Title

Partner services in adults with acute and early HIV infection

Journal

AIDS, 31(2)

ISSN

0269-9370

Authors

Green, Nella
Hoenigl, Martin
Chaillon, Antoine
et al.

Publication Date

2017-01-14

DOI

10.1097/qad.0000000000001308

Peer reviewed

Partner services in adults with acute and early HIV infection

Nella Green[a], Martin Hoenigl[a,b,c], Antoine Chaillon[a], Christy M. Anderson[a], Sergei L. Kosakovsky Pond[d], Davey M. Smith[a,e] and Susan J. Little[a]

Background: To examine the yield of HIV partner services provided to persons newly diagnosed with acute and early HIV infection (AEH) in San Diego, United States.

Design: Observational cohort study.

Methods: The study investigated the yield (i.e. number of new HIV and AEH diagnoses, genetically linked partnerships and high-risk uninfected partners) of partner services (confidential contact tracing) for individuals with AEH enrolled in the San Diego Primary Infection Resource Consortium 1996–2014.

Results: A total of 107 of 574 persons with AEH (19%; i.e. index cases) provided sufficient information to recruit 119 sex partners. Fifty-seven percent of the 119 recruited partners were HIV infected, and 33% of the 119 were newly HIV diagnosed. Among those newly HIV diagnosed, 36% were diagnosed during AEH. There were no significant demographic or behavioral risk differences between HIV-infected and HIV-uninfected recruited partners. Genetic sequences were available for both index cases and partners in 62 partnerships, of which 61% were genetically linked. Partnerships in which both index case and partner enrolled within 30 days were more likely to yield a new HIV diagnosis ($P = 0.01$) and to be genetically linked ($P < 0.01$).

Conclusion: Partner services for persons with AEH within 30 days of diagnosis represents an effective tool to find HIV-unaware persons, including those with AEH who are at greatest risk of HIV transmission.

AIDS 2017, **31**:287–293

Keywords: acute and early HIV infection, contact tracing, epidemiology, HIV transmission, men who have sex with men

Introduction

Universal HIV testing is a cornerstone in efforts to achieve epidemic control as HIV-infected and unaware people are associated with the majority of HIV transmission events [1]. In particular, during acute and early HIV infection (AEH), people who are unaware of their HIV status represent a subgroup with a disproportionate risk of HIV transmission due to high HIV viral loads [2–4], ongoing sexual risk behaviors [2] and greater per-contact infectivity [5].

The CDC recommends provision of confidential partner services to provide HIV risk reduction education and HIV testing to the recent sex or needle-sharing partners of newly HIV diagnosed people [6]. By linking recently

[a]Division of Infectious Diseases, University of California San Diego (UCSD), San Diego, California, USA, [b]Section of Infectious Diseases and Tropical Medicine, [c]Division of Pulmonology, Department of Internal Medicine, Medical University of Graz, Graz, Austria, [d]Institute for Genomics and Evolutionary Medicine, Temple University, Philadelphia, Pennsylvania, and [e]Veterans Affairs Healthcare System, San Diego, California, USA.

Correspondence to Martin Hoenigl, MD, Antiviral Research Center, Division of Infectious Diseases, Department of Medicine, University of California, San Diego, 200 West Arbor Drive #8208, San Diego, CA 92103, USA.

Tel: +1 619 543 8080; fax: +1 619 543 5066; e-mail: mhoenigl@ucsd.edu
Received: 1 September 2016; revised: 8 October 2016; accepted: 17 October 2016.

DOI:10.1097/QAD.0000000000001308

ISSN 0269-9370

exposed persons to testing and treatment, this public health intervention has been used to limit the spread of sexually transmitted infections (STIs), such as syphilis and gonorrhea, since the early 20th century [7]. In the setting of HIV, however, partner services has had its limitations. In 2006, Katz *et al.* [8] estimated that fewer than half of newly HIV-diagnosed persons received partner services at public health departments across the United States. Reasons include that partner services is not mandated by law for HIV infection and more importantly that HIV remains a highly stigmatizing condition with significant implications for direct or indirect disclosure. Not only is partner services underutilized, but it can be limited in finding HIV unawares in the setting of newly diagnosed chronic HIV infection in which persons are often required to recall partners from several years prior [7,9]. In 2007, the Task Force on Community Preventive Services, in reviewing the efficacy of partner services, showed that 20% (range 14–26%) of all referred partners were newly diagnosed with HIV [10].

Persons with AEH likely represent a group particularly appropriate for partner services, as recall of recent sexual or needle-sharing partners may be more likely to identify putative transmission partners (i.e. as defined by similar HIV genetic sequence). Studies of partner services in the setting of recent HIV infection are limited [11,12], but demonstrate a greater yield of new HIV diagnoses in the setting of newly diagnosed acute HIV infection (AHI) as compared with partner services provided to chronically HIV-infected persons.

We examined the yield of HIV partner services provided to persons newly diagnosed with AEH in San Diego for identification of HIV-unaware persons, individuals with AEH, genetically linked partners [13,14] and HIV-uninfected individuals at high risk for acquiring HIV infection.

Materials and methods

Adults and adolescents (13 years of age or older) were offered confidential and free-of-charge screening for acute, early and established HIV infection at multiple community-based sites in San Diego as part of the San Diego Primary Infection Resource Consortium (SD PIRC) from 1996 to 2014 [15,16]. Before 2007, a quantitative HIV RNA (Amplicor HIV Monitor; Roche Diagnostic Systems, Indianapolis, Indiana, USA) was performed in HIV antibody–negative persons presenting with signs or symptoms of AEH and behavioral risks for HIV infection (i.e. risk-based screening for AHI but universal screening for HIV). Beginning in 2007, HIV nucleic acid testing (Procleix HIV-1/HCV Assay; Chiron, Emeryville, California, USA; Genprobe, San Diego, California, USA) was provided to all HIV antibody–negative persons regardless of symptoms and exposures (i.e. universal screening for AHI) [16–20]. AHI was defined by a negative or indeterminate HIV antibody test in the presence of detectable HIV-1 RNA, corresponding to Fiebig stages I–II. Early HIV infection was characterized by using one of the available assays to estimate recency [Vironostika HIV-1 enzyme immunoassay (EIA); Durham, North Carolina, USA) [21], Less-Sensitive or Detuned Vitros anti-HIV 1+2 assay (Ortho-Clinical Diagnostics, Rochester, New York, USA) [22] and limiting antigen [23]] and defined as HIV antibody+/detuned HIV antibody consistent with infection less than 170 days. Consenting antiretroviral (ART)-naive individuals with AEH were offered enrollment and longitudinal follow-up in the observational SD PIRC study. Prompt linkage to HIV primary care services was provided for all clients. Routine clinical laboratories and HIV drug resistance testing were performed at baseline; demographic and behavioral risk data were collected for all individuals. Longitudinal follow-up included visits at weeks 2, 4, 8, 12 and every 24 weeks thereafter.

HIV partner services were offered to all AEH clients (index cases) and included education and counseling to elicit information about recent sex or needle-sharing partners [6]. Index cases were offered 'self-disclosure' (i.e. index case was trained to disclose their HIV status to their partners and refer their partners to our study for HIV testing), 'dual-disclosure' (i.e. partners got notified by the index and one trained study staff member during an appointment) and 'third-party notification' (i.e. partners got notified by trained study staff, identities of the index were not disclosed to the partners) for recruiting their recent sex or needle-sharing contacts. Study staff providing partner services received structured partner services training by the California Department of Public Health or Centers for Disease Control and Prevention. These structured trainings (duration 2–3 days) were repeated by our study staff every 5 years. The trainings included how to elicit partners from index cases, including prompts and reinterviews, and delivering exposure notifications to partners. Privacy concerns were taken very seriously, in particular when an index case chose third-party notification (e.g. index cases and partners were not scheduled on the same day for study visits). Partners successfully contacted (recruited partners) were offered free-of-charge HIV testing and counseling through SD PIRC or a testing facility of their choice and linkage to prevention and treatment services. Those with positive HIV test results who reported unknown or negative HIV serostatus before HIV testing were defined as newly HIV diagnosed, whereas those who reported positive serostatus or found (by screening local clinical and research HIV repositories) to have been diagnosed previously were defined as previously diagnosed. All recruited partners who underwent HIV testing and counseling with the SD PIRC provided behavioral risk information, and recruited partners identified with AEH

Table 1. Number of index cases, recruited partners and their unique partnerships.

	Index cases ($n=107$)	Unique partnerships ($n=128$)
Identified one recruited partner (*n*, %)	90 (84%)	90 (70%)
Identified two recruited partners (*n*, %)	13 (12%)	26 (20%)
Identified three recruited partners (*n*, %)	4 (4%)	12 (9%)
	Recruited partners ($n=119$)	**Unique partnerships ($n=128$)**
Identified by one index case (*n*, %)	112 (94%)	112 (88%)
Identified by two index cases (*n*, %)	6 (5%)	12 (9%)
Identified by four index cases (*n*, %)	1 (1%)	4 (3%)

were also offered enrollment into SD PIRC as index clients (with subsequent provision of partner services). Partnerships were characterized as genetically linked if the HIV population sequence from an index case and their recruited partner were less than or equal to 1.5% genetically different using the Tamura-Nei model (TN93) [24]. The study focused on sex or needle-sharing partners recruited within 6 months of diagnosis of the index case.

Statistical analysis was performed using SPSS version 22 (IBM Corp., Armonk, New York, USA) and SAS 9.3 (SAS Institute, Cary, North Carolina, USA). The efficacy of partner services provided to AEH clients was assessed by the number of index cases needed to interview (NNTI) to identify recruited partners: for HIV/STI testing, newly diagnosed with HIV infection, AEH infection and genetically linked index and recruited partners. We compared demographic and behavioral characteristics between HIV-infected and HIV-uninfected recruited partners by using two-tailed *t* tests and two-tailed χ^2 analyses. Because both index and recruited partners were occasionally represented in multiple different partnerships, mixed-effects logistic modeling was performed for genetic linkage and new HIV diagnoses.

The UCSD Human Research Protections Program approved the study protocol, consent and all study-related procedures. All study participants provided voluntary, written informed consent before any study procedures were undertaken.

Results

A total of 574 ART-naive individuals were newly diagnosed with AEH and offered partner services between 1996 and 2014. Among those index clients, 107 (18.6%) provided contact information sufficient to successfully identify and test partner(s) [6/87 (7%) index clients diagnosed with AEH between 1996 and 2000, 33/128 (26%) between 2001 and 2004, 41/192 (21%) between 2005 and 2009 and 27/167 (16%) between 2010 and 2014]. These 107 index cases identified 119 recruited partners and 128 distinct partnerships (Table 1). Only for two recruited partners, needle sharing was identified as the most likely mode of HIV transmission (Table 2). There were nine individuals who served as both index case and recruited partner in distinct partnerships (Table 2).

Index case and recruited partner demographics were not significantly different. The majority of both, index cases and recruited partners were non-Hispanic white (59 and 64%, respectively) men (96 and 95%, respectively), MSM (94 and 92%, respectively). The median age of index cases and recruited partners was not significantly different (30 and 32 years of age, respectively) (Table 2). Behavioral risks were also not significantly different between AEH index cases and recruited partners (both HIV-infected and HIV-uninfected). In addition, there were no significant demographic or behavioral risk differences between HIV-infected and HIV-uninfected recruited partners except for age (Table 3).

Of the 128 distinct partnerships identified, 52 (40.6%) were HIV serodiscordant, and the remaining 76 (59.4%) were HIV seroconcordant. Paired HIV resistance test sequences were available in 62 of 76 (81.6%) seroconcordant partnerships and demonstrated genetic linkage in 38 (61.2%) of these partnerships. Genetic linkage between the index case and recruited partner was used to identify putative transmission pairs and was observed in 50% of recruited partners with AEH and 50% of recruited partners with chronic HIV infection. Behavioral risks were not significantly different between index cases who were part of a genetic cluster (i.e. $\geq$2 connected individuals) and those who were not (data not shown).

Evaluation of the time between identification of the index case and recruited partners showed that those recruited partners enrolled within 30 days of their index (72.7% of all partnerships and 82.3% of seroconcordant partnerships) were significantly more likely to be newly diagnosed with HIV ($P=0.01$) and genetically linked to their index ($P<0.01$) than partners identified later. The results were robust to whether partnerships were treated as independent or were corrected for belonging to multiple partnerships in the mixed-effects framework.

Table 2. Baseline demographic, laboratory and risk behavior characteristics for index cases with acute or early HIV infection and recruited partners.

	Index cases $n=98$	Recruited partners $n=110$	Both index case and recruited partner $n=9$	P value for comparing index[a] cases and recruited partners
Demographics				
Age (median, IQR; *n*)	30 (24–37; 98)	32 (26–39; 107)	28 (23–39; 9)	0.17
Male sex (%, *n*)	95.9 (93/97)	95.2 (98/103)	100.0 (9/9)	>0.2
Race/ethnicity				>0.2
White non-Hispanic	58.8 (57/97)	64.4 (65/101)	77.8 (7/9)	
Black non-Hispanic	5.2 (5/97)	5.9 (6/101)	0 (0/9)	
Hispanic	32.0 (31/97)	22.8 (23/101)	0 (0/9)	
Other (including multiracial)	4.1 (4/97)	6.9 (7/101)	22.2 (2/9)	
HIV transmission risk				
MSM (%, *n*)	93.7 (89/95)	92.2 (94/102)	100.0 (9/9)	>0.2
IDU transmission risk (%, *n*)	3.1 (3/98)	1 (1/100)	11.1 (1/9)	>0.2
Laboratory data at first visit				
$CD4^+$ cell count (cells/μl), (median, IQR; *n*)	504 (378–672; 98)	419 (294–595; 23)	543 (390–633; 9)	0.045
VL (HIV-1 RNA $\log_{10}$ copies/ml), (median, IQR; *n*)	4.9 (4.0–5.6; 98)	4.7 (3.8–5.2; 23)	5.4 (4.7–6.0; 9)	0.10
Self-reported risk behavior in prior 3 months				
Number of partners (median, IQR; *n*)	2 (1–5; 85)	3 (1–6; 88)	5 (3–6; 7)	>0.2
Condom use RAI (%, *n*)				
Always (100%)	11.7 (9/77)	17.3 (9/52)	33.3 (2/6)	>0.2
Usually (50–99%)	29.9 (23/77)	25.0 (13/52)	16.7 (1/6)	
Sometimes (1–49%)	20.8 (16/77)	26.9 (14/52)	16.7 (1/6)	
Never (0%)	37.7 (29/77)	30.8 (16/52)	33.3 (2/6)	
Methamphetamine use, any route (%, *n*)	22.9 (8/35)	21.1 (4/19)	20 (1/5)	>0.2
Any drug use, any route[b] (%, *n*)	36.6 (15/41)	31.6 (6/19)	20 (1/5)	>0.2

IDU, injection drug use; IQR, interquartile ratio; MSM, men who have sex with men; RAI, receptive anal intercourse; RPR, rapid plasma regain; VL, viral load.
[a]Persons who were both index case and recruited partner excluded from comparison.
[b]Excluding alcohol and cannabis.

Table 3. Baseline characteristics for HIV-uninfected recruited partners and HIV-infected recruited partners.

	Recruited partners HIV uninfected $n=51$	Recruited partners HIV infected $n=68$	P value[a]
Demographics			
Age (median, IQR; *n*)	34 (28–41; 48)	30 (26–35; 68)	0.040
Male sex (%, *n*)	91.7 (44/48)	98.4 (63/64)	0.16
Race/ethnicity (%, *n*)			>0.2
White non-Hispanic	68.9 (31/47)	65.1 (41/63)	
Black non-Hispanic	8.9 (4/47)	3.2 (2/63)	
Hispanic	17.8 (8/47)	23.8 (15/63)	
Other (including multiracial)	4.4 (4/47)	7.9 (5/63)	
HIV transmission risk			
MSM (%, *n*)	87.5 (42/48)	96.8 (61/63)	0.074
IDU transmission risk (%, *n*)	0 (0/46)	3.2 (2/63)	>0.2
Self-reported risk behavior in prior 3 months			
Number of partners (median, IQR; *n*)	3 (1–5; 41)	2 (1–6; 54)	>0.2
Condom use RAI (%, *n*)			0.031
Always (100%)	5 (1/20)	26.3 (10/38)	
Usually (50–99%)	25 (5/20)	23.7 (9/38)	
Sometimes (1–49%)	45 (9/20)	18.4 (7/38)	
Never (0%)	25 (5/20)	31.6 (12/38)	
Methamphetamine use, any route (%, *n*)	22.2 (2/9)	20 (3/15)	>0.2
Any drug use, any route[b] (%, *n*)	22.2 (2/9)	26.7 (4/15)	>0.2

IDU, injection drug use; IQR, interquartile ratio; MSM, men who have sex with men; RAI, receptive anal intercourse; RPR, rapid plasma regain; VL, viral load.
[a]Overlap excluded (two persons in separate partnerships: once as an HIV-uninfected partner and once as an HIV-infected partner).
[b]Excluding alcohol and cannabis.

The mean NNTI to successfully recruit a partner for testing (HIV positive or negative) was five (574/119) and 15 (574/39) to identify a newly HIV diagnosed partner. Overall, 68 of 119 (57.1%) recruited partners were HIV infected, with 39 of 68 (57%) newly HIV diagnosed and the remaining 29 (43%) previously aware of their HIV-infected status. Of the 39 newly HIV diagnosed partners, 36% ($n = 14$) were identified with AEH (NNTI = 41) and 64% ($n = 25$) had established HIV infection. Of the 29 recruited partners who were already aware of their HIV diagnosis, 72% ($n = 21$) had established HIV, whereas 28% ($n = 8$) were still in acute or early stage when presenting for the study (Fig. 1).

Discussion

We found that partner services for persons with AEH represents an effective tool to find HIV-unaware persons, particularly when partner services is performed within 30 days of diagnosis. Importantly, more than a third of the newly HIV-diagnosed recruited partners were still in the acute and early phases of HIV infection, that is the phase with the greatest risk of HIV transmission. Partner services also identified putative transmission partners, with genetically linked partners representing 61% of the seroconcordant partnerships. Finally, partner services identified a high-risk HIV-uninfected cohort, whose risk behaviors did not differ from those newly diagnosed with HIV infection.

The HIV epidemic is propagated by HIV unawares, particularly during the phase of AEH. We demonstrated that HIV screening within the sexual contact network of persons diagnosed with AEH is an effective strategy to identify HIV unawares in early stages of HIV infection. In this study, one out of three recruited partners was newly diagnosed with HIV infection and one out of seven with AEH. This was 12 times higher than the overall yield of voluntary community-based HIV screening of MSM with the SD PIRC (one out of 41 tests positive for HIV and one out of 87 positive for AEH), the HIV-screening program used to identify the index participants in this study [25]. Also, the recruited partners identified in this study represented a more high-yield cohort than previously documented [11,12]. In two prior studies of partner services in AHI [11,12], 7–10% of all recruited partners identified were newly diagnosed with HIV, as compared with 33% in this study. Partner services might contribute to broader public health goals to end the epidemic. Although we found a decrease over time in the number of recruited partners (26% of index cases identified partners between 2001 and 2004, whereas only 16% identified partners between 2010 and 2014), which may be explained in part by the success of anonymous, internet-based sexual networks [26], partner services continued to be high yield in terms of identifying HIV-positive individuals (67% of partners identified between 2010 and 2014 were HIV positive).

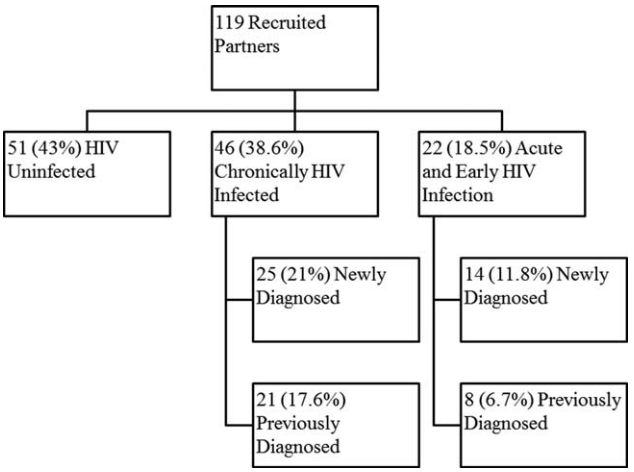

Fig. 1. Partner services yield in individuals diagnosed with acute or early HIV infection in San Diego from 1996 to 2014.

Another key finding was that the immediacy of partner services was essential. Partners identified in the first 30 days of a new AEH diagnosis were more likely to yield a new HIV diagnosis ($P = 0.01$) and a putative transmission link to the index case ($P < 0.01$). In addition, 29% of genetic linkages occurred in partnerships in which the recruited partner also had AEH, showing that partner services coupled with phylogenetic analysis could potentially be an effective tool in identifying and targeting real-time transmission outbreaks among AEH persons.

The HIV-uninfected recruited partners in this study reported behavioral risks that were comparable with AEH-infected index cases. Because they belonged to the sexual network of an individual with high infectivity, and because their risk behaviors did not differ from HIV-infected recruited partners, this group may represent ideal candidates for focused HIV-prevention services, including preexposure prophylaxis (PrEP).

Limitations of this study included the observational study design and the convenience sampling used to identify the study cohort. Further, this study was performed among MSM and in San Diego, among whom the HIV epidemic may differ from other areas of the world. Despite the fact that new HIV diagnoses within this studies were based on laboratory findings, self-report (i.e. previous unknown or negative HIV serostatus), and also checked against local HIV clinical and research databases, we can't rule out that a proportion of recruited partners classified as newly diagnosed may, in fact, have been diagnosed with HIV before. Also, our study participants identified fewer recruited partners when compared with two prior studies of partner services (NNTI of 5 as compared with NNTI of 2 [11] and 2.2 [12]). This is most likely

because field-services (i.e. actually knocking on the doors of identified partners, in case the index case chose third-party notification and the partners could not be reached by phone) were not provided in this study, as compared with the two prior studies in which partner services was performed by the local public health departments [11,12].

In conclusion, our study indicates that provision of partner services to persons with AEH within the first 30 days of diagnosis represents an effective tool for finding HIV-unaware persons, including those with AEH who are at greatest risk of HIV transmission. In addition, partner services in this setting identifies HIV-uninfected partners who may greatly benefit from targeted prevention services, such as PrEP. These findings may suggest that in settings in which time and funding are too limited to perform partner services in all new HIV diagnoses, partner services should be focused on individuals diagnosed with AEH and performed within 30 days of diagnosis. Increased focus of partner services on individuals with AEH in these settings may potentially improve partner services delivery by clinicians and public health departments, identification of HIV-unawares and persons during AEH and identification of a high-risk HIV-uninfected cohort appropriate for prioritized prevention services and PrEP.

Taken together, these could translate into a larger impact on HIV epidemic control than partner services has had to date. Modeling studies evaluating the downstream effects of targeted partner services, that is the effects of combined identification and treatment of high-transmission risk persons, PrEP in those found to be HIV-uninfected and also real-time identification of AEH outbreaks are needed. These studies would further elucidate the impact of partner services in persons with AEH on epidemic control.

Acknowledgements

Authors' contributions: N.G. and S.J.L. designed the study, N.G. and M.H. analyzed and interpreted the data and drafted the manuscript. A.C. and C.M.A. provided the data, C.M.A. also performed statistical data analysis and A.C. performed part of the statistical analysis. S.K. performed network analysis. D.S. provided ideas and content critical to this manuscript and participated in the drafting of the manuscript. All authors revised the manuscript critically for important intellectual content and approved the final version of the manuscript.

The work was supported by funds from the following: Interdisciplinary Research Fellowship in NeuroAIDS (R25-MH081482); Developmental grant from the UC San Diego Center for AIDS Research (NIAID 5 P30 AI036214); TMARC pilot study (P50DA026306); the California HIV/AIDS Research Program Grant F13SD321; the Bettencourt-Schueller Foundation and grants from the National Institutes of Health: AI007036, AI106039, AI043638, AI074621, AI036214, AI108351 and MH100974. The funders had no role in study design and conduct of the study, nor collection, management, analysis and interpretation of the data, nor preparation, review or approval of the manuscript.

The authors wish to thank David A. Rodriguez, testing manager at the antiviral Research Center (AVRC), for his valuable advice and input.

Conflicts of interest

M.H. served on the speakers' bureau of Merck. D.M.S. reported receiving grant funding from ViiV Healthcare (Pfizer joint venture) and having served as a consultant for Genprobe and Testing Talent Services. S.J.L. reported funding from Gilead Sciences, Inc. All other authors report no conflicts of interest.

Original data of this manuscript have been presented in part at CROI 2016 in Boston, Massachusetts, USA (poster number 16-1773).

References

1. Skarbinski J, Rosenberg E, Paz-Bailey G, Hall HI, Rose CE, Viall AH, *et al*. **Human immunodeficiency virus transmission at each step of the care continuum in the United States.** *JAMA Intern Med* 2015; **175**:588–596.
2. Colfax GN, Buchbinder SP, Cornelisse PG, Vittinghoff E, Mayer K, Celum C. **Sexual risk behaviors and implications for secondary HIV transmission during and after HIV seroconversion.** *AIDS* 2002; **16**:1529–1535.
3. Pilcher CD, Joaki G, Hoffman IF, Martinson FE, Mapanje C, Stewart PW, *et al*. **Amplified transmission of HIV-1: comparison of HIV-1 concentrations in semen and blood during acute and chronic infection.** *AIDS* 2007; **21**:1723–1730.
4. Hoenigl M, Chaillon A, Little SJ. **CD4/CD8 cell ratio in acute HIV infection and the impact of early antiretroviral therapy.** *Clin Infect Dis* 2016; **63**:425–426.
5. Robb ML, Eller LA, Kibuuka H, Rono K, Maganga L, Nitayaphan S, *et al*. **Prospective study of acute HIV-1 infection in adults in east Africa and Thailand.** *N Engl J Med* 2016; **374**:2120–2130.
6. Centers for Disease Control and Prevention (CDC). **Recommendations for partner services programs for HIV infection, syphilis, gonorrhea, and chlamydial infection.** *MMWR Recomm Rep* 2008; **57 (RR-9)**:1–83quiz CE1-4.
7. Frieden TR, Foti KE, Mermin J. **Applying public health principles to the HIV epidemic – how are we doing?** *N Engl J Med* 2015; **373**:2281–2287.
8. Katz DA, Hogben M, Dooley SW Jr, Golden MR. **Increasing public health partner services for human immunodeficiency virus: results of a second national survey.** *Sex Transm Dis* 2010; **37**:469–475.
9. Golden MR. **HIV partner counseling and referral services: finally getting beyond the name.** *Am J Prev Med* 2007; **33 (2 Suppl)**:S84–S85.
10. Hogben M, McNally T, McPheeters M, Hutchinson AB. **The effectiveness of HIV partner counseling and referral services in increasing identification of HIV-positive individuals a systematic review.** *Am J Prev Med* 2007; **33 (2 Suppl)**:S89–100.
11. Ahrens K, Kent CK, Kohn RP, Nieri G, Reynolds A, Philip S, Klausner JD. **HIV partner notification outcomes for HIV-infected patients by duration of infection, San Francisco, 2004 to 2006.** *J Acquir Immune Defic Syndr* 2007; **46**:479–484.

12. Moore ZS, McCoy S, Kuruc J, Hilton M, Leone P. **Number of named partners and number of partners newly diagnosed with HIV infection identified by persons with acute versus established HIV infection.** *J Acquir Immune Defic Syndr* 2009; **52**:509–513.
13. Smith DM, May SJ, Tweeten S, Drumright L, Pacold ME, Kosakovsky Pond SL, *et al*. **A public health model for the molecular surveillance of HIV transmission in San Diego, California.** *AIDS* 2009; **23**:225–232.
14. Hoenigl M, Chaillon A, Kessler HH, Haas B, Stelzl E, Weninger K, *et al*. **Characterization of HIV transmission in South-East Austria.** *PLoS One* 2016; **11**:e0151478.
15. Hoenigl M, Anderson CM, Green N, Mehta SR, Smith DM, Little SJ. **Repeat HIV-testing is associated with an increase in behavioral risk among men who have sex with men: a cohort study.** *BMC Med* 2015; **13**:218015-0458-5.
16. Morris SR, Little SJ, Cunningham T, Garfein RS, Richman DD, Smith DM. **Evaluation of an HIV nucleic acid testing program with automated internet and voicemail systems to deliver results.** *Ann Intern Med* 2010; **152**:778–785.
17. Hoenigl M, Graff-Zivin J, Little SJ. **Costs per diagnosis of acute HIV infection in community-based screening strategies: a comparative analysis of four screening algorithms.** *Clin Infect Dis* 2016; **62**:501–511.
18. Hoenigl M, Weibel N, Mehta SR, Anderson CM, Jenks J, Green N, *et al*. **Development and validation of the San Diego Early Test Score to predict acute and early HIV infection risk in men who have sex with men.** *Clin Infect Dis* 2015; **61**:468–475.
19. Hoenigl M, Green N, Camacho M, Gianella S, Mehta SR, Smith DM, Little SJ. **Signs or symptoms of acute HIV infection in a cohort undergoing community-based screening.** *Emerg Infect Dis* 2016; **22**:532–534.
20. Hoenigl M, Chaillon A, Mehta SR, Smith DM, Graff-Zivin J, Little SJ. **Screening for acute HIV infection in community-based settings: cost-effectiveness and impact on transmissions.** *J Infect* 2016[Epub ahead of print].
21. Kothe D, Byers RH, Caudill SP, Satten GA, Janssen RS, Hannon WH, Mei JV. **Performance characteristics of a new less sensitive HIV-1 enzyme immunoassay for use in estimating HIV seroincidence.** *J Acquir Immune Defic Syndr* 2003; **33**:625–634.
22. Keating SM, Hanson D, Lebedeva M, Laeyendecker O, Ali-Napo NL, Owen SM, *et al*. **Lower-sensitivity and avidity modifications of the vitros anti-HIV 1+2 assay for detection of recent HIV infections and incidence estimation.** *J Clin Microbiol* 2012; **50**:3968–3976.
23. Duong YT, Qiu M, De AK, Jackson K, Dobbs T, Kim AA, *et al*. **Detection of recent HIV-1 infection using a new limiting-antigen avidity assay: potential for HIV-1 incidence estimates and avidity maturation studies.** *PLoS One* 2012; **7**:e33328.
24. Tamura K, Nei M. **Estimation of the number of nucleotide substitutions in the control region of mitochondrial DNA in humans and chimpanzees.** *Mol Biol Evol* 1993; **10**:512–526.
25. Hoenigl M, Chaillon A, Morris SR, Little SJ. **HIV infection rates and risk behavior among young men undergoing community-based testing in San Diego.** *Sci Rep* 2016; **6**:25927.
26. Brown MJ, Pugsley R, Cohen SA. **Meeting sex partners through the Internet, risky sexual behavior, and HIV testing among sexually transmitted infections clinic patients.** *Arch Sex Behav* 2015; **44**:509–519.