Cost-effectiveness of provider-based HIV partner notification in urban Malawi

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Provider-initiated partner notification for HIV effectively identifies new cases of HIV in sub-Saharan Africa, but is not widely implemented. Our objective was to determine whether provider-based HIV partner notification strategies are cost-effective for preventing HIV transmission compared with passive referral. We conducted a cost-effectiveness analysis using a decision-analytic model from the health system perspective during a 1-year period. Costs and outcomes of all strategies were estimated with a decision-tree model. The study setting was an urban sexually transmitted infection clinic in Lilongwe, Malawi, using a hypothetical cohort of 5000 sex partners of 3500 HIV-positive index cases. We evaluated three partner notification strategies: provider notification (provider attempts to notify indexes’ locatable partners), contract notification (index given 1 week to notify partners then provider attempts notification) and passive referral (index is encouraged to notify partners, standard of care). Our main outcomes included cost (US dollars) per transmission averted, cost per new case identified and cost per partner tested. Based on estimated transmissions in a 5000-person cohort, provider and contract notification averted 27.9 and 27.5 new infections, respectively, compared with passive referral. The incremental cost-effectiveness ratio (ICER) was $3560 per HIV transmission averted for contract notification compared with passive referral. Provider notification was more expensive and slightly more effective than contract notification, yielding an ICER of $51 421 per transmission averted. ICERs were sensitive to the proportion of partners not contacted, but likely HIV positive and the probability of transmission if not on antiretroviral therapy. The costs per new case identified were $36 (provider), $18 (contract) and $8 (passive). The costs per partner tested were $19 (provider), $9 (contract) and $4 (passive). We conclude that, in this population, provider-based notification strategies are potentially cost-effective for identifying new cases of HIV. These strategies offer a simple, effective and easily implementable opportunity to control HIV transmission.

Keywords Cost-benefit analysis, contact tracing, HIV, sub-Saharan Africa
KEY MESSAGES

- Partner notification for HIV is a simple, effective and easily implementable strategy in sub-Saharan African settings.
- Provider-initiated partner notification for HIV is reasonably cost-effective in the Malawian setting in terms of dollars per transmission averted.
- Provider-initiated partner notification for HIV is an inexpensive opportunity to identify new cases of HIV and link patients to care earlier.

Introduction

A substantial portion of HIV transmission is attributable to persons unaware of their HIV-positive status (Marks et al. 2006; CDC 2008). This transmission pattern is also expected in more resource-limited settings. Interventions targeting these individuals are critical for HIV prevention. One important and accessible group of persons unaware of their status is sexual partners of persons with newly diagnosed HIV infection. These partners, if not already infected, are at high risk of acquiring infection due to their ongoing exposure to the virus. Identifying and testing sexual partners of persons recently diagnosed with HIV may be an important component of expanded prevention and treatment services.

Partner notification effectively identifies new cases of HIV infection in high-income countries (Landis et al. 1992; Mathews et al. 2002; Brewer 2005; Hogben et al. 2007; Golden et al. 2009; Marcus et al. 2009). In partner notification, sexual partners of a newly diagnosed person with HIV (index) are notified of their potential exposure and encouraged to seek testing. Partner notification strategies include ‘provider notification’, where a medical provider notifies the exposed partner(s); ‘contract notification’, where the index patient attempts to notify partner(s) within 1–2 weeks, after which the provider completes the notification process and ‘passive referral’, where the index patient notifies partner(s) without any direct provider contact. Provider and contract notifications for syphilis and HIV infection have been mainstays of public health control efforts in high-income countries (European Partner Notification Study 2001; CDC 2003). Provider-based notification strategies increase the rate of partner testing (Mathews et al. 2002) and, although costs vary across sites (Shrestha et al. 2009), are believed to be cost-effective for preventing future cases of HIV infection in high-income countries (Rahman et al. 1998; Varghese et al. 1999).

Despite its success in high-income countries, provider-based partner notification has not been widely adopted in sub-Saharan Africa. However, in Malawi and Cameroon, provider and contract notification appear to be feasible and effective in identifying previously unknown infected persons and linking these persons to care (Muffhi et al. 2009; Brown et al. 2011). In Malawi, rates of partner return were twice as high with provider-based notification, compared with passive referral in a randomized trial (Brown et al. 2011). Among partners who presented for testing, 64% tested HIV positive; of partners testing positive, most (81%) were new diagnoses. Many (28%) were eligible for antiretroviral therapy (ART) based on Malawi’s national guidelines of CD4 $\leq$ 250 cells/mm$^3$. The programme was well accepted among sexually transmitted infection (STI) patients, with only 11% of eligible index cases refusing participation.

In this study, we evaluated the cost-effectiveness of partner notification strategies to identify sexual partners of HIV-infected index patients at STI clinics in Lilongwe, Malawi. We estimated the costs associated with tracing and testing locatable partners. We modelled transmission rates and behavioural modifications after testing to evaluate cost per partner tested, cost per new case identified and cost-effectiveness of HIV transmissions averted by each notification strategy. We compared our estimates of cost-effectiveness to those of widely accepted transmission prevention interventions, such as HIV testing and counselling (HTC) and nevirapine to prevent mother-to-child transmission (Sweat et al. 2004; Menzies et al. 2009; Orlando et al. 2010). To our knowledge, this study is the first cost-effectiveness analysis of partner notification in the sub-Saharan African context.

Methods

We developed a decision-tree model (Figure 1), constructed using Excel™ 2010 (Microsoft Corp, Redmond, WA, USA), to simulate costs, outcomes and incremental cost-effectiveness ratios (ICERs) of implementing partner notification for HIV in STI clinics in Lilongwe, Malawi. We used a health system perspective, incorporating system-level costs incurred by tracing, testing and treating eligible partners. Indirect patient costs (i.e. travel time, lost wages, etc.) were not considered. Costs and outcomes were evaluated during 1 year of programme operation.

We used the trial of partner notification in an STI clinic in Lilongwe as the primary basis for the model (Table 1) (Brown et al. 2011). We obtained other parameter estimates from relevant studies conducted in Malawi or elsewhere in sub-Saharan Africa. The principal outcome was the number and cost per secondary infection avoided as a result of integrating partner notification in this setting. Additional outcomes included the cost per new case identified and cost per partner tested.

Transmissions and infections averted

We built a partner-centric model following a hypothetical cohort of 5000 men and women aged 15–49 years who are partners of indexes at an STI clinic. Index cases on average received provider notification, contract notification or passive...
referral. Locatable partners are partners that the index reports having had sexual contact with within the past 3 months and for whom the index has either a phone number or address. Success of the programme was modelled based on varying partner return rates (Brown et al. 2011, Antelman et al. 1999, Kilewo et al. 1999, and Temmerman et al. 1995). Transmission events can be from the index to a negative partner or from a positive partner to a person other than the index.

The stage of infection at diagnosis [acute, chronic or treatment eligible (i.e. CD4 ≤250 cells/mm³)] predicts likelihood of HIV transmission (Leynaert et al. 1998; Wawer et al. 2005; Girardi et al. 2007; Hollingsworth et al. 2008). We used estimates that reflect the distribution of disease stage at diagnosis as observed at a Lilongwe STI clinic, excluding acute infection in that it is not screened for in the setting of interest. Twenty-eight per cent of partners (range 0.224–0.336) were eligible for ART at baseline (CD4 ≤250 cells/mm³) (Powers et al. 2007; Brown et al. 2011). Transmission probabilities were based on observed transmissions among serodiscordant couples in Uganda and are independent of coital frequency, representing probability of transmission during 12 months (Hollingsworth et al. 2008). We assumed that all partners who are tested and eligible for treatment according to Malawian guidelines will begin ART immediately, with retention in care across 1 year at ~70% (Rosen and Fox 2011). The reduced

**Figure 1** Decision tree modelling three strategies for partner notification. Partners of index patients may be notified of their exposure to HIV by provider notification, contract notification or passive referral. Partners who return to the clinic and agree to HIV testing may test positive or negative, and those partners who test positive may be in the chronic phase of infection and not treatment eligible, or may be eligible for treatment (CD4 ≤250 cells/mm³). Persons who test and are HIV negative may change their sexual risk behaviours, affecting their risk of acquisition in their serodiscordant partnership with the index partner. Transmission probabilities from positive partners account for the variability of infectivity at different stages of infection, as well as reduced infectiousness for those who are eligible and retained on ART. Transmission also accounts for the probability of HIV-infected partners in the cohort having sexual partnerships with HIV-negative persons outside of the index partnership.
Table 1  Model input parameters

| Parameter | Base case (range) | References |
|-----------|------------------|------------|
| Probability of partner return and testing | | |
| Return (PN) | 0.51 (0.4–0.73) | Brown et al. (2011) |
| Return—traced (CN) | 0.18 (0.144–0.216) | Brown et al. (2011) and Muffih et al. (2009) |
| Return—not traced (CN) | 0.33 (0.264–0.396) | Brown et al. (2011) |
| Return (PR) | 0.24 (0.14–0.34) | Brown et al. (2011), Antelman et al. (1999), Kilewo et al. (1999) and Temmerman et al. (1995) |
| Test (PN) | 0.95 (0.8–1.0) | Brown et al. (2011) and Muffih et al. (2009) |
| Test (CN) among traced partners | 0.97 (0.8–1.0) | Brown et al. (2011) and Muffih et al. (2009) |
| Test (CN) among not traced partners | 1.0 (0.8–1.0) | Brown et al. (2011) |
| Test (PR) | 1.0 (0.8–1.0) | Brown et al. (2011) |
| HIV prevalence and disease stage among partners (%) | | |
| Antibody positive (PN, CN and PR) | 0.64 (0.51–0.77) | Brown et al. (2011), Muffih et al. (2009) and Temmerman et al. (1995) |
| Antibody positive, no return (PN, CN and PR) | 0.64 (0.34–0.94) | Assumed |
| End-stage if antibody positive | 0.28 (0.224–0.336) | Brown et al. (2011) |
| New diagnosis if antibody positive | 0.81 (0.648–0.972) | Brown et al. (2011) |
| Acute if antibody negative | 0.0325 (0.02–0.045) | Brown et al. (2011), Powers et al. (2007) Pilcher et al. 2004 and Pilcher et al. (2007) |
| Behaviour change and transmission probabilities | | |
| Behaviour change if negative | 0.35 (0.2–0.5) | Allen et al. (1992, 2003), Baeten et al. (2012), Celum et al. (2010), Voluntary HIV-1 Counseling and Testing Efficacy Study Group (2000), Cohen et al. (2011), Denison et al. (2008), Hughes et al. (2012), Kennedy et al. (2010) and Rosenberg et al. (2012) |
| Transmission if behaviour change | 0 | Assumed |
| Partnership probabilities | | |
| Index patient is sole partner | 0.7 (0.5–0.82) | Brown et al. (2011) and Allen et al. (2003) |
| Outside partner is HIV positive | 0.141 (0.069–0.214) | UNAIDS (2009) and WHO (2008) |
| Probability of transmission (no behaviour change) | | |
| Acute | 0.1975 (0.105–0.2875) | Hollingsworth et al. (2008) |
| Chronic | 0.1 (0.05–0.15) | Hollingsworth et al. (2008) |
| Treatment eligible (no ART) | 0.43 (0.27–0.62) | Hollingsworth et al. (2008) |
| Treatment eligible (ART) | 0.003 | Del Romero et al. (2010), Wilson et al. (2008) and Donnell et al. (2010) |
| Acquisition if negative | 0.075 (0.03–0.1) | Brown et al. (2011) and Hollingsworth et al. (2008) |

Costs (in 2010 US$)\(^b\)

| Personnel | | |
| Provider hourly wage | $2 ($1.40–$2) | |
| Provider time (additional counselling for index patients) (min) | 5 (3–10) | |
| Provider time (tracing) (min) | 35 (25–90) | |
| Provider time (testing notified partners) (min) | 30 (20–45) | |
| Driver hourly wage | $1.40 ($1–$2.40) | |
| Driver time (tracing) (min) | 35 (25–90) | |
| Supervisor cost\(^c\) | $532 ($304–$760) | |

| Tracing and transportation | | |
| Tracing distance (km) | 15 (5–25) | |
| Fuel costs per km (car) | $0.24 ($0.19–$0.29) | |
| Fuel costs per km (motorbike) | $0.09 ($0.07–$0.10) | |
| Yearly cost of vehicle (car)\(^c\) | $3750 ($3000–$4500) | |
| Yearly cost of vehicle (motorbike)\(^c\) | $400 ($320–$480) | |

(continued)
Table 1 Continued

| Parameter                          | Base case (range) | References                                      |
|-----------------------------------|-------------------|------------------------------------------------|
| Cost of insurance (car)$^{a}$     | $2667$ ($2400–2933$) |                                                 |
| Cost of insurance (motorbike)$^{a}$| $267$ ($240–293$)  |                                                 |
| Testing and treatment             |                   |                                                 |
| Cost of condoms (10 per person tested) | $0.30$ ($0.10–0.50$) | Malawi Ministry of Health (Kamoto and Schouten 2007), CHAI 2012 ART Pricing List |
| Rapid antibody HIV test kits      | $2$ ($1–3$)       | CHAI 2012 ART Pricing List                      |
| Consumables                       | $1$ ($0.80–1.20$) |                                                 |
| Cost of care (non-ART)            | $100$ ($80–120$)  | Malawi Ministry of Health (Kamoto and Schouten 2007), CHAI 2012 ART Pricing List |
| Cost of care (ART)                | $285$ ($228–342$) |                                                 |
| Training$^{c}$                    | $152$ ($122–183$) |                                                 |

CN, contract notification; PN, provider notification; PR, passive referral.

$^{a}$Treatment eligible are those persons testing with a CD4 ≤250 cells/mm$^3$.

$^{b}$All costs from personal communication with administrators at UNC Project in Lilongwe unless otherwise indicated.

$^{c}$Fixed year-one costs, not dependent on partner return or testing rate.

The likelihood of HIV acquisition for partners assumes a stable partnership between the index and the tested partner; most partners who are locatable and who agree to testing are main or steady partners (Kissinger et al. 2003; Brown et al. 2011). Based on observed distribution of CD4 counts among index partners in the primary study, 37% of index cases were identified as being treatment eligible and were placed on therapy. Using the same estimated retention in ART care as applied to partners in the model (70%), transmission probability to an HIV-negative partner from the index partner was constructed as a weighted average, between index cases retained on ART and the remaining being in the chronic stage of infection and not on ART (Brown et al. 2011).

Cost inputs

The incremental costs associated with partner notification were derived from resources required to trace, test and counsel, and potentially treat partners of newly diagnosed HIV-positive index cases (Table 1). The incremental cost of integrating partner notification into an existing STI clinic is expressed in 2010 US dollars (US$). Many cost parameters were provided in Kwacha (Malawian currency) directly from a district hospital in Lilongwe.\(^1\) We use a nominal exchange rate of 150 Kwacha/2010 US$ (Financial Management Service). The costs of adverse events that may result from partner notification, including partner violence or partnership dissolution (Rothenberg et al. 1995; Maher et al. 2000; Maman et al. 2001), were excluded from this analysis. Adverse events were extremely rare in the Malawi-based trial (Brown et al. 2011). In
addition, among women visiting an antenatal clinic in a similar setting, adverse events were not increased among women who disclosed their HIV status to their partners (Semrau et al. 2005).

Personnel costs were captured as a proportion of full-time work dedicated to notification services. Salaries were transformed into hourly wages based on the assumption of full-time employment equivalent to 2000 h/year. We assumed that partners of indexes would not otherwise seek HIV testing during the 12-month period, and thus include the time for pre- and post-test counselling (Zanera and Miteka 2004).

Transportation costs (fuel, insurance and driver time) were calculated using the average distance travelled to notify partners in the Lilongwe catchment area, a base case of 15 km and a range of 5–25 km. Providers attempted to locate all partners in the provider notification arm. Tracing costs are lower in the contract notification arm, as a proportion of partners are expected to return within the predefined 1-week period after notification by the index. No tracing costs are associated with the passive referral arm.

The costs associated with care and treatment for HIV-positive persons are fully subsidized by the government in Malawian public clinics and were included as a cost for all who tested positive in this model. Costs in the model did not account for the expense of HIV-related hospitalizations. We assumed a 50% loss to follow-up from care among persons who test positive but are not eligible for ART, and conducted one-way sensitivity varying this from 30 to 70% (Zachariah et al. 2010; Rosen and Fox 2011). Persons not retained in care do not accumulate costs of pre-ART care, such as drugs for HIV-related opportunistic infections, broad-spectrum antibiotics for prophylaxis against opportunistic infections and other staff and laboratory support costs. ART expenses account for most treatment costs inflated from 2007 US$ using Malawi gross domestic product (GDP) implicit price deflator (Kamoto and Schouten 2007; Malawi Country Report). Prices were also estimated using Clinton Health Access Initiative (CHAI) price lists for ART in Malawi from May 2012. We assumed 70% of all eligible persons, as assessed by CD4 count at diagnosis, begin and adhere to ART.

Sensitivity analyses
Deterministic (one-way univariate) and probabilistic (multivariate) sensitivity analyses were performed to assess the robustness of the assumptions in the decision model (Briggs 2000). One-way sensitivity analyses were conducted for parameters identified as major drivers of the ICER for either provider or contract notification. Probabilistic sensitivity analyses using Monte Carlo simulations (5000 trials) were executed with Crystal Ball version 11.1.2 (Oracle, Redwood Shores, CA, USA). To assess variation in input parameters and assumptions, probabilities assumed beta distributions and all costs assumed gamma distributions. Distribution of probabilities was based on observed ranges reported in primary literature (Table 1). Where data were lacking or unavailable, assumption ranges were generally set to ±0.25.

An alternative scenario assessed the use of a motorbike for tracing in the provider and contract notification arms, instead of the base-case assumption of a car and driver. Cost savings in the motorbike scenario include reduced vehicle and driver costs, improved gas efficiency, faster travel time and lower insurance premiums. An additional scenario considered the possibility of patients who test negative being in the acute phase of HIV infection.

Results
In our model of 5000 locatable partners of HIV-positive indexes, we estimated that 2436 and 2537 would receive HIV testing services in the provider and contract notification arms, respectively, compared with 1207 returning for testing with passive referral. Provider notification identified 1267 new HIV cases and contract notification identified 1320 new cases compared with 627 in the passive referral arm.

We conducted sequential comparisons rank ordered by total cost (Gold et al. 1996; Muennig 2008). Passive referral was the least expensive, followed by contract notification. Provider notification was the most costly. The effectiveness of each alternative strategy was evaluated as transmissions averted, compared with the next most expensive strategy. We estimated that compared with passive referral, contract notification would avert 27.5 transmissions over 1 year. Our base-case analysis comparing contract notification with passive referral resulted in an ICER of $3560 per transmission averted (Table 2). Although more expensive than contract notification, provider notification averts an additional 0.4 transmissions over 1 year, corresponding to an ICER of $51421 per transmission averted.

In some settings, provider notification may be a more viable or operationally preferable option compared with contract notification based on site-specific factors such as staffing constraints, clinic catchment areas and testing volumes. In light of this, we compared provider notification with passive

| Table 2 | Base-case cost-effectiveness of provider-based partner notification strategies |
|---------|-------------------------------------------------|
|          | Total costs  | Total transmissions | Incremental costs  | Incremental effectiveness | ICER ($/transmission averted) |
| Passive referral | $77411 | 233.9 | – | – | – |
| Contract notification | $175468 | 206.4 | $98058 | 27.5 | $3560 |
| Provider notification | $191798 | 206.0 | $16330 | 0.4 | $51421 |
| Provider notification vs passive referral scenario | | | | |
| Passive referral | $77411 | 234.0 | – | – | – |
| Provider notification | $191798 | 206.0 | $114387 | 28.0 | $4106 |
referral. The associated ICER is $4106 per transmission averted (Table 2—‘provider notification vs passive referral scenario’).

Excluding the cost of treatment for persons identified as positive, the cost per new case identified was $36, $18 and $8 for provider notification, contract notification and passive referral, respectively. New identified cases are patients who are traced or voluntarily return to the clinic and subsequently receive an HIV-positive test result, excluding the proportion of persons who test positive and were already aware of their HIV status. The cost per partner contacted and tested, again excluding costs associated with treatment for positive partners, was $19, $9 and $4 for provider notification, contract notification and passive referral, respectively. We used costs obtained directly from the site at which all trial activities were conducted. We excluded costs that would not be incurred outside of the trial setting.

Sensitivity analyses

In one-way sensitivity analyses, we estimated the potential range of ICERS for the strategies, evaluating contract notification compared with passive referral, provider notification compared with contract notification and provider notification compared with passive referral across the probable range of input parameters. The results from the most influential input parameters are presented in Table 3. ICERS were most sensitive to the probability of persons who did not return being HIV positive. The wide confidence interval reflects uncertainty of this estimate (0.34–0.94). The transmission probability for persons eligible for ART but not on therapy also had a substantial influence on ICERS, as did the probability that the index partner was the only partner, with greater partnership dissolutions resulting in more favourable ICERS. At certain extremes, provider notification was dominated by contract notification, demonstrating a scenario in which the provider notification strategy was less effective and more expensive.

Probabilistic sensitivity analysis demonstrates an overall robust model, where each input parameter is simultaneously varied across a given range of values from the parameter’s defined distribution. With each ‘draw’, a new incremental cost and incremental effectiveness is calculated, as compared with the referent passive referral. The resulting point estimates are presented in Figure 2 (ICER planes), representing the ICERS of the 5000 draws executed through Monte Carlo simulation. The contract notification strategy is dominated (i.e. the strategy is both less effective and more costly compared with passive referral) 7.2% of the time. The provider notification strategy is dominated 22.9% of the time when compared with contract notification, and 7.7% of the time when compared with passive referral.

Alternative scenarios

Motorbike tracing

Assuming the same number of cases identified when providers use a motorbike, and excluding the cost of treatment, the motorbike scenario resulted in an ICER of $3248 per transmission averted for contract notification, compared with passive referral. Comparing motorbike tracing to our base case (car and driver), this ICER corresponds to a cost savings of $312 per case

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**Table 3** One-way sensitivity analyses comparing partner notification strategies

| Parameter | Input | CN vs PR ($/transmission averted) | PN vs CN ($/transmission averted) | PN vs PR ($/transmission averted) |
|-----------|-------|----------------------------------|----------------------------------|----------------------------------|
|           |       | Low | High | Low | High | Low | High | Low | High |
| Probability positive PR (no return) | 0.34 | 0.94 | $2843 | $4760 | $51 421 | $51 421 | $3287 | $5459 |
| Probability of transmission if treatment eligible (no ART) | 0.27 | 0.62 | $4707 | $2769 | $19 532 | Dominated | $5284 | $3254 |
| Probability IP only sexual partner | 0.5 | 0.82 | $2683 | $4525 | Dominated | $13 771 | $3167 | $5008 |
| Probability acquire infection if negative (no behaviour change) | 0.03 | 0.1 | $4462 | $3200 | Dominated | $18 429 | $5378 | $3628 |
| Probability positive (PN) | 0.31 | 0.77 | $3560 | $3560 | $8956 | $21 664 | $3252 | $4853 |
| Probability retained in care among ART-eligible patients | 0.5 | 0.9 | $4440 | $2960 | $22 807 | Dominated | $5010 | $3468 |
| Probability positive (CN) | 0.51 | 0.77 | $2705 | $4263 | $15 628 | $6095 | $4106 | $4106 |
| Probability positive PN (no return) | 0.34 | 0.94 | $3560 | $3560 | Dominated | $3406 | $4891 | $3537 |
| Probability return PN | 0.4 | 0.73 | $3560 | $3560 | $1570 | $3625 | $4900 | $3590 |
| Probability positive CN (no return) | 0.34 | 0.94 | $4251 | $3062 | $3406 | Dominated | $4106 | $4106 |
| Probability behaviour change if negative | 0.2 | 0.5 | $4161 | $3111 | $24 350 | Dominated | $4730 | $3627 |
| Probability test after notification (PN) | 0.8 | 1 | $3560 | $3560 | $20 187 | $43 715 | $3305 | $4363 |
| Probability return PR | 0.14 | 0.34 | $3434 | $3840 | $51 421 | $51 421 | $3832 | $4707 |
| Average tracing distance (km) | 5 | 25 | $3482 | $3639 | $20 629 | $82 213 | $3678 | $4534 |
| Probability lost to follow-up among non-ART-eligible patients | 0.3 | 0.7 | $4006 | $3114 | $54 360 | $48 482 | $4513 | $3698 |
| Probability positive (PR) | 0.51 | 0.77 | $3912 | $3174 | $51 421 | $51 421 | $4430 | $3750 |
| Cost of ART + care | $228 | $342 | $3207 | $3918 | $53 761 | $49 081 | $3783 | $4433 |

CN, contract notification; IP, index partners; PN, provider notification; PR, passive referral.

*Only parameters with a CN or PN ICER difference >$650 listed.
Figure 2  ICER planes. (a) Contract notification vs passive referral. (b) Provider notification vs contract notification. (c) Provider notification vs passive referral. The probabilistic sensitivity analysis simultaneously varies the input parameters across a given range of values from the parameter's distribution. With each draw, a new incremental cost and incremental effectiveness is calculated, as compared with the next least expensive arm. The resulting point estimates represent the ICERs of the 5000 draws executed with probabilistic sensitivity analyses. In (a) contract notification is compared with passive referral. In (b) the next most expensive option (provider notification) is compared with contract notification. Finally, in (c) we compare provider notification with passive referral.
A small percentage of persons who test negative with traditional antibody tests will actually be in the highly infectious stage of acute HIV infection (AHI) (Pilcher et al. 2004; Powers et al. 2007; Brown et al. 2011; Pilcher et al. 2007). AHI testing is not routinely available in STI clinics and these patients will be misclassified as HIV negative. In this scenario, 3% of patients who tested negative were assigned transmission probabilities consistent with AHI (0.178, range 0.09–0.25) (Holllingsworth et al. 2008; Brown et al. 2011). Including AHI as an infection state among partners who tested antibody negative did not qualitatively alter our results.

**Discussion**

To combat the HIV epidemic in sub-Saharan Africa, cost-effective, acceptable and feasible interventions to reduce HIV transmission are necessary. Currently, substantial efforts are being directed towards prevention strategies that require significant logistical effort and expense, such as pre-exposure prophylaxis and provision of ART for prevention. But active partner notification, a simple, effective and easily implementable strategy, has been largely neglected, relying solely on passive referral and HIV status disclosure.

We have demonstrated that provider and contract notification for HIV compare favourably to existing interventions in terms of cost per HIV case averted, and may be cost-effective strategies for identifying new cases and averting subsequent infections in Malawi (Sweat et al. 2004; Menzies et al. 2009). In our model, provider and contract notification cost only $28 and $10 more than passive referral, per new case identified. Using a motorbike for transportation reduces these costs further to only an additional $11 (provider) and $3 (contract) per new case identified, compared with passive referral. Contract and provider notification were more effective than passive referral in identifying cases and averting secondary transmissions over a wide range of probability estimates. This work builds upon our previous trial which demonstrated a high yield of provider-based notification strategies with minimal adverse consequences (Brown et al. 2011).

Our outcomes, in terms of cost per partner tested and cost per new HIV case identified, compare favourably to other HTC strategies. In Uganda, comparing stand-alone, hospital-based, household-member and door-to-door HTC, cost per HTC client ranged from $8.29 (door-to-door) to $19.26 (stand-alone) (2007 US$) (Menzies et al. 2009), comparable to the costs of provider or contract referral in 2010 US$. However, the cost per HIV infection identified observed in Uganda was much higher than the cost per HIV infection identified estimated in the model, ranging from $43 for hospital-based HTC to $232 for household-member HTC. We observed a cost per new HIV positive diagnosis of $36 (provider) and $18 (contract), demonstrating the efficiency of identifying new positives in the high-risk population of partners of HIV-positive indexes. These findings likely generalize to other urban STI clinics in sub-Saharan Africa. Key parameters in our study, including partner return rates and prevalence of infection, are consistent with results of partner notification in Cameroon, where more than 56% of partners were tested through provider notification and 51% of partners tested were HIV positive, comparable to the 64% who tested positive in the Malawian trial (Muffih et al. 2009; Brown et al. 2011). Our parameter estimates and model results may be less applicable to rural settings given potentially different HIV prevalence, partnership patterns and tracing distances and associated costs.

Despite the compelling outcomes of the cost per new case identified, the cost-effectiveness of these provider-initiated partner notification strategies compared with passive referral is less certain as no accepted cost-effectiveness threshold exists for cost per infection averted. The commonly accepted World Health Organization (WHO) standards of <3 times GDP per capita as cost effective and <1 times GDP per capita as highly cost-effective relate to dollar per quality-adjusted life year outcomes. Importantly, evaluating cost-effectiveness based on country-specific ability to pay may not apply to the poorest countries, especially when most resources for HIV prevention and treatment are provided by external donors (Haacker 2008). Cost-effectiveness of provider-initiated partner notification strategies is better assessed through comparison with similar prevention strategies which evaluate averted infections, such as the use of nevirapine for prevention of mother-to-child transmission (PMTCT). This strategy is a widely adopted policy across sub-Saharan Africa and its cost per infection averted compares favourably with those ICERs observed in this analysis: a 2004 study found that the cost per infant case averted ranged from $1808 (Botswana) to $9258 (Côte d’Ivoire) (2000 US$) (Sweat et al. 2004). Further contextualizing the outcomes from this study to the Malawian setting, an evaluation of PMTCT from two Malawi health centres identified an ICER of $998 per infant case averted (2007 US$) (Orlando et al. 2010). Another Malawi-based cost-effectiveness analysis evaluated the opportunity to avert HIV infections through expanded treatment for STI among high-risk males, estimating an ICER of $15.42 per HIV case averted (2000 US$) (Price et al. 2006). Importantly, policy makers must consider the cost-effectiveness of alternative HIV-prevention strategies and the potential ethical obligations to inform persons who have been exposed to an HIV-infected partner.

Our findings are likely a conservative estimate of the cost-effectiveness associated with provider-assisted notification strategies. The model permits only a single transmission for each HIV-positive person in serodiscordant partnerships. This restriction underestimates the total number of transmissions that may be attributed to an individual, as persons may have multiple partners. We selected conservative estimates for behaviour change within serodiscordant couples based on observed rates of protective behaviour (Kennedy et al. 2010), and did not include any behaviour change for partners who test positive. The model also addresses only the first year after diagnosis, which will underestimate future transmission events if behaviour change is sustained. In addition, we did not explicitly model additional expenses, such as hospitalizations.
and lost productivity. Incorporation of these expenses would improve the cost-effectiveness of strategies that linked persons into care earlier. Although the cost per new case identified was higher with the provider-based notification strategies, earlier entry into care may be associated with considerable future savings. Costs due to hospitalization and outpatient visits are reduced when ART is initiated prior to an AIDS-defining illness (Harling and Wood 2007). Other costs associated with delayed linkage into care, such as lost productivity, are difficult to capture, but their omission from this evaluation likely leads to a conservative assessment of cost-effectiveness.

As a policy model intended to inform policy makers regarding the potential consequences of incorporating different notification strategies into existing voluntary HIV counselling and testing programmes, all costs are limited to a 1-year time frame—appropriate for budget planning, but limited in that we are not able to account for costs or transmissions that occur outside of this time frame. The appropriate strategy and feasible scalability of a provider-initiated partner notification programme will vary by setting, and staffing constraints are not considered in this model. However, clinic catchment area and associated tracing distances, which may vary clinic-to-clinic, had only a minor effect on estimated ICERs. The acceptability of provider-based partner notification in the urban STI clinic setting was encouraging, with only 11% refusal in the initial trial (Brown et al. 2011). However, if index cases were unwilling to provide partner names or locator information, the estimated cost-effectiveness of provider-initiated partner notification programmes would be less favourable. Importantly, among patients who refused trial participation, 20% refused for reasons related to fear or unwillingness to notify partners, which translates to approximately 2% of all potential participants.

Despite robust, trial-based data, our model assumptions introduced uncertainty into cost-effectiveness estimates. We modelled HIV protective behaviour as an all-or-nothing change for 35% of the HIV-negative partners. We would see a similar result if a higher percentage of persons ‘reduced’ their risky behaviour after testing, as suggested by recent meta-analysis focused on HIV behaviour change in low- and middle-income countries (Kennedy et al. 2010). Lower rates of behaviour change would reduce the benefits of provider and contract notification relative to passive referral; higher rates would increase the benefit. We evaluated the impact of behaviour change in sensitivity analyses—behaviour change among partners testing HIV negative had a meaningful impact on estimated cost-effectiveness: varying the probability of behaviour change from 20 to 50% changes the estimated ICER to $1050 for contract notification compared with passive referral. Importantly, in the partner notification setting, partners who test negative are now likely aware of their being in a serodiscordant couple, which is associated with high rates of protective behaviour change (Allen et al. 1992, 2003; Denison et al. 2008; Celum et al. 2010; Cohen et al. 2011; Hughes et al. 2012; Rosenberg et al. 2012). Even if the partnership has dissolved, this testing scenario may have a more substantial impact on reducing risk behaviours as the individual has been directly informed of HIV exposure. Not shown are scenario analyses in which partners who test HIV positive are also given a 35% probability of protective behaviour change, thereby reducing their likelihood of transmitting to any HIV-negative partners. Behaviour change among this group decreased the ICER comparing contract notification to passive referral by ∼$700.

Our primary effectiveness outcome depends on the reliability of partner return rates and the HIV prevalence among returning and non-returning partners. The former was empirically measured by the trial, whereas the latter relied on our modelling an assumed rate of infection. Data to support higher or lower rates of infection among partners who did not return are not available, and compelling arguments can be made for both scenarios. We accounted for this uncertainty by incorporating a wide probability distribution. Some notified partners may have sought alternative testing locations, but the likelihood of partners seeking testing outside of the trial-designated clinic was minimized by co-ordinating with area STI clinics and using study-specific referral cards (Brown et al. 2011). According to the most recent available data, annual testing rates for the general population in Lilongwe are ∼14% (MOH 2007). We assessed the influence of the underlying natural testing rate on the model in sensitivity analyses (not shown). There was no meaningful change in estimated ICERs when this testing rate was incorporated into the model for persons who were not notified and, therefore, not tested through one of the three partner notification strategies. As such, all testing costs are included in this model as they are considered incremental expenses that would not otherwise be incurred. Scenario analyses in which these costs were excluded had only a minor effect on ICERs. Accurately estimating transmission rates relies on properly describing infectiousness of HIV-positive partners. HIV transmission is dynamic, varying by gender, partner susceptibility, stage of infection, viral characteristics and treatment. We modelled transmission variability as amplified by stage of infection, but did not account for other biological co-factors that contribute to transmission probability differences, such as STIs. We accounted for the reduced infectiousness for persons on ART, assuming all eligible persons immediately began therapy, as occurred in our trial, estimating retention in care which is relevant for transmission probabilities and ART-associated costs (Wilson et al. 2008; Del Romero et al. 2010; Donnell et al. 2010; Brown et al. 2011; Rosen and Fox 2011). Accounting for the heterogeneity of ART efficacy across individuals was beyond the scope of this study and differential survival projections are not included in this model. The effect that delayed ART initiation and differential survival would have on model estimates is unknown as it would reduce costs in all arms, but would also affect expected transmissions.

Partner notification is a logistically feasible HIV prevention intervention that has been underutilized in sub-Saharan Africa, and may be a cost-effective addition to existing testing and prevention strategies. Alternative solutions that identify persons earlier in the course of infection may include community- or home-based testing, and these approaches should be considered in future cost-effectiveness analyses. Many of the most promising prevention interventions require reaching large segments of the population for HIV testing. Active partner notification, either contract or provider-based, provides an effective, efficient and likely cost-effective strategy in a resource-limited setting. Increasing efforts to reach partners of
known HIV-infected persons is a reasonable and appropriate adjunct to any HIV prevention programme.

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Endnote

1 Data obtained from UNC Project administrators, Lilongwe, Malawi.

References

Allen S, Meinzen-Derr J, Kautzman M et al. 2003. Sexual behavior of HIV discordant couples after HIV counseling and testing. AIDS 17: 733–40.
Allen S, Tice J, Van de Perre P et al. 1992. Effect of serotesting with counselling on condom use and seroconversion among HIV discordant couples in Africa. BMJ 304: 1605–9.
Antelman G, Daaya S, Mbwambo J, Fawzi W, Msamanga GI, Hunter D, Smith Fawzi MC. Year. Factors related to disclosure of an HIV-positive test result to a sexual partner or any other confidant in Dar es Salaam, Tanzania. In: Conference on Global Strategies for Prevention of HIV Transmission for Mothers to Infants. Canada: 1999 Montreal.
Baeten JM, Donnell D, Ndase P et al. 2012. Antiretroviral prophylaxis for HIV prevention in heterosexual men and women. New England Journal of Medicine 367: 399–410.
Brewer DD. 2005. Case-finding effectiveness of partner notification and cluster investigation for sexually transmitted diseases/HIV. Sexually Transmitted Diseases 32: 78.
Briggs AH. 2000. Handling uncertainty in cost-effectiveness models. Pharmacoeconomics 17: 479–500.
Brown L, Miller WC, Kamanga G et al. 2011. HIV partner notification is effective and feasible in sub-Saharan Africa: opportunities for HIV treatment and prevention. Journal of Acquired Immune Deficiency Syndrome 56: 437–42.
CDC. 2003. HIV Partner Counseling and Referral Services. Atlanta: CDC. http://www.cdc.gov/hiv/topics/prev_prog/ahp/resources/guidelines/Interim_partnercounsel.htm, accessed 10 December 2010.
CDC. 2008. Sexually Transmitted Diseases Surveillance. CDC. http://www.cdc.gov/std/stats08/tables.htm, accessed 20 November 2009.
Celum C, Wald A, Lingappa JR et al. 2010. Acyclovir and transmission of HIV-1 from persons infected with HIV-1 and HSV-2. New England Journal of Medicine 362: 427–39.
Cohen MS, Chen YQ, McCauley M et al. 2011. Prevention of HIV-1 infection with early antiretroviral therapy. New England Journal of Medicine 365: 493–505.
Crepaz N, Lyles CM, Wolitski RJ et al. 2006. Do prevention interventions reduce HIV risk behaviours among people living with HIV? A meta-analytic review of controlled trials. AIDS 20: 143–57.
Del Romero J, Castilla J, Hernando V, Rodriguez C, Garcia S. 2010. Combined antiretroviral treatment and heterosexual transmission of HIV-1: cross sectional and prospective cohort study. BMJ 340: c2205.
Denison JA, O’Reilly KR, Schmid GP, Kennedy CE, Sweat MD. 2008. HIV voluntary counseling and testing and behavioral risk reduction in developing countries: a meta-analysis, 1990–2005. AIDS and Behavior 12: 363–73.
Donnell D, Baeten JM, Kiarie J et al. 2010. Heterosexual HIV-1 transmission after initiation of antiretroviral therapy: a prospective cohort analysis. Lancet 375: 2092–8.
Efficacy of voluntary HIV-1 counselling and testing in individuals and couples in Kenya, Tanzania, and Trinidad: a randomised trial. The Voluntary HIV-1 Counseling and Testing Efficacy Study Group. Lancet 356: 103–12.
European Partner Notification Study G. 2001. Recently diagnosed sexually HIV-infected patients: seroconversion interval, partner notification period and a high yield of HIV diagnoses among partners. Quarterly Journal of Mathematics 94: 379.
Financial Management Service. Bureau of the US Department of the Treasury. Washington DC. http://www.fms.treas.gov/intn.html, accessed 30 December 2010.
Girardi E, Sabin CA, Monforte AD. 2007. Late diagnosis of HIV infection: epidemiological features, consequences and strategies to encourage earlier testing. Journal of Acquired Immune Deficiency Syndrome 46(Suppl 1): S3–8.
Gold MR, Siegel JE, Russell LB, Weinstein MC (eds). 1996. Cost-Effectiveness in Health and Medicine. New York: Oxford University Press.
Golden MR, Dombrowski JC, Wood RW, Fleming M, Harrington RD. 2009. A controlled study of the effectiveness of public health HIV partner notification services. AIDS 23: 133–5.
Haacker M. 2008. Financing the response to AIDS: some fiscal and macroeconomic considerations. AIDS 22(Suppl 1): S17–22.
Harling G, Wood R. 2007. The evolving cost of HIV in South Africa: changes in health care cost with duration on antiretroviral therapy for public sector patients. Journal of Acquired Immune Deficiency Syndrome 45: 348–54.
Hogben M, McNally T, McPheeters M, Hutchinson AB. 2007. The effectiveness of HIV partner counseling and referral services in increasing identification of HIV-positive individuals a: systematic review. American Journal of Preventive Medicine 33: S89–100.
Hollingsworth TD, Anderson RM, Fraser C. 2008. HIV-1 transmission, by stage of infection. Journal of Infectious Diseases 198: 687–93.
Hughes JP, Baeten JM, Lingappa JR et al. 2012. Determinants of per-coital-act HIV-1 infectivity among African HIV-1-serodiscordant couples. Journal of Infectious Diseases 205: 358–65.
Kamoto K, Schouten E. 2007. 100,000 People Started on ART with Very Limited Human Resources: Experiences from Malawi, Lilongwe, Malawi: HIV/AIDS Unit, Ministry of Health.
Kennedy CE, Medley AM, Sweat MD, O’Reilly KR. 2010. Behavioural interventions for HIV positive prevention in developing countries: a...
systematic review and meta-analysis. *Bulletin of the World Health Organization* **88**: 615–23.

Kilewo C, Massawe A, Lyamuwa E, Kalokola V, Semali I, Karisson K, Mhalu F, Biferfield G. Year. HIV testing of pregnant women in sub-Saharan Africa: the PETRA experience in Dar es Salaam, Tanzania. In: *Xth International Conference on AIDS and STDs in Africa*. Zambia: 1999 Lusaka.

Kissinger PJ, Nicollai LM, Magnus M et al. 2003. Partner notification for HIV and syphilis: effects on sexual behaviors and relationship stability. *Sexually Transmitted Diseases* **30**: 75–82.

Landis SE, Schoenbach VJ, Weber DJ et al. 1992. Results of a randomized trial of partner notification in cases of HIV infection in North Carolina. *New England Journal of Medicine* **326**: 101–6.

Leynaert B, Downs AM, de Vincenzi I. 1998. Heterosexual transmission of human immunodeficiency virus: variability of infectivity throughout the course of infection. European Study Group on Heterosexual Transmission of HIV. *American Journal of Epidemiology* **148**: 88–96.

Maher JE, Peterson J, Hastings K et al. 2000. Partner violence, partner notification, and women’s decisions to have an HIV test. *Journal of Acquired Immune Deficiency Syndrome* **25**: 276–82.

Malawi Country Report. Global Finance. http://www.gfmag.com/gdp-data-country-reports/227-malawi-gdp-country-report.html, accessed 27 October 2010.

Maman S, Mbambo J, Hogan NM, Kilonzo GP, Sweat M. 2001. Women’s barriers to HIV-1 testing and disclosure: challenges for HIV-1 voluntary counselling and testing. *AIDS Care* **13**: 595–603.

Marcus JL, Bernstein KT, Klausner JD. 2009. Updated outcomes of partner notification for human immunodeficiency virus. San Francisco, 2004-2008. *AIDS* **23**: 1024–6.

Marks G, Crepaz N, Janssen RS. 2006. Estimating sexual transmission of HIV from persons aware and unaware that they are infected with the virus in the USA. *AIDS* **20**: 1447.

Mathews C, Coetzee N, Zwarenstein M et al. 2002. A systematic review of strategies for partner notification for sexually transmitted diseases, including HIV/AIDS. *International Journal of STD & AIDS* **13**: 285–300.

Menzies N, Abang B, Wanyenze R et al. 2009. The costs and effectiveness of four HIV counseling and testing strategies in Uganda. *AIDS* **23**: 395–401.

Metsch LR, Pereyra M, Messinger S et al. 2008. HIV transmission risk behaviors among HIV-infected persons who are successfully linked to care. *Clinical Infectious Diseases* **47**: 577–84.

MOH. 2007. Report of a Country-wide Survey of HIV/AIDS Services in Malawi for the Year 2006. Lilongwe: HIV Unit, Department of Clinical Services, MOH.

Muennig P. 2008. Cost-effectiveness Analysis in Health: A Practical Approach. San Francisco: John Wiley & Sons.

Muffly PT, Forguey G, Welty T, Welty S, Harrington C. 2009. Integrated Contact/Tracing Partner Notification in Cameroon: a feasible HIV infection risk reduction intervention for resource-poor settings. *International AIDS Society Conference*. Cape Town, South Africa.

Orlando S, Marazzi MC, Mancinelli S et al. 2010. Cost-effectiveness of using HAART in prevention of mother-to-child transmission in the DREAM-Project Malawi. *Journal of Acquired Immune Deficiency Syndrome* **55**: 631–4.

Pilcher CD, Joaki G, Hoffman IF, Martinson FE, Mapanje C, Stewart P, Powers KA, Galvin S, Chilongozi D, Gama S, Price MA, Fiscus SA, Cohen MS. 2007. Amplified transmission of HIV-1: comparison of HIV-1 concentrations in semen and blood during acute and chronic infection. *AIDS* **21**: 1723–30.

Pilcher CD, Price MA, Hoffman IF et al. 2004. Frequent detection of acute primary HIV infection in men in Malawi. *AIDS* **18**: 517–24.

Powers KA, Miller WC, Pilcher CD et al. 2007. Improved detection of acute HIV-1 infection in sub-Saharan Africa: development of a risk score algorithm. *AIDS* **21**: 2237–42.

Price MA, Stewert SR, Miller WC et al. 2006. The cost-effectiveness of treating male trichomoniasis to avert HIV transmission in men seeking sexually transmitted disease care in Malawi. *Journal of Acquired Immune Deficiency Syndrome* **43**: 202–9.

Rahman M, Fukui T, Asai A. 1998. Cost-effectiveness analysis of partner notification program for human immunodeficiency virus infection in Japan. *Journal of Epidemiology* **8**: 123–8.

Rosen S, Fox MP. 2011. Retention in care between testing and treatment in sub-Saharan Africa: a systematic review. *PLoS Medicine* **8**: e1001056.

Rosenberg N, Pettifor A, Delany-Moore S et al. 2012. Couples HIV testing and counseling leads to immediate and sustained consistent condom use among South African stable HIV discordant couples. *International AIDS Conference*. Washington DC.

Rothenberg KH, Paskey SJ, Reuland MM, Zimmerman SJ, North RL. 1995. Domestic violence and partner notification: implications for treatment and counseling of women with HIV. *Journal of American Medical Women's Association* **50**: 87–93.

Semrau K, Kuhn L, Vwalika C et al. 2005. Women in couples antenatal HIV counseling and testing are not more likely to report adverse social events. *AIDS* **19**: 603–9.

Shrestha RK, Begley EB, Hutchinson AB et al. 2009. Costs and effectiveness of partner counseling and referral services with rapid testing for HIV in Colorado and Louisiana, United States. *Sexually Transmitted Diseases* **36**: 637–41.

Sweat MD, O’Reilly KR, Schmid GP, Denison J, de Zovya I. 2004. Cost-effectiveness of nevirapine to prevent mother-to-child HIV transmission in eight African countries. *AIDS* **18**: 1661–71.

Temmerman M, Ndinya-Achola J, Ambani J, Piot P. 1995. The right not to know HIV-test results. *Lancet* **345**: 969–70.

UNAIDS. 2009. *AIDS Epidemic Update*. Joint United Nations Programme on HIV/AIDS (UNAIDS) & WHO. Geneva, Switzerland.

Varghese B, Peterman TA, Holgrave DR. 1999. Cost-effectiveness of counseling and testing and partner notification: a decision analysis. *AIDS* **13**: 1745–51.

Wawer MJ, Gray RH, Sewankambo NK et al. 2005. Rates of HIV-1 transmission per coital act, by stage of HIV-1 infection, in Rakai, Uganda. *Journal of Infectious Diseases* **191**: 1403–9.

Weinhardt LS, Carey MP, Johnson BT, Bickham NL. 1999. Effects of HIV counseling and testing on sexual risk behavior: a meta-analytic review of published research, 1985-1997. *American Journal of Public Health* **89**: 1397–405.

WHO. 2008. *Epidemiological Fact Sheet on HIV and AIDS: Core Data on Epidemiology and Response*. Geneva, Switzerland: WHO Press.

Wilson DP, Law MG, Grulich AE, Cooper DA, Kaldor JM. 2008. Relation between HIV viral load and infectiousness: a model-based analysis. *Lancet* **372**: 314–20.

Zachariah R, Taylor Smith K, Manzi M et al. 2010. High loss to follow up rate among individuals in urgent need of antiretroviral treatment in Malawi and Kenya. Cohort reporting that does not include this group is biased and misleading! Vienna: IAS.

Zanera D, Miteka I. 2005. *Chapter 11: HIV/AIDS and Other Sexually Transmitted Infections. Malawi Demographic and Health Survey*, Zomba, Malawi: National Statistical Office.