 2.94 |
| High/severe | | | | |
| No MCC | 8.59 | 279 200 | — | 3.77 |
| MCC | 9.54 | 308 300 | 30 500 | 3.42 |
| Moderate | | | | |
| No MCC | 9.13 | 287 500 | — | 3.59 |
| MCC | 10.26 | 315 900 | 25 200 | 3.15 |
| Low | | | | |
| No MCC | 14.23 | 420 000 | — | 1.97 |
| MCC | 14.31 | 425 800 | 77 400 | 1.93 |

Abbreviations: ICER, incremental cost-effectiveness ratio; MCC, medical care coordination program; pp, per-person; PY, person-year; QALY, quality-adjusted life-year.

[a]Results are weighted based on 362 high/severe-acuity cases, 621 moderate-acuity cases, and 221 low-acuity cases.

[b]Discounted 3% per year.

[c]Transmission rates include first-order transmissions only and are calculated over a 10-year horizon.

costs increased from $311 300 with No MCC to $335 100 with MCC. Compared with No MCC, the MCC strategy had an ICER of $27 400/QALY. For the high/severe-acuity group, discounted life expectancy increased from 8.59 QALYs (No MCC) to 9.54 QALYs (MCC), with per-person discounted lifetime medical costs increasing from $279 200 (No MCC) to $308 300 (MCC), resulting in an ICER of $30 500/QALY. For the moderate-acuity group, MCC resulted in a greater increase in discounted life expectancy (No MCC: 9.13 QALYs; MCC: 10.26 QALYs) and a smaller increase in costs (No MCC: $287 500; MCC: $315 900); the ICER for the moderate-acuity patients was therefore lower (ICER: $25 200/QALY). The low-acuity group showed the smallest improvement in clinical outcomes, with a small increase in discounted life expectancy from 14.23 QALYs to 14.31 QALYs and increased costs from $420 000 to $425 800. The ICER for the low-acuity group was $77 400/QALY. Overall, HIV transmission rates over 10 years decreased from 3.28/100 PY in the No MCC strategy to 2.94/100 PY for the MCC strategy.

### Sensitivity Analyses

#### *One-Way Sensitivity Analysis*

The most influential parameters affecting cost-effectiveness results were MCC 2-year viral suppression and MCC program costs (Figure 1). MCC remained cost-effective compared with No MCC (ICER <$100 000/QALY) if patients in the MCC achieved 2-year viral suppression >34% or annual 2-year program costs remained <$35 000 per person (13x the estimated annual per-person cost of the LAC MCC program). If ART costs were halved, as could occur with generic ART, the ICER for MCC decreased to $15 800/QALY.

When the duration of MCC was extended to 4 years, including both benefits and costs, the program had an ICER of $32 600/QALY. For the high/severe-, moderate-, and low-acuity groups, the ICERs increased to $35 500/QALY, $29 200/QALY, and $107 400/QALY. In the "optimistic" scenario, in which the benefits of MCC persisted over 4 years despite the program and its costs ending at 2 years, the ICER for the overall population decreased to $28 900/QALY. The ICERs for high/severe, moderate, and low acuity also decreased: $30 900/QALY, $26 200/QALY, and $69 000/QALY. In the "pessimistic" scenario, where the benefit of MCC ended after 2 years but the program and its costs continued for 4 years, the ICER increased to $46 800/QALY in the overall group. For the high/severe-, moderate-, and low-acuity groups, the ICERs increased to $51 300/QALY, $41 900/QALY, and $146 500/QALY.

#### *Multiway Sensitivity Analysis*

In multiway sensitivity analysis, we varied the 2 most important parameters: annual MCC program costs and MCC 2-year viral suppression (Figure 2). Using the 2-year horizon for both program benefits and costs, MCC was cost-effective compared with No MCC, as long as it improved overall viral suppression to 39% at 2 years, and the annual cost of the program was <$8100 per person. We also examined the scenario of a less intensive strategy, which might focus only on those with a detectable viral load. We found that MCC would be cost-effective compared with No MCC if MCC improved viral suppression from 33% to at least 34% at an annual cost of $1200, or $100/month.

### Health Care System Costs

The projected total 2-year undiscounted cost to the health care system for the No MCC strategy was $60 million per 1000 patients, and for the MCC strategy it was $68 million per 1000 patients (Figure 3). MCC services alone cost $5 million (69% of additional costs or 8% of total costs) over the 2 years. However, MCC resulted in $2 million in savings in non-ART costs (including costs of acute events, routine care, and CD4 and HIV viral load tests) compared with the No MCC strategy. ART constituted the majority of the costs of care ($44 million for No MCC and $48 million for MCC). At 5 years, total undiscounted costs were $128 million (No MCC) and $138 million (MCC); the increased costs in the MCC strategy were due both to the costs of the MCC program and to more patients being engaged in care and taking ART.

## DISCUSSION

The LAC MCC program was designed to address multiple challenges to effective HIV care for PWH with psychosocial and medical comorbidities. The program substantially increased the proportion of individuals suppressed on ART and retained in care over 2 years. Using a microsimulation model of HIV disease to project long-term outcomes, we found that the MCC

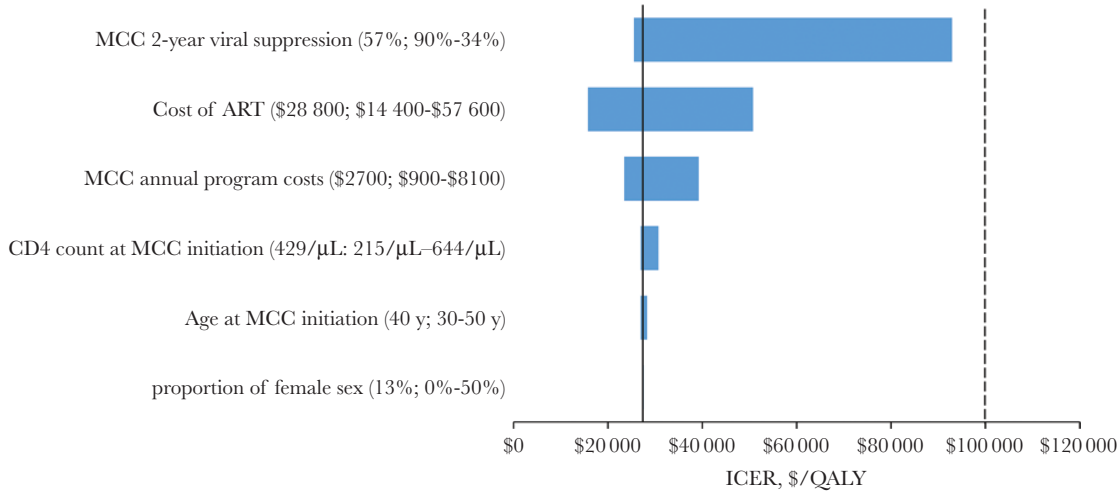


**Figure 1.** One-way sensitivity analysis on demographic, clinical, and cost parameters of the cost-effectiveness of the MCC program. This tornado diagram displays the impact of varying individual parameters on the ICER of MCC compared with No MCC. The solid vertical line shows the base case ICER of $27 400/QALY. The dashed line on the right shows the cost-effectiveness threshold ($100 000/QALY). Each row shows the effect of varying a single parameter; the base case value is stated in parentheses, followed by the range evaluated, with the values resulting in the lowest ICER on the left and the highest ICER on the right. The width of the bar reflects the change in ICER across the parameter range. The ICER increases to above $100 000/QALY only if MCC viral suppression at 2 years falls below 34% when 2-year suppression in No MCC is 33%. Abbreviations: ART, antiretroviral therapy; ICER, incremental cost-effectiveness ratio; MCC, medical care coordination program; QALY, quality-adjusted life-year.

program was cost-effective compared with No MCC (ICER: $27 400/QALY), offering excellent value given that the lower bound on the ICER for any program that improves viral suppression or retention in care will be around $25 000/QALY, due to the annual cost of ART.

Although the MCC program was cost-effective for all patient acuity levels, it offered the best value for moderate-acuity patients, suggesting that a focus on these patients may provide the best value for this type of intervention. The MCC program cost less per patient for those in the low-acuity subgroup but led to less improvement in viral suppression and thus was less cost-effective. For the high/severe-acuity patients, MCC prompted a greater improvement in viral suppression but at higher per-person costs because these patients required more intensive case management and other support.

In addition to acuity level, the cost-effectiveness of the MCC program was most sensitive to changes in the overall 2-year viral suppression achieved in MCC and annual MCC program

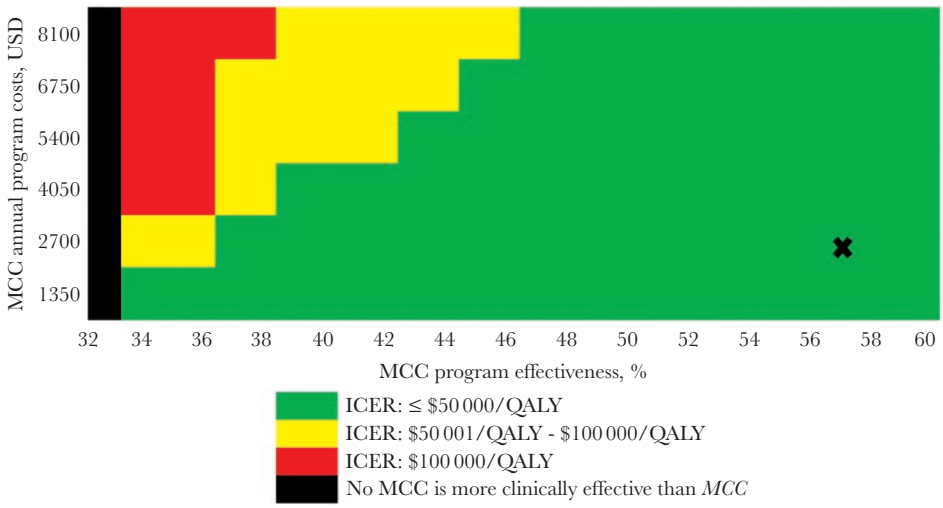


**Figure 2.** Multiway sensitivity analysis on 2-year viral suppression and annual program costs. Viral suppression in the MCC program varied from 32% to 60%, whereas MCC annual program costs varied from $1400 to $8100. The black X denotes the MCC base case viral suppression at 2 years (57%) and annual program costs ($2700). Compared with the No MCC strategy, MCC viral suppression rates ≤33% provided no clinical benefits. If the MCC annual program cost was $2700, the ICER remained below $50 000/QALY (green area) when 2-year viral suppression was between 37% and 60%. Abbreviations: ICER, incremental cost-effectiveness ratio; LAC, Los Angeles County; MCC, medical care coordination program; QALY, quality-adjusted life-year.

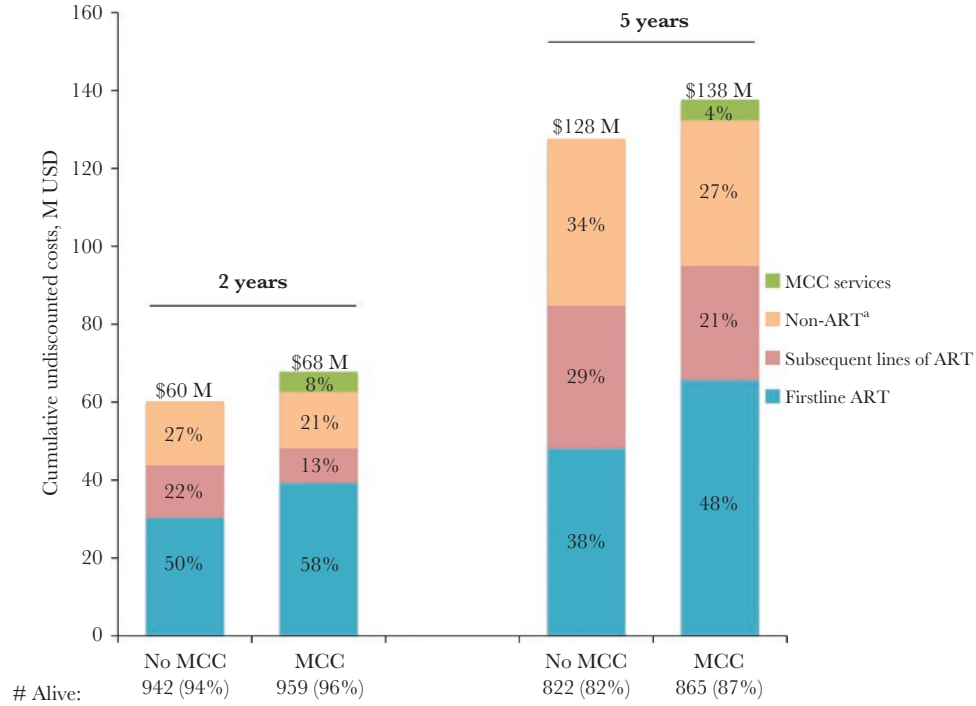


**Figure 3.** Health care system costs of implementing a medical care coordination program over 2-year and 5-year time horizons per 1000 patients. The number of patients alive at each time point is shown below the figure. [a]Non-ART costs include acute OI events, routine care, mortality costs, and CD4 and HIV RNA testing costs. In the MCC at 2 years, over half of the total costs (58%) were attributable to firstline ART; the cost of the MCC program made up 8% of total costs. At 5 years, the proportion of firstline ART decreased to 48%, but it remained the largest contributor to costs. Abbreviations: ART, antiretroviral therapy; M, million; MCC, medical care coordination program; OI, opportunistic infection.

costs. We found that MCC was cost-effective, even if program costs were as much as 3 times the actual estimated cost (increased from $2700 to $8100 per person), as long as the program increased 2-year suppression by at least 6% (from 33% to 39%). An increase of 6% suppression is a conservative goal given that the program nearly doubled the proportion of patients with viral suppression (from 33% to 57%), and LAC MCC program data through 2017 demonstrate 1-year suppression of 79% [41, 42].

In the analysis of health care system costs, we found that total costs for a cohort of 1000 patients increased by $8 million at 2 years and $10 million at 5 years for MCC relative to No MCC. Most of the increase was in firstline ART costs because more PWH received treatment; there were substantial offsetting reductions in second-line ART and other acute care costs. Although these are costs that may be incurred by the larger safety-net health care system, such costs may be mitigated for Ryan White–supported programs through other payer sources.

Our findings add to the literature supporting the cost-effectiveness of programs that improve viral suppression and retention in care for PWH, if such programs are clinically effective and targeted to populations in need [21]. Components of the MCC program are common in models of coordinated HIV care and other interventions, including an interdisciplinary team of clinical and nonclinical providers and access to a comprehensive array of medical, behavioral health, and psychosocial services [43–45]. Although a similar New York MCC program was not found to be cost-effective given higher programmatic costs and limited clinical impact [20], other cost-effectiveness analyses have found that even moderately effective interventions can be cost-effective in patient groups with low baseline levels of viral suppression [46–51].

Although the MCC program achieved considerable clinical success and was cost-effective, additional resources are needed to meet the 90-90-90 targets [52] and the US Department of Health and Human Services goal to End the HIV Epidemic [53], particularly among PWH with complex comorbidities. To expand the reach of LAC MCC, a Patient Retention Specialist was added in 2016 to provide field-based re-engagement activities. However, additional programs and partnerships beyond the traditional clinic setting are needed to achieve population-level viral suppression targets, such as have been effective in the RAPID ART program in San Francisco and the Max Clinic in Seattle [54–56]. Increased collaboration with local partners in substance use, mental health, sexual health, and housing is critical to address the social determinants associated with HIV acquisition, transmission, and health outcomes.

These results should be interpreted in the context of several limitations. Simulated PWH in the No MCC strategy were

assumed to have characteristics similar to MCC patients before they entered the program. However, outcomes from the year before MCC may have been uncharacteristically poor, so that some of the projected benefits of MCC may be related to "regression to the mean" [57]. However, we found that even a small benefit attributable to MCC, such as increased viral suppression of 1%, would lead to a cost-effective program at current programmatic costs. We assumed that only PWH in MCC experienced improved viral suppression over time. We did not adjust quality-of-life weights to account for comorbidities other than HIV.

As advances in HIV treatment have improved health outcomes for many PWH, serious morbidity and mortality have become increasingly concentrated among PWH with severe psychological and social needs [2, 58, 59]. Without integrated service efforts, viral suppression is unacceptably low. LAC MCC services nearly doubled viral suppression for a cohort of people at risk for poor health outcomes with considerable medical and behavioral comorbidities, at an estimated annual cost of $2700 per person. We found that such a program will substantially increase life expectancy and be cost-effective. Similar programs are likely to be of high value in other cities and regions in the United States and can augment other strategies toward meeting national retention and viral suppression goals.

## Supplementary Data

Supplementary materials are available at *Open Forum Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

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## References

1. Wohl AR, Carlos JA, Tejero J, et al. Barriers and unmet need for supportive services for HIV patients in care in Los Angeles County, California. AIDS Patient Care STDS **2011**; 25:525–32.
2. Aidala AA, Wilson MG, Shubert V, et al. Housing status, medical care, and health outcomes among people living with HIV/AIDS: a systematic review. Am J Public Health **2016**; 106:e1–23.
3. Kupprat SA, Dayton A, Guschlbauer A, Halkitis PN. Case manager-reported utilization of support group, substance use and mental health services among HIV-positive women in New York City. AIDS Care **2009**; 21:874–80.
4. Larios SE, Davis JN, Gallo LC, et al. Concerns about stigma, social support and quality of life in low-income HIV-positive Hispanics. Ethn Dis **2009**; 19:65–70.
5. Wohl AR, Galvan FH, Myers HF, et al. Do social support, stress, disclosure and stigma influence retention in HIV care for Latino and African American men who have sex with men and women? AIDS Behav **2011**; 15:1098–110.
6. Antiretroviral Therapy Cohort Collaboration. Life expectancy of individuals on combination antiretroviral therapy in high-income countries: a collaborative analysis of 14 cohort studies. Lancet **2008**; 372:293–9.
7. Samji H, Cescon A, Hogg RS, et al; North American AIDS Cohort Collaboration on Research and Design (NA-ACCORD) of IeDEA. Closing the gap: increases in life expectancy among treated HIV-positive individuals in the United States and Canada. PLoS One **2013**; 8:e81355.
8. Vargas RB, Cunningham WE. Evolving trends in medical care-coordination for patients with HIV and AIDS. Curr HIV/AIDS Rep **2006**; 3:149–53.
9. Shojania KG, Ranji SR, McDonald KM, et al. Effects of quality improvement strategies for type 2 diabetes on glycemic control: a meta-regression analysis. JAMA **2006**; 296:427–40.
10. Morando F, Maresio G, Piano S, et al. How to improve care in outpatients with cirrhosis and ascites: a new model of care coordination by consultant hepatologists. J Hepatol **2013**; 59:257–64.
11. Irvine MK, Chamberlin SA, Robbins RS, et al. Improvements in HIV care engagement and viral load suppression following enrollment in a comprehensive HIV care coordination program. Clin Infect Dis **2015**; 60:298–310.
12. Kastner M, Cardoso R, Lai Y, et al. Effectiveness of interventions for managing multiple high-burden chronic diseases in older adults: a systematic review and meta-analysis. CMAJ **2018**; 190:E1004–12.
13. White House Office of National AIDS Policy. National HIV/AIDS strategy for the United States: updated to 2020. Available at: http://www.hiv.gov/federal-response/national-hiv-aids-strategy/nhas-update. Accessed 5 September 2019.
14. Oregon Health Authority. HIV medical care coordination: standards of services. Available at: http://public.health.oregon.gov/DiseasesConditions/HIVSTDViralHepatitis/HIVCareTreatment/Documents/care/MCCStandards.pdf. Accessed 5 September 2019.
15. Family Service of Greater Baton Rouge. HIV care coordination. Available at: http://www.fsgbr.org/index.php?option=com_content&view=article&id=10&Itemid=10. Accessed 5 September 2019.
16. NYC Health. HIV care coordination tools. Available at: http://www1.nyc.gov/site/doh/health/health-topics/aids-hiv-care-coord-tools.page. Accessed 5 September 2019.
17. Indiana State Department of Health. HIV care coordination program. Available at: http://www.in.gov/isdh/23738.htm. Accessed 5 September 2019.
18. Robertson MM, Waldron L, Robbins RS, et al. Using registry data to construct a comparison group for programmatic effectiveness evaluation: the New York City HIV care coordination program. Am J Epidemiol **2018**; 187:1980–9.
19. Robertson MM, Penrose K, Irvine MK, et al. Impact of an HIV care coordination program on durable viral suppression. J Acquir Immune Defic Syndr **2019**; 80(1):46–55.
20. Stevens ER, Nucifora KA, Irvine MK, et al. Cost-effectiveness of HIV care coordination scale-up among persons at high risk for sub-optimal HIV care outcomes. PLoS One **2019**; 14:e0215965.
21. Nosyk B, Krebs E, Eyawo O, et al. Cost-effectiveness analysis along the continuum of HIV care: how can we optimize the effect of HIV treatment as prevention programs? Curr HIV/AIDS Rep **2014**; 11:468–78.
22. Los Angeles County Department of Public Health Division of HIV and STD Programs. Medical care coordination services for persons living with HIV in Los Angeles County: a robust strategy to strengthen the HIV care continuum. Available at: http://publichealth.lacounty.gov/dhsp/Reports/HIV/MCC_Year-1_EvaluationReport-FINAL.pdf. Accessed 5 September 2019.
23. County Health Rankings & Roadmaps. California HIV prevalence. Available at: http://www.countyhealthrankings.org/app/california/2017/measure/outcomes/61/data. Accessed 5 September 2019.
24. Los Angeles County Department of Public Health Division of HIV and STD Programs. Medical care coordination. Available at: http://www.publichealth.lacounty.gov/dhsp/MCC.htm. Accessed 5 September 2019.
25. Los Angeles County Department of Public Health Division of HIV and STD Programs. Medical care coordination guidelines. Available at: http://www.publichealth.lacounty.gov/dhsp/Contractors/MCC/MCCProtocolMarch2013.pdf. Accessed 5 September 2019.

26. Los Angeles County Department of Public Health Division of HIV and STD Programs. Guidelines for the provision of HIV/AIDS medical care coordination services in Los Angeles County. Available at: http://publichealth.lacounty.gov/dhsp/docs/MCC-Guidelines9-16.pdf. Accessed 5 September 2019.
27. Schackman BR, Jeng PJ, Flash MJE, et al. Cost of an HIV medical care coordination program in Los Angeles County. J Acquir Immune Defic Syndr **2019**; 81:e15–7.
28. Ross EL, Weinstein MC, Schackman BR, et al. The clinical role and cost-effectiveness of long-acting antiretroviral therapy. Clin Infect Dis **2015**; 60:1102–10.
29. Borre ED, Hyle EP, Paltiel AD, et al. The clinical and economic impact of attaining national HIV/AIDS strategy treatment targets in the United States. J Infect Dis **2017**; 216:798–807.
30. Los Angeles County Department of Public Health Division of HIV and STD Programs. 2014 Los Angeles County HIV cascades and PLWH estimate. Available at: http://publichealth.lacounty.gov/dhsp/Reports/HIV/HIVcascadesHIVEstimate2014.pdf. Accessed 5 September 2019.
31. Panel on Antiretroviral Guidelines for Adults and Adolescents. Guidelines for the use of antiretroviral agents in adults and adolescents living with HIV. Available at: http://aidsinfo.nih.gov/contentfiles/lvguidelines/adultandadolescentgl.pdf. Accessed 5 September 2019.
32. 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**; 316:1093–103.
33. Neumann PJ, Cohen JT, Weinstein MC. Updating cost-effectiveness—the curious resilience of the $50 000-per-QALY threshold. N Engl J Med **2014**; 371:796–7.
34. Los Angeles County Department of Public Health Division of HIV and STD Programs. 2014 annual HIV/STD surveillance report. Available at: http://publichealth.lacounty.gov/dhsp/Reports/HIV-STDsurveillanceReport2014.pdf. Accessed 5 September 2019.
35. Los Angeles County Department of Public Health Division of HIV and STD Programs. Information for DHSP contracted providers. Available at: http://publichealth.lacounty.gov/dhsp/InfoForContractors.htm. Accessed 5 September 2019.
36. Red Book. Available at: http://www.micromedexsolutions.com.ezp-prod1.hul.harvard.edu/micromedex2/librarian/CS/FB5A8C/ND_PR/evidencexpert/ND_P/evidencexpert/DUPLICATIONSHIELDSYNC/9529CA/ND_PG/evidencexpert/ND_B/evidencexpert/ND_AppProduct/evidencexpert/ND_T/evidencexpert/PFActionId/redbook.FindRedBook?navitem=topRedBook&isToolPage=true. Accessed 5 September 2019.
37. Levinson DR. Medicaid Drug Price Comparisons: Average Manufacturer Price to Published Prices. Washington, DC: US Department of Health and Human Services; **2005**.
38. Attia S, Egger M, Müller M, et al. Sexual transmission of HIV according to viral load and antiretroviral therapy: systematic review and meta-analysis. AIDS **2009**; 23:1397–404.
39. Schackman BR, Fleishman JA, Su AE, et al. The lifetime medical cost savings from preventing HIV in the United States. Med Care **2015**; 53:293–301.
40. Bureau of Labor Statistics. Consumer price index. Available at: https://data.bls.gov/PDQWeb/ap. Accessed 5 September 2019.
41. Los Angeles County Department of Health, Division of HIV and STD Programs. Core HIV medical services for persons living with HIV. Available at: http://publichealth.lacounty.gov/dhsp/Contractors/2019_AOM_MCC_Successful_Bidders_Conference_June2019.pdf. Accessed 29 October 2019.
42. Li MJ, Su E, Garland WH, et al. Comorbid conditions, viral trajectories, and coordinated care in Los Angeles County. Available at: https://www.croiconference.org/sessions/comorbid-conditions-viral-trajectories-and-coordinated-care-los-angeles-county. Accessed 29 October 2019.
43. Ojikutu B, Holman J, Kunches L, et al. Interdisciplinary HIV care in a changing healthcare environment in the USA. AIDS Care **2014**; 26:731–5.
44. Gardner LI, Giordano TP, Marks G, et al; Retention in Care Study Group. Enhanced personal contact with HIV patients improves retention in primary care: a randomized trial in 6 US HIV clinics. Clin Infect Dis **2014**; 59:725–34.
45. Metsch LR, Feaster DJ, Gooden L, et al. Effect of patient navigation with or without financial incentives on viral suppression among hospitalized patients with HIV infection and substance use: a randomized clinical trial. JAMA **2016**; 316:156–70.
46. Goldie SJ, Paltiel AD, Weinstein MC, et al. Projecting the cost-effectiveness of adherence interventions in persons with human immunodeficiency virus infection. Am J Med **2003**; 115:632–41.
47. Freedberg KA, Hirschhorn LR, Schackman BR, et al. Cost-effectiveness of an intervention to improve adherence to antiretroviral therapy in HIV-infected patients. J Acquir Immune Defic Syndr **2006**; 43(Suppl 1):S113–8.
48. de Bruin M, Oberjé EJM, Viechtbauer W, et al. Effectiveness and cost-effectiveness of a nurse-delivered intervention to improve adherence to treatment for HIV: a pragmatic, multicentre, open-label, randomised clinical trial. Lancet Infect Dis **2017**; 17:595–604.
49. Gopalappa C, Farnham PG, Hutchinson AB, Sansom SL. Cost effectiveness of the National HIV/AIDS Strategy goal of increasing linkage to care for HIV-infected persons. J Acquir Immune Defic Syndr **2012**; 61:99–105.
50. Ownby RL, Waldrop-Valverde D, Jacobs RJ, et al. Cost effectiveness of a computer-delivered intervention to improve HIV medication adherence. BMC Med Inform Decis Mak **2013**; 13:1–16.
51. Zaric GS, Bayoumi AM, Brandeau ML, Owens DK. The cost-effectiveness of counseling strategies to improve adherence to highly active antiretroviral therapy among men who have sex with men. Med Decis Making **2008**; 28:359–76.
52. Avert. HIV and AIDS in the United States of America (USA). Available at: https://www.avert.org/professionals/hiv-around-world/western-central-europe-north-america/usa#footnote9_rcc7tn0. Accessed 22 October 2019.
53. Health Resources and Services Administration. Ending the HIV epidemic: a plan for America. Available at: https://www.hrsa.gov/ending-hiv-epidemic. Accessed 22 October 2019.
54. Coffey S, Bacchetti P, Sachdev D, et al. RAPID antiretroviral therapy: high virologic suppression rates with immediate antiretroviral therapy initiation in a vulnerable urban clinic population. AIDS **2019**; 33:825–32.
55. Dombrowski JC, Ramchandani M, Dhanireddy S, et al. The max clinic: medical care designed to engage the hardest-to-reach persons living with HIV in Seattle and King County, Washington. AIDS Patient Care STDS **2018**; 32:149–56.
56. Hood JE, Katz DA, Bennett AB, et al. Integrating HIV surveillance and field services: data quality and care continuum in King County, Washington, 2010–2015. Am J Public Health **2017**; 107:1938–43.
57. Hughes JP, Haley DF, Frew PM, et al. Regression to the mean and changes in risk behavior following study enrollment in a cohort of U.S. women at risk for HIV. Ann Epidemiol **2015**; 25:439–44.
58. Milloy MJ, Marshall BD, Montaner J, Wood E. Housing status and the health of people living with HIV/AIDS. Curr HIV/AIDS Rep **2012**; 9:364–74.
59. Burch LS, Smith CJ, Anderson J, et al. Socioeconomic status and treatment outcomes for individuals with HIV on antiretroviral treatment in the UK: cross-sectional and longitudinal analyses. Lancet Public Health **2016**; 1:e26–36.