Identifying Hidden Sexual Bridging Communities in Chicago

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ABSTRACT Bridge populations can play a central role in the spread of human immunodeficiency virus (HIV) by providing transmission links between higher and lower prevalence populations. While social network methods are well suited to the study of bridge populations, analyses tend to focus on dyads (i.e., risk between drug and/or sex partners) and ignore bridges between distinct subpopulations. This study takes initial steps toward moving the analysis of sexual network linkages beyond individual and risk group levels to a community level in which Chicago's 77 community areas are examined as subpopulations for the purpose of identifying potential bridging communities. Of particular interest are "hidden" bridging communities; that is, areas with above-average levels of sexual ties with other areas but whose below-average AIDS prevalence may hide their potential importance for HIV prevention. Data for this analysis came from the first wave of recruiting at the Chicago Sexual Acquisition and Transmission of HIV Cooperative Agreement Program site. Between August 2005 through October 2006, respondent-driven sampling was used to recruit users of heroin, cocaine, or methamphetamine, men who have sex with men regardless of drug use, the sex partners of these two groups, and sex partners of the sex partners. In this cross-sectional study of the sexual transmission of HIV, participants completed a network-focused computer-assisted self-administered interview, which included questions about the geographic locations of sexual contacts with up to six recent partners. Bridging scores for each area were determined using a matrix representing Chicago's 77 community areas and were assessed using two measures: non-redundant ties and flow betweenness. Bridging measures and acquired immunodeficiency syndrome (AIDS) case prevalence rates were plotted for each community area on charts representing four conditions: below-average bridging and AIDS prevalence, below-average bridging and above-average AIDS prevalence, above-average bridging and AIDS prevalence, and above-average bridging and below-average AIDS prevalence (hidden bridgers). The majority of the 1,068 study participants were male (63%), African American (74%), and very poor, and the median age was 44 years. Most (85%) were sexually active, and 725 provided useable geographic information regarding 1,420 sexual partnerships that involved 57 Chicago community areas. Eight community areas met or came close to meeting the definition of hidden bridgers. Six areas were near the city's periphery, and all eight areas likely had high inflows or outflows of low-income persons displaced by gentrification. The results suggest that further research on this method is warranted, and we propose a means for public health officials in other cities to duplicate the analysis.

KEYWORDS HIV/STIs, Drug users, Sexual networks, Bridging, Gentrification, Respondent-driven sampling, HIV prevention planning

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INTRODUCTION

Bridge populations can play a central role in the epidemic spread of infectious diseases, including sexually transmitted diseases (STDs) because, by definition, they link subgroups that might otherwise remain unlinked. Of particular importance is the idea that bridge populations can create links between groups whose members become infected at high rates and members of a lower risk, more general population¹⁻³. Historically, the focus of STD epidemiology has been on the attributes and behaviors of individuals, an approach consistent with the dominant perspectives in clinical medicine, chronic disease epidemiology, and psychology.⁴ Social network studies of STD epidemics often attend to (1) 'super-propagators', individuals or subgroups whose sexual practices in milieus with a high background prevalence of an STD make them particularly likely to acquire and spread an infection, and (2) risk groups, such as injection drug users and men who have sex with men, which provide the necessary social density of risky individuals to sustain a high level of STD transmission. Public health professionals seeking to stem outbreaks of STDs often focus their interventions on geographic areas where the presence of super-propagators and high-risk groups result in a high incidence of infection.

With the recognition that the likelihood of becoming infected and infecting others with an STD depends not only on an individual's risk practices but also on the risk factors of one's sex partners, social network analyses of STD transmission dynamics gained more attention.⁵⁻⁹ Two limitations have made it difficult, however, to more fully develop network research on STDs. First, the level of analysis in network-focused studies of STDs typically is limited to dyads. Based on the 'contact tracing' method commonly used in STD treatment settings⁵ or 'residential area studies',^{10, 11} most studies have focused on dyadic relationships between infected people and their partners. With some exceptions,¹² such studies infrequently aggregate their data to the level of communities and thus are unable to identify risk factors that lie at a community level beyond individual attributes and dyadic relationships.

Second, few studies^{1,6,13,14} have focused on the bridges between distinct subpopulations. For example, even though Person A may have a higher probability of being infected than Person B, Person B can be a much more efficient (powerful) propagator of an STD if he or she has sex partners in distinct subpopulations. In an ideal example of such a case, it would be impossible for one group to transmit infection to another group without Person B, the 'bridger', being infected. Bridgers are defined by their ability to transmit infectious diseases from one subpopulation to another effectively based on their positions in networks. Thus, bridge groups could exhibit a relatively low infection rate but still play a key role in propagating an infectious disease by linking otherwise low-risk areas or subpopulations to those at high risk. It may be possible, therefore, to discover groups that play an important role in propagating STDs through their bridging connections but are largely invisible to public health practitioners because of low or modest infection rates.

The objective of this paper is to take some initial steps toward moving the analysis of sexual network linkages beyond individual and risk group levels to a community level in which Chicago's 77 community areas are examined as subpopulations for the purpose of identifying potential bridging *communities*.

We see two advantages to analyzing socio/politico/geographic units such as community areas. First, the distribution of human immunodeficiency virus (HIV) prevention funds by cities is likely to take such units into consideration, and this type of analysis provides information at that level. Second, as heterosexual

transmission produces a more generalized epidemic requiring community-level interventions, this type of analysis may improve the selection of targets. This initial analysis will be based on the self-reported behavior of participants in a cross-sectional study of potential HIV spread. Findings will be discussed with respect to their potential contributions to public health practice and the reduction of HIV/STD incidence.

METHODS

Sample Recruitment Methods

Data for this analysis came from the Chicago site of the Sexual Acquisition and Transmission of HIV Cooperative Agreement Program (SATHCAP). A detailed description of study methods has been presented elsewhere.¹⁵ Briefly, participants in the Chicago sample were recruited in two waves from August 2005 through October 2006 (wave 1) and from November 2006 through August 2008. Only wave 1 data are used in this analysis. All participants were recruited through respondent-driven sampling,^{16,17} beginning with six ‘seed’ recruiters selected by study personnel. The seed recruiters included men and women, injection and non-injection drug users, and men who had sex with men, and all were gregarious individuals thought by staff to be members of large networks of persons eligible for the study. After enrolling in the study and completing data collection, seeds were given seven coded coupons to refer eligible peers to the study: three coupons for drug users or men who have sex with men regardless of drug use, three coupons for sex partners, and one coupon for either a non-drug-using sex partner or—if the recruiter was man who had sex with men—for a female sex partner. Among recruits, drug users and men who have sex with men were likewise given seven recruiting coupons, while sex partners received only three coupons to distribute to their sex partners. No coupons were given to sex partners of sex partners.

Persons were eligible for enrollment in the study if they (1) possessed a respondent-driven sampling (RDS) coupon or had been selected as a ‘seed’ recruiter, (2) were at least 18 years old, (3) spoke English or Spanish, and (4) in the past 6 months, (a) used heroin, cocaine, or methamphetamine or engaged in any illicit drug injection or (b) were a man who had anal sex with another man, or (c) were a sex partner of the study participant who recruited them. Age was verified by showing photo identification. Verification of illicit drug use, sexual partnerships between men, and sexual partnerships between recruits and their recruiters was based on having the correct coupon, self-report, and correctly answering screening questions used to identify those who misrepresented their status.

Recruiting, screening, enrollment, and data collection took place at four community-based field stations operated by the University of Illinois at Chicago, School of Public Health, Community Outreach Intervention Projects. The field stations are located in areas of the north, near northwest, southeast, and west sides of Chicago that have substantial populations of low-income residents. In most of these areas, African Americans or Latinos are the majority population. These longstanding sites offer HIV/STD prevention services provided by indigenous staff, along with medical care, mental health services, and case management for persons living with HIV. Each site also includes phlebotomy labs and computers equipped for audio computer-assisted self-interviews. Services and other research at the field stations largely target illicit drug users and their sex partners.

Data Collection

After providing informed consent, participants completed a network-focused interview that was self-administered on a computer. Participants were interviewed in private rooms and had the option of having the computer read the interview to them over headphones. However, to minimize errors in the reporting of geographical data, a problem we experienced in the early interviews, questions asking for cross-street names near where participants recently engaged in sex or used drugs were administered by study coordinators at the end of the interview. The study coordinators also were available to assist respondents if they had problems with the survey. The interview collected demographic data and asked in detail about HIV-related drug use and sexual risk practices with up to six recent partners.

Once participants completed the survey and received pre-test counseling, they gave blood samples for HIV and syphilis testing and urine for gonorrhea and Chlamydia testing. Participants were then given RDS coupons and directions regarding the recruitment of peers. Participants were invited to return in 2 weeks to review their progress in distributing coupons and to receive results from the HIV/STD testing. Participants received as compensation \$5 per 15 min for the survey interview with a maximum of \$50 (the modal payment was \$40). They also received \$20 for participating in the coupon review and \$25 for each person who returned one of their coupons and was deemed eligible for the study (enrollment in the study by the potential recruit was not required). The study was approved by the institutional review boards at the University of Illinois at Chicago and at the study coordinating center, RAND Corporation.

Measures and Data Analysis

This study measures potential bridging of HIV (and other STDs) by Chicago's 77 community areas and compares this bridging potential to each area's AIDS prevalence, measured as the number of persons living with AIDS as of 2006 per 100,000 residents.¹⁸ Official community areas were established in the 1920s through a collaboration between the University of Chicago and the Chicago Department of Health for the purpose of creating neighborhood-level analytic units that were fixed and thus comparable over time. The original 75 community areas remain the same, one (O'Hare Airport) was added in the 1950s and one (Edgewater) was carved out of an existing area (Uptown) in 1980. Figure 1 shows a map of Chicago with the name and number of each community area.

To calculate a bridging score for each of the 77 community areas in Chicago, we first created a 77×77 matrix. The SATHCAP questionnaire asked respondents for the places where they had sex in the last 6 months, including the nearest cross-streets. We recoded the cross-street data to reflect the community area within which each cross-street location lies. If a respondent had sex with one partner (e.g., "Partner A") in neighborhood 7 and with another partner (e.g., "Partner B") in neighborhood 8, we assumed that neighborhood 7 was linked to neighborhood 8 via this respondent. To reflect this link, we increased the cell frequency in our matrix by one for (7,8) and (8,7). Because the respondent had sex in neighborhood 7, we assumed that he or she made some contribution to the transmission of STDs within neighborhood 7 via sex with the Partner A; thus, we increased the cell frequency for (7,7) by one. Likewise, the cell frequency for (8,8) is increased by one.

Two bridging scores were used that had been developed for social network analysis: non-redundant ties¹⁹ and flow betweenness.²⁰ The ideal bridging actor is not the one with many ties but the one with many non-redundant ties that place the

FIGURE 1. Chicago community area names, numbers, and 2005 Chicago AIDS Prevalence¹⁸ ($n=77$).

actor in a position potentially capable of filling a structural hole by linking otherwise unconnected parties. In general, ties from community i to j are redundant to the extent that community i has substantial ties with another community, q , to which j has a strong tie. In other words, ties from i to j are redundant to the extent that there is another path from i to j through q : redundancy of the tie between i and j through $q=p_{iq}m_{jq}$, where p_{iq} is the proportion of i 's ties with q (ties with q divided by the sum of i 's ties), and m_{jq} is the marginal amount of community j 's ties with community q (ties with q divided by the j 's

largest ties with any community). Thus, one minus this expression is the non-redundant proportion of ties and the sum across ties of the non-redundant proportion in each contact is the number of non-redundant ties.¹⁹ Let NR_i be the number of redundant ties of community i , then

$$NR_i = \sum_{j=1}^N [1 - \sum_{q=1}^N p_{iq} m_{jq}], q \neq i, j \text{ where}$$

$$p_{iq} = \frac{(z_{iq} + z_{qi})}{\sum_{k=1}^N (z_{ik} + z_{ki})}, i \neq k \text{ and } z_{ik} \neq 0 \text{ and } z_{ki} \neq 0 \text{ and}$$

$$m_{jq} = \frac{(z_{jq} + z_{qj})}{\max(z_{jk} + z_{kj})}, j \neq k$$

Z_{ij} represents the magnitude of the relationship from i to j , which can be measured by strength, frequency, or closeness.

The alternative bridging score we examined, flow betweenness, takes into account the maximum flow introduced by Ford and Fulkerson.^{21,22} That is, the flow betweenness measure considers longer indirect ties when it calculates the score. If i can play a bridging role between j and k through longer ties (for example, ties of ties of ties), the flow betweenness measure captures this relationship while the redundant tie measure does not. Ford and Fulkerson provided a way to calculate the maximum flow from any source p_i to p_j based on two constraints: (1) the flow out of p_i must be equal to the flow into p_i and (2) the flow out of each intermediate point on any indirect path connecting p_i to p_j must be equal to the flow into that point. Then, flow betweenness of p_i between j and k can be expressed as follows:

$$C(p_i) = \sum_{j < i}^n \sum_k^n m_{jk}(p_i)$$

where m_{jk} is the maximum flow from p_i to p_k that passes through p_i . Whereas the measure of non-redundant ties takes into account only indirect ties of the second degree (ties of ties), the flow betweenness measure considers all the possible indirect ties between community areas.

Bridging measures and AIDS case prevalence rates were plotted for each community area on charts constructed as quadrants. Each chart contains a secondary horizontal axis and secondary vertical axis that represent the mean AIDS prevalence rate for Chicago community areas and the mean number of bridging ties, respectively. The quadrants represent the following conditions for community areas: (1) lower left quadrant, lower-than-average bridging and AIDS prevalence; (2) lower right quadrant, lower-than-average bridging and above-average AIDS prevalence; (3) upper right quadrant, higher-than-average bridging and AIDS prevalence; and (4) upper left quadrant, higher-than-average bridging and lower-than-average AIDS prevalence. The community areas in the upper left quadrant are designated “hidden communities” regarding HIV because their lower-than-average AIDS prevalence rates hide the potentially important role they may have in bridging HIV to other Chicago community areas.

RESULTS

In total, 1,068 participants completed interviews in the wave 1 study. The present analysis was limited to wave 1 study participants who reported sexual activity in the previous 6 months and provided information on their recent sexual partnerships ($n=885$). These 885 eligible participants provided information on a total of 1,927 sexual partnerships. Useable geographic information was obtained from 725 participants (82%) for 1,420 sexual partnerships (74%). Approximately two thirds of the missing data were due to responses that could not be geocoded (parallel streets, unknown street names), and one-third were due to non-response. Two respondents were dropped from the analysis because their partnerships were outside Chicago, leaving a total of 723 participants and 1,417 sexual partnerships available for the remaining analyses.

The analysis sample was 63% male, 74% African American, 19% Hispanic and 5% non-Hispanic white, and the median age was 44 years. Over one third (38%) of the respondents reported less than high school education, while 27% reported some post-secondary education. The sample was largely poor, with 83% being disabled or unemployed; 74% reported a monthly income of \$500 or less, and 42% reported homelessness within the past year. Seven percent tested positive for HIV; about half of that group reported knowing that they were positive at the time of the interview.

Lifetime injection drug use was reported by 42% of participants, and 27% had injected drugs in the past month. Among current injectors, the median number of times injected in the past 30 days was 25. A majority of participants (61%) reported crack cocaine use in the past month, 40% reported using heroin alone, 26% reported using heroin and cocaine together (speedball), 21% reported powder cocaine, and 5% reported use of amphetamines or methamphetamine. Among current crack cocaine users, the median number of times used in the past 30 days was 15.

For participants with valid location information, 490 participants (68%) reported sex only in their own neighborhood, 57 (8%) reported sex only outside of their own neighborhood, and 177 (24%) reported sex both inside and outside of their own neighborhood.

Study participants reported sexual partnerships involving 56 of Chicago's 77 community areas. The results of the community area matrix for these relationships are depicted in Figure 2. For easier reading, numbers in the matrix were dichotomized so that the lines between community areas only show the presence of sexual ties without differentiating the magnitude of those ties. Network analyses below utilized the original non-dichotomized matrix.

Figure 3 shows the results when Chicago community areas are scored based on non-redundant ties. The horizontal axis shows the average prevalence rate of AIDS cases for each community area, and the vertical axis marks the number of non-redundant ties. The mean value for AIDS prevalence is 355.9 per 100,000 residents. The mean number of non-redundant ties is 3.7. Each value is marked by a line on its respective axis. Community areas to the right of the vertical line have AIDS case prevalence rates higher than the Chicago average. Community areas above the horizontal line scored above average for the presence of non-redundant sexual ties, indicating a greater likelihood of functioning as bridges for the spread of HIV or other STDs.

Five community areas—one on the north side (14) and four nearly contiguous areas on the south and southeast sides (48, 49, 51, and 73)—occupy the upper left

FIGURE 3. Non-redundant sexual bridging ties compared to AIDS case prevalence rates for 56 Chicago community areas (see Figure 1 for legend) with sexual ties reported by SATHCAP wave 1 participants.

22, and 71) with AIDS prevalence rates only slightly above the Chicago mean but bridging ties well above the mean. Under this measure, community area 4 again was found to lead all other community areas in bridging ties, while community area 14 was no longer found to have ties above the average.

DISCUSSION

Four potentially hidden bridging community areas were identified by both measures of bridging. These areas have below-average AIDS prevalence rates and, for the population we examined, above average bridging ties. Four other community areas came close to meeting this definition by having elevated levels of bridging and HIV prevalence rates that were only slightly above average. If AIDS case prevalence rates were used by public health officials to identify community areas most in need of HIV prevention interventions, these areas are unlikely to warrant much interest. Our analysis suggests, however, that the sexual ties of these hidden community areas to other community areas may be important for transmitting HIV more widely in Chicago, at least among low-income drug users.

Of the eight community areas identified as potential hidden bridging areas, six (46, 48, 49, 51, 71, and 73) form a nearly contiguous band across the far south and southeast sides of the city. These areas have elevated levels of poverty, and the majority of residents are African Americans. That these areas are located nearer to the city’s periphery than to its center is noteworthy. In Chicago and elsewhere, poor and working-class African Americans and Latinos are being driven from the city’s core by the destruction of high-rise public housing and the gentrification of central-

FIGURE 4. Flow betweenness measure of sexual bridging ties compared to AIDS case prevalence rates for 56 Chicago community areas (see Figure 1 for legend) with sexual ties reported by SATHCAP wave 1 participants.

city neighborhoods, and many settle in low-income neighborhoods nearer the city's edge.^{23,24} As this process unfolds, persons pushed to peripheral neighborhoods may maintain ties—including sexual ties—with those who remain behind. It is plausible, therefore, that the elevated level of sexual bridging in these communities reflects in part dislocations associated with gentrification. The relatively low prevalence of persons living with AIDS in these areas may also be a consequence in part of their location near the periphery of Chicago rather than near central areas of the city where high-risk populations were concentrated around major illicit drug markets, gay-friendly neighborhoods, and areas with high concentrations of social services.

The remaining two community areas (22 and 24) identified as potential hidden bridging communities differ substantially from the six areas described above. These areas are in the near northwest side of Chicago and are in advanced stages of gentrification.²⁵ While about half the residents in these areas are Latinos, the broad trend here has been the displacement of lower-income Puerto Ricans by higher income non-Hispanic whites. What these two areas share with the six on the far south/southeast side is the displacement of people through gentrification. Rather than receiving displaced persons, however, these areas are displacing residents. Nonetheless, higher-than-average levels of sexual bridging again may be fueled by connections between people remaining in and being pushed out of a community area.

The relatively low prevalence of persons living with AIDS in these two areas cannot be explained by the same conditions we suggested for the six community areas on the periphery. Injection drug users in these once largely Puerto Rican

community areas experienced high levels of HIV early in the epidemic,²⁵ most likely a consequence of ties with two early epicenters, Puerto Rico and New York City. For these areas, high levels of AIDS mortality,²⁶ steep declines in HIV incidence among injection drug users in Chicago^{27,28} and gentrification pushing out low-income drug users who may have been living with AIDS likely explain their current relatively low AIDS prevalence rate.

Our analysis also identified one community area (Uptown) that had the highest bridging ties on both measures and the highest AIDS prevalence rate. We suspect that at least three factors contribute to Uptown's exceptionally high sexual bridging. First, like areas 22 and 24, Uptown is in an advanced stage of gentrification;^{29,30} thus, there may be many current residents with ties to persons who have been pushed out of Uptown to other community areas. Second, Uptown has long been a hub for social services, including homeless shelters, which attract low-income persons from areas around the city. In our experience, persons who come to Uptown from other areas of the city seeking services often report both maintaining ties to their former community areas as well as forging new sexual relationships in Uptown. Third, Uptown is on the northern border of the community area widely recognized as home to Chicago's gay community. Low-income men of color who have sex with men and who are from other community areas but wish to live in the gay community are far more likely to find affordable housing in neighboring Uptown. As with persons seeking social services, such men may maintain contacts, including sexual relationships with persons in their original neighborhoods.

Our goal in this paper was to take some initial steps to move the focus of sexual bridging to a community level that treats distinct community areas of Chicago as subpopulations. The fact that all eight hidden or nearly hidden community areas shared at least one notable characteristic—either receiving or expelling low-income substance using residents through the forces of gentrification—offers some empirical support for the existence of hidden bridging communities. That is, if hidden bridging communities had been identified but had little in common with one another and no discernable characteristics that suggested a plausible process through which above average bridging might be operating, we might then suspect that our identification of such areas was simply an artifact of our methods. Instead, the findings suggest the beginning of a theory of hidden bridging community areas and warrant further development of this approach.

At this early stage, our analysis has limitations that need to be considered when reviewing the results. First, our measures of bridging were borrowed from social network analyses designed for purposes other than the study of STDs. Measures more attuned to the community level analysis of STDs need to be developed. In constructing the matrix, the addition method we used for diagonal cells is based on the assumption that, in the example we used, partners "A" and "B" might have another sex partner within the community areas 7 and 8, respectively. While we cannot be sure that this assumption is robust, it is plausible. When we repeated the analysis without this assumption, we again found hidden bridging communities, although the order of bridging scores for some communities changed. Second, data on geographic ties between study participants and their sex partners were incomplete because we did not ask about all sex partners in the past 6 months and about a quarter of the sample provided unusable responses. Third, behavioral data were self-reported and thus subject to biases associated with the accuracy or completeness of reporting. The use of audio computer self-administered interviews should have minimized socially desirable reporting. Fourth, study results are not

generalizable beyond Chicago nor to the entire population of Chicago. We believe that findings are generalizable, however, to the population of low-income substance users living in the areas included in our analysis.¹⁵ This population is at high risk of HIV infection. Fifth, the analysis shows a potential for sexual bridging at the level of community areas but did not substantiate that actual bridging of infections occurred.

Hidden bridging community areas may warrant attention in HIV prevention planning. For example, when HIV prevention funds are allocated in Chicago, South Chicago (area 46) typically is ranked in the lowest priority tiers of community areas based HIV data. However, our analysis found South Chicago was second in sexual bridging ties for a population at high risk of infection, low-income, largely African American drug users. Effectively targeting an area such as South Chicago might reduce the spread of HIV from high- to low-prevalence areas of the city. HIV prevention planning might also benefit from the identification of areas such as Uptown (area 4), with its remarkably high bridging and AIDS prevalence. City HIV prevention planners are well aware of the extent of HIV/AIDS in Uptown, but our analysis suggests that even among community areas that rank in the highest priority tier, Uptown is a special case. Here, funds might be used to increase the targeting of low-income, drug-using subpopulations likely to contribute the most to sexual bridging: those impacted by gentrification, men of color who have sex with men and who come from other areas of the city, and those using social services such as shelters. Finally, the analysis presented in this study could be used not only to identify hidden bridging communities but also the community areas they link, information that might improve the ability of a city's HIV prevention planners to coordinate their efforts more effectively.

One question that remains is whether cities realistically can gather data needed for an analysis of community-level sexual bridging. While this study provided a seemingly unique opportunity to gather such data that is not normally available to cities, a new opportunity may exist for cities that participate in the Center for Disease Control and Prevention's National HIV Behavioral Surveillance (NHBS) program.³¹ The NHBS regularly surveys three populations in alternating years: injection drug users, high-risk heterosexuals, and men who have sex with men. A short set of questions could be added to the survey to capture the data needed for a community area bridging analysis. At a minimum, cities would need to gather information regarding the cross-streets near to where they had sex with recent partners. By considering these data along with traditional HIV prevalence or incidence measures, public health officials might improve their ability to set HIV prevention priorities for the different areas of their respective cities.

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