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Community coverage and HIV prevention: Assessing metrics for estimating HIV incidence through syringe exchange

Robert Heimer

Department of Epidemiology and Public Health, Yale School of Medicine, New Haven, CT

Abstract

Background—Evaluations of syringe exchange programme effectiveness that attempt to measure “coverage” by determining the percentage of the at-risk population reached by a programme are insufficient since programmes must provide syringes on a continual basis. Determining the relationship between the extent of programme coverage and its impact (i.e., reductions in disease risk or incidence) is complicated by the lack of controlled trials with cohorts of drug users and instead has to be estimated by imputation, mathematical modeling, or ecological data analysis. This report offers an approach to determine community-wide impact and to discuss the limitations of that approach

Methods—Easily created programme tracking data were maintained by exchanges in New Haven, CT, USA and Chicago, IL, USA. Data compiled by month quantified the number of unique participants visiting syringe exchange programmes and the number of syringes distributed. “Coverage”, defined either as the percentage of individuals reached or percentage of community syringe need met, was estimated by incorporating measures of the size of the injector population or injection frequency. These measures of coverage are placed in the context of changing programme operations to estimate the effect of these changes on coverage. Finally, data on AIDS cases from New Haven and Chicago were used to estimate the community-wide impact of syringe exchange.

Results—Two mobile syringe exchange programmes operated with very different exchange policies. Programme data revealed that coverage of individuals rarely exceeded 10% and was higher in New Haven than in Chicago. On the other hand, coverage measured as the percentage of syringe need met was higher at the Chicago exchange that employed the less restrictive policy. The impact of syringe exchange in the two cities was measured by comparing subsequent AIDS cases. The relative reduction in injection-related AIDS cases as a function of all new AIDS diagnoses was 21.7% in New Haven and 41.4% in Chicago.

Conclusions—A modest investment in the collection of programme data can yield reliable and interpretable information on the extent of programme reach and retention. Limitations to the approach result from the ecological nature of the data and from the need to use data from outside the programme that may be less reliable. For the cases presented here, coverage rates will vary as a function of the programme policies; however, even modest coverage rates -- well below those recommended by UNAIDS -- can have significant impacts on HIV epidemics. Restrictive policies appeared to increase the coverage if measured only by the proportion of monthly participants and not by the proportion of syringe need met by a programme. More generally, programmes can collect programmatic data and some rapid assessment data (estimates of IDU population and injection frequency) to estimate of the impact of their programmes.

Keywords

syringe exchange; harm reduction; HIV; coverage

INTRODUCTION

The effectiveness of syringe exchange programmes (SEPs) in preventing HIV is most directly measured by determining the effect the programme has on decreasing the HIV incidence rate in the communities they serve (Normand, Vlahov, & Moses, 1995; Wodak & Cooney, 2006). However, measuring incidence directly is difficult: cohort studies are expensive and the time extensive. Therefore, other metrics of programme effectiveness are needed. SEPs can succeed in reducing incidence in two ways: by providing the means for a sufficient number of individuals in the at-risk population to have uncontaminated equipment so that epidemic transmission is prevented and by getting individuals to change their habits to prevent the multi-person use of infectious injection equipment and hence the transmission of the virus. In practice, SEPs must provide “coverage” to a large enough fraction of the population to make a difference.

In previous discussions on the subject (Burrows, 2006; Sharma, Burrows, & Bluthenthal, 2007), the semantics of coverage has created confusion. Most discussions of coverage have set targets for coverage simply in term of the percentage of drug users in a community that an SEP contacts. For example, a global report calls for 60% coverage -- six in ten IDUs in a community must be encountered by SEP staff (Anonymous, 2006; Sharma et al., 2007). This guideline fails to take into account that for an SEP to be successful it must get clean syringes to the target population. Syringes are consumables that need to be replenished, and measurements of programme success need to incorporate measures of syringe consumption. Contacting an individual once and providing him with a number of syringes is not the same as repeated contacts to replace used syringes. Although it is obvious that analysis of the impact of an SEP must have a temporal dimension -- indeed, the UNAIDS guidelines do recognize a category of coverage they term “regular reach” -- the most important dimension to measure is the extent to which an SEP reduces syringe scarcity throughout the community on an ongoing basis (Burrows, 2006). This is often quantified by attempting to determine the average number of syringes provided to each client during a period of time. To make such an average relevant to local conditions, it is also important to determine the average number of injections made during that period and compare average number of injections to the average number of syringes available. These numbers can then be used to construct models of HIV incidence. And while it is possible to model how much coverage is necessary to reduce incidence, it is important that some of the assumptions necessary to construct a model are informed using real-world data.

This report seeks to benefit from studying SEPs in communities in which the SEP was the sole legal source of syringes at the time of their establishment using data from SEPs that have kept careful records of their exchanges. The approach is ecological in nature in that it tries to place syringe consumption in the context of the entire community of injectors that the SEP serves. It compares two American SEPs that have very divergent exchange policies. The SEP in New Haven was established in 1990, mandated one-for-one exchange, and until 2006 limited the number of syringes that could be exchanged per visit. The five-syringe initial cap was increased to ten in 1992 and to thirty in mid-1999 (Bray, Lawson, & Heimer, 2001). The SEP in Chicago was established in 1992 and operated with no restrictions on the number of syringes that could be exchanged per visit. Initially, two new syringes were exchanged for each of first ten, but over time the policy has changed and eventually staff gave customers the number of syringes they requested regardless of how many they returned. Thus, these two SEPs represent opposite ends of the syringe exchange policy spectrum.

Estimates of coverage require three sets of data. The first set comes from detailed reporting of exchanges maintained by the New Haven and Chicago exchanges. The second set is an estimate for the number of injectors in the community which, combined with the number of injectors served, allows an estimation of the extent to which individuals are covered. The third set is the injection frequency data which, combined with the second set, allows an estimation of the number of syringes needed to meet the US Public Health Service guidelines of a new, sterile syringe for every injection (Gayle, O'Neill, Gust, & Mata, 1997). It is then possible to estimate the coverage in terms of syringes distributed.

The extent of coverage must somehow be integrated into an analysis of the impact of the SEPs on the entire community. It has not been possible to achieve this by direct experiment or by traditional data collection and analysis since to do so requires ascertaining pre- and post-intervention incidence rates among exchange customers, post-intervention incidence rates for the injector population as a whole, and the sizes of the customer and total populations. Although data on changes in incidence among SEP customers and the size of the injector community may be available, data on HIV incidence rates among the entire population of injectors generally are not. Sample sizes may need to be very large for such an approach to work if SEPs suppress incidence sufficiently (Vlahov & Brookmeyer, 1994). Surveillance data on HIV infections are generally inadequate to the task of estimating the impact of prevention interventions such as SEPs. Even if comprehensive surveillance data were available, it would not pinpoint when the infection had occurred. As a result, most attempts in this direction have involved mathematical modeling exercises that estimate incidence using a combination of behavioral, transmission, and programme data. For example, our past work has been widely recognized in demonstrating that the New Haven SEP substantially reduced new HIV infections among programme participants, with a decline in incidence conservatively placed at one-third (Kaplan, 1994; Kaplan & Heimer, 1994, 1995; Kaplan & O'Keefe, 1993). Similar work has recently been conducted to estimate the impact of the SEPs in the United Kingdom and Belarus (Vickerman, Hickman, Rhodes, & Watts, 2006).

However, an alternative approach can take advantage of the reporting of AIDS cases, which can give an approximate picture of changes in infection rates ten years earlier (Hendriks et al., 1998; Pezzotti et al., 1999). While not an exact measurement of the time of infection, it is possible to use this information to estimate population-wide changes in HIV incidence resulting from the institution of the SEPs in New Haven and Chicago. With this information, it may then be possible to determine the programme's effectiveness in reducing HIV incidence given the level of coverage it obtained.

METHODS

The data for the analysis presented in this report come from several sources. Programme operations and methods to measure customer participation derived from SEP tracking logs have been described elsewhere (Brahmbhatt, Bigg, & Strathdee, 2000; Heimer, Khoshnood, Bigg, Guydish, & Junge, 1998; Kaplan, 1991; Kaplan & O'Keefe, 1993). Estimates of the total number of injectors come from several sources. Estimates on injection frequency come from surveys of active injectors. Data on injection-related AIDS cases come from local health department surveillance programmes.

SEP Operations in New Haven

The New Haven SEP, operated by the city health department, opened in November 1990 using an evaluation system that uniquely numbered all syringes and allowed each customer to select a unique pseudonym. At each exchange, the outgoing syringes were logged along with the date and the customer's pseudonym and the returned syringes were placed in a canister labeled with the date and pseudonym (Kaplan, 1991). Merging of the two databases -- one containing the

information on distributed syringes and the second containing the information on returned syringes permitted the tracking of the nearly 100,000 syringes distributed between November 1990 and October 1993 (Heimer, Khoshnood, Stephen, Jariwala-Freeman, & Kaplan, 1996; Kaplan & Heimer, 1995). During this period, the number of injectors making use of the New Haven syringe exchange programme in any given month can be determined from the programme logs. Two years into this period, the state of Connecticut changed its laws and the number of syringes that could be exchanged per visit was increased from five to ten.

Additional data were obtained for the 18-month period between November 1999 and April 2001 following changes in the state statute that increased the number of syringes that could be exchanged per visit from ten to thirty (Bray et al., 2001). These data were collected by SEP staff as part of their state reporting requirements and a grant to explore the consequences of the change in statute (Heimer et al., 2002).

SEP Operations in Chicago

The SEP operated by the Chicago Recovery Alliance (CRA) was opened in 1992. Since 1994, it has used a unique identifier system for each participant that recorded the number of syringes provided at each visit (Brahmbhatt et al., 2000; Heimer et al., 1998). The CRA SEP has used three different exchange policies. Initially, individuals were given two syringes for each one returned. Rules were relaxed in 1997, and through 1999 factory-sealed bags of ten syringes were distributed to the nearest ten reported returned. Beginning in 2000 the policy was further relaxed and syringes were distributed in response the question, "How many do you need?"

Injection Frequency

Data on injection frequency come from the literature. In New Haven, data collected from two convenience samples of 1523 injectors between 1990 and 1993 and from 320 injectors between 1999 and 2001 found mean injections per month of 87 and 82, respectively (Buchanan et al., 2006; Kaplan & Heimer, 1994; Khoshnood, 1995). In Chicago, data collected from two independent convenience samples of 733 injectors between 1997 and 2000 and from 289 injectors between 1998 and 2000 both found mean injections per month of 75 (Bluthenthal et al., 2004; Ouellet, Huo, & Bailey, 2004). For our analysis, I used mean monthly injection frequencies of 85 for New Haven and 75 for Chicago.

Injectors in New Haven and Chicago

The number of injectors in New Haven was estimated by two methods. The first estimate of 2250 comes from a published study in which the estimate was derived from data about the AIDS case rates between 1981 and 1992, the percentage of injectors who were HIV positive in 1990, and the rate at which the HIV positive injectors developed AIDS (Kaplan & Soloshatz, 1993). The second estimate of 2550 was based on data obtained from the sole local methadone maintenance treatment programme in 2001. Of the 850 opiate dependent New Haven residents in maintenance, 60% (or 510) had been injectors prior to entry. The total population of injectors was estimated based on the supposition that only one in five injectors was in methadone maintenance (510×5) yielding an estimate of 2550 injectors. While each of these estimates is predicated on unverifiable assumptions, these two completely independent estimates yield similar figures in calculations nearly a decade apart. This may just be coincidence, but here the average number of 2400 injectors will be used as the denominator for the total number of injectors in New Haven.

The number of injectors in Chicago comes from a published estimate that relied on a modified Delphi analysis that obtained estimates of drug injector populations in 96 US metropolitan areas (Friedman et al., 2004). The estimate of the total number of injectors in Chicago, 33,432,

is the average of the numbers independently provided to the research team by local substance providers and academic researchers.

Coverage

Two measures of coverage can be determined given the data assembled. First, the percent of all injectors in New Haven or Chicago making use of the SEP can be determined by dividing the programme's customers by the total population of injectors, i.e., the number of the unique injectors visiting the exchange divided by the estimated number of injectors in the population (2,400 in New Haven and 33,432 in Chicago). For the analysis of coverage it makes sense to use monthly participation in the exchange as an indicator of coverage since syringes are consumable items that need to be replenished by return visits to the SEP.

For the second measure, a more conservative estimate can be applied by determining the extent to which the SEP provided syringes sufficient for each injection to be made with a new, sterile syringe (Gayle et al., 1997). This fraction has as its numerator the number of syringes actually dispensed by the programme each month. The denominator is equal to the number of injectors citywide multiplied by the average number of injections they would make in thirty days. Based on the number of injectors citywide and the mean monthly injection frequency, the number of syringes needed for a new, sterile syringe for each injection was calculated to be 209,000 per month in New Haven (2,400 injectors $\times$ 85 injections per month) and 2,375,000 per month in Chicago (33,432 injectors $\times$ 75 injections per month).

For both measures of coverage, monthly rates were compiled into distinct time periods and within-city differences in coverage between periods were compared using t-tests.

AIDS Cases

City-level AIDS data are compiled by the state health departments in Connecticut and Illinois (HIV/AIDS Surveillance Programme, 2007; HIV/Surveillance, 2007). To account for the lag between HIV infection and progression to AIDS (Hendriks et al., 1998; Pezzotti et al., 1999), AIDS case rates were compared more or less than ten years after the start of the syringe exchange programme in New Haven and Chicago. For the comparison of New Haven and Springfield, case rates between before and after 2000 were compared. For Chicago, cases rates before and after 2002 were compared. Differences in the number of cases attributed to injection drug use (IDU and IDU/MSM) were compared to cases attributed to all other causes (from unsafe sex whether MSM or heterosexual, from nosocomial, from contaminated blood products) using chi-square tests.

RESULTS

Coverage

The estimates of coverage for New Haven and Chicago are each divided into three time periods, reflecting the differences in exchange policies. Chicago always employed the more liberal policy, and after 2000, the policy there was tantamount to replacing exchange with distribution. In contrast, New Haven's policy remained restricted, maintaining a strict one-for-one scheme as the cap increased from five, to ten, and finally thirty. In New Haven, the number of unique customers of the SEP increased from November, 1990 to July, 1992 but declined subsequently due to a change in the law that permitted injectors to legally purchase syringes without a prescription at pharmacies for the first time since the early 1970s (Figure 1A). Estimates of coverage based on the percentage of injectors who obtained syringes at least monthly averaged 10.5% ($\pm 2.5\%$) prior to the change in the law and declined after July, 1992 to 6.7% ($\pm 1.7\%$) % in the 16 months following the change (Table 1). The decline was statistically significant ($t = 4.74$, $p < 0.0001$). The number of syringes distributed monthly also began to decline after

July, 1992 (Figure 1A), but estimates of coverage in terms of syringes supplied for the two periods as a whole were the same. Coverage in terms of syringes averaged 1.2% ($\pm 0.7\%$) when the cap was five and 1.1% ($\pm 0.2\%$) when the cap was increased to ten. Thus, the loss of customers after July 1992 negated any benefits gained from enlarging the cap. When coverage was re-investigated using data from after the cap was increased to thirty, it was estimated that the SEP covered 7.9% ($\pm 2.0\%$) of all injectors citywide but the percent of needed syringes was unchanged at 1.3% (0.4%). These estimates were not statistically different from those from the period when the cap was ten.

In Chicago, customer and syringe tracking began about a year and half after the CRA began SEP operations. By that time, the SEP was averaging 1,000 different customers every month (Figure 1B). Use of the SEP by the city's injectors remained fairly constant except for a modest decline between December, 1997 and April, 2001. Coverage in terms of the percentage of injectors served on a monthly basis was 3.3% ($\pm 0.4\%$), 2.3% ($\pm 0.6\%$), and 3.2% ($\pm 0.8\%$) in the three periods (Table 1). Coverage was significantly lower in the middle period compared to the first ($t = 10.50$; $p < 0.0001$) or third period ($t = 10.26$; $p < 0.0001$). Coverage in terms of the percentage of syringes provided on a monthly basis was 4.2% ($\pm 1.0\%$), 4.7% ($\pm 1.2\%$), and 7.5% ($\pm 1.4\%$) in the three periods (Table 1). The first policy change had a modest, but not statistically significant effect in increasing the coverage in terms of syringes even though attendance in terms of the percentage of the city's IDUs who visited each month was down. In contrast, the change from exchange to distribution significantly increased coverage in terms of syringes per IDU citywide per month ($t = 9.52$, $p < 0.0001$).

AIDS Case Rates

Given the lag between HIV infection and progression to AIDS, it was hypothesized that increased syringe access in New Haven, which began in late 1990, should have begun to influence the rates of injection-related AIDS in New Haven after 2000. Of the 2,510 AIDS cases reported among city residents through 2006, 1,443 were attributed to injection drug use (Table 2). While there has been a decline in AIDS diagnoses in New Haven, with an annual decline in all-cause diagnoses of 12.9%, the decline in cases attributed to injection drug use has declined more steeply. Through 2000, 59.9% were attributed to injection drug use, but thereafter, only 40.8% were, a significant decline ($p < 0.001$). In New Haven, there was a clear breakpoint between 2000 and 2001 when the percent of AIDS cases attributed to IDUs declined from 63.9% to 48.8%. In no year since has this percentage increased above 52.6%. Thus, the decline in AIDS cases in New Haven has increased faster than the decline in all-cause AIDS cases by 21.7% (Table 2).

In Chicago, it was hypothesized that the increase in syringe access attendant upon the establishment of the CRA SEP should have begun to influence the rates of injection-related AIDS diagnoses after 2002. Of the 17,864 AIDS cases diagnosed between 1992 and 2006, 5,016 were attributed to injection drug use (Table 2). While the percentage attributed to injection drug use was 30.4% between 1992 and 2002, the percentage for 2003–2006 was significantly lower at 17.6% ($p < 0.001$). As in New Haven, there was a decline in annual diagnoses of any cause for the latter period relative to the preceding decade. And as in New Haven, the decline in cases attributed to injection drug use declined more steeply, by 63.2%, while all-cause annual diagnoses declined by 37.2%. Thus, the decline in AIDS cases in Chicago has been faster than the decline in all-cause AIDS cases by 41.4% (Table 2).

DISCUSSION

The approaches taken in this report to create usable metrics for coverage of SEPs do not directly establish their effectiveness in reducing HIV incidence either among the customers or for the overall population of IDUs in a community. Instead, they are intended to provide simple ways

for programmes with limited resources to track their activities and at the same time estimate the impact of their programme. The metrics offered require little beyond practical record keeping, a modicum of behavioral data, standard surveillance data, and elementary descriptive and analytical statistics. Indeed, for the purposes of process analysis, programmes themselves need only to track their exchanges, use easily learned rapid assessment skills (Rhodes et al., 1999; Needle et al., 2003; Fitch et al., 2004; Stimson et al., 2006), and apply descriptive statistics to estimate coverage.

Limitations

The primary limitation to collecting coverage data in the manner detailed in this report is the need to obtain data from multiple sources in order to estimate coverage. Errors in any one of these would reduce the accuracy of the estimates. Although the number of unique customers using the exchange and the number of syringes are direct measurements, the numbers of injectors citywide are based on estimates from only one or two points in time and no effort was made to investigate the extent to which the number of IDUs fluctuated over the many years considered in the analysis. Data on injection frequency, needed to calculate the need for clean syringes, were obtained by self-report, which may be inaccurate. In this analysis, an attempt was made to minimise this problem by using self-reported averages from two different studies conducted at different times for each city. In implementing an analysis at a SEP using these metrics, it would be useful to have several independent estimates of the size of the IDU population and the frequency at which they inject. Therefore, in calculating their budgets, SEPs should include funds for rapid assessment to obtain the data external to programme operations needed to estimate coverage.

In this approach to understanding the community-wide impact on HIV transmission, longer-term outcome studies are needed that require AIDS case data and more analytical statistics. Full explication of the impact of starting a programme or changing its operating procedures will have to wait a decade or more, substantially reducing the ability of programmes to “prove” their effectiveness or provide compelling rationales for maintaining or abandoning operational changes. Therefore, it is hard to use these data when arguing for impact immediately following the establishment of programmes. For this, mathematical modelling may remain the most appropriate form of analysis. However, there are several reasons why this may not be feasible. First, modelling is mathematically complicated, often beyond the capabilities of most programmes and the modest evaluation teams they assemble. Second, and in order to gauge the impact of a programme community-wide, much of the same data -- injection frequency, risk behaviors and an enumeration of injectors -- needed for the analysis described in this report is required.

The present attempt to gauge the impact of programme implementation uses a simpler approach but it relies heavily on enumeration of subsequent AIDS cases a decade after implementation. Such enumeration is complicated by changes in case definitions, improvements in treatment that reduce the likelihood of progression to AIDS, and migration of the at-risk population into or out of the cities under study. An attempt was made to minimise the problem these changes pose by calculating the change in the percentage of cases diagnosed that can be attributed to injection drug use relative to the change in all-cause diagnoses but, without much further study, it cannot be determined if the problem has been minimised to the point where it is inconsequential to the analysis.

It is worth noting that improvements in the treatment of HIV infection, most notably HAART, may not have influenced the analysis all that much and might actually have reduced the ability to detect the impact of establishment of SEPs. By all accounts in the literature, IDUs in North America tend to get the least care and often are made to wait until an actual AIDS diagnosis before initiating HAART therapy. This delay for IDUs would, in fact, suggest that the impact

of the exchanges on infections among IDUs is underestimated in an approach that uses AIDS cases because IDUs are more likely than others who became infected at the same time to have their disease progress far enough for officialdom to record the infections in an AIDS case registry.

It is also worth noting that HIV infection (as opposed to AIDS) case registry data cannot be reliably used for estimating long-term impact in the United States for at least two reasons. First, HIV case registries would clearly overestimate, not underestimate, the cases attributed to IDUs. It has been shown that more than 90% of urban American IDUs have been tested, that HIV-negative IDUs are likely to be recently tested, and that SEP customers are slightly more likely than non-customers to have been tested (Heimer et al., *AJPH*, 2007). In contrast, it is estimated that a quarter of all those with HIV infection do not know their status (Fleming et al., 2002; CDC, 2005). Therefore, IDUs are more likely than non-IDUs to appear in HIV case registries. Second, the registries tell us nothing about when individuals have been infected – it could have been last month or years ago. This is further complicated by the reasons underlying testing. MSM and high risk heterosexuals often get tested in response to perceived risk - i.e., sex with someone perceived to be infected - and thus infections may be detected early, whereas IDUs tend to get tested as a result of structural forces such as entering substance abuse treatment or prison, a more random pattern at least in terms of its relationship to the cause of the infection. At least for AIDS cases, there is enough data to conclude that progression to AIDS in developed countries occurs following a similar delay post-infection for IDUs, MSM, and women infected through unsafe sex.

Concluding remarks

Although the results were obtained from only two SEPs, there are some conclusions one can draw even from this limited set of data. First, it seems that an exchange with a cap meets far less of the need in terms of syringes than an exchange that operates without one. Increasing the cap appeared to have little impact in increasing coverage by either of the metrics applied to the tracking data. This is consistent with previous reports using other metrics that the gradual increase in the cap in New Haven did little to increase syringe availability or reduce risk (Buchanan et al., 2006; Heimer et al., 2002). On the other hand, coverage decreased significantly when the state legalized over-the-counter sale of syringes in 1992. This change has been extensively discussed in earlier work (Heimer et al, 1996; Heimer et al., 2002).

The other finding that has implications for the application of the metrics used in this report is that restrictive policies can appear to reach more of the at-risk population when coverage is defined only in terms of the percentage of the population served. However, this metric neglects the effect of secondary exchange, which is encouraged by programmes that do not limit the number of syringes offered to customers (Bluthenthal et al., 2004; Bluthenthal et al., 2007). The data collected for this report suggest that the Chicago SEP, with its open distribution policy, provided better coverage, as defined by syringe need, when a policy based on syringe exchange was replaced with one based on syringe distribution. This finding was, in turn, supported by the finding on AIDS cases, which revealed a twofold greater relative decline in IDU-attributable AIDS cases in Chicago than in New Haven. Therefore, it is important that both data to assess both definitions of coverage be collected and analyzed.

It is widely agreed that it is important that SEPs and other expanded syringe access programmes estimate coverage. The advantages of the metrics provided in this report are at least threefold. First, they rely heavily on data easily collected by the programmes themselves. Second, additional necessary data can be collected using simple rapid assessment techniques. Third, the estimates of coverage are dynamic; in this report they are presented monthly but they can be calculated for other periods as needed by programmes and their funders. But perhaps most importantly, the extent of coverage estimated using the metrics offered in this report is much

lower than that recommended by international agencies responding to IDU-driven HIV epidemics (Anonymous, 2006). In New Haven, the two levels of coverage, one based on customers served and the second based on percentage of necessary syringes provided, was at most 13.7% and 2.0%, respectively, in any given month. Nevertheless, the impact on incidence, even given the modest coverage, has been appreciable. This is so not only in the present analysis of the distribution of AIDS cases but also in mathematical models of incidence, where the decline in HIV incidence among SEP customers was estimated to exceed 40% (Heimer et al., 1996; Kaplan, 1994; Kaplan & Heimer, 1995). Declines citywide appear to be more modest but are nonetheless considerable; the estimate from AIDS cases places the decline at 21.7% (Table 2). What can account for such declines? One answer may be that SEPs do more than provide clean syringes and remove contaminated ones from circulation. They can promote the health of injectors community-wide by teaching injectors how to reduce the risks of virus transmission and by promoting changes in community norms. The combination of clean syringes and safer behaviors could synergistically reduce the risk of transmission.

It seems logical to conclude that even the modest levels of coverage afforded by the New Haven and Chicago SEPs appeared sufficient to substantially reduce HIV transmission citywide. In trying to understand the larger implications of this finding for other SEPs and prevention efforts, it is necessary to determine how the modest coverage could produce such large benefits and whether similar results could be expected elsewhere. First, it is important to note that the idea of coverage is derived, more broadly, from other infectious disease prevention interventions. Such programmes are predicated on the supposition that if few enough individuals become infected and infectious and if enough of the population is protected against transmission, then the burden of disease can be appreciably reduced. Once a certain threshold of protection is reached, epidemics can be controlled. The most common situations in which the determination of community protection is discussed have involved either the vaccination of populations or the reduction of a disease vector or intermediate host. In estimating the extent of protection afforded by the vaccination of individuals, it is felt that 70–95% of the population must be vaccinated to protect the population as a whole (Anderson & May, 1992). However, these calculations are for infectious diseases like measles or smallpox that are highly contagious, that people can transmit for only short periods of time, and for which the entire susceptible population is potentially at risk. SEPs may act more like vector control programmes than vaccination programmes in that they seek to eliminate an intermediate vector of the disease, the contaminated syringe, and (at least in the case of malaria) involve human hosts persistently infected with the pathogen. For these sorts of prevention programmes, large-scale vector reduction or elimination is necessary to achieve significant decreases in disease incidence (Gramiccia & Hempel, 1972; Yekutieli, 1980). But the low rates of “vector elimination” in New Haven or Chicago, where the SEPs never distributed more than 10% of syringes needed to assure a sterile syringe for each injection, would not be expected to have much effect on disease transmission if syringe exchange were analogous to vector control. To the contrary, significant reductions in HIV transmission appear to have occurred despite much lower levels of coverage than would be expected based on an analogy with vaccination or vector control programmes.

The reason for this may be that SEPs, unlike vaccination or vector control, involve active participation from the infected and susceptible populations. This includes the adoption of injection practices that reduce risky behaviors. In New Haven, our studies have detected such reductions among the 197 continuing customers interviewed 4 to 33 months after they first used the New Haven SEP (Khoshnood, 1995). Whereas 57 (28.9%) reported some form of risky injection practice upon enrollment in the SEP, only 36 (18.3%) reported risk at follow-up ($p < 0.01$). Anecdotally, many customers reported becoming advocates for behavior change. This suggests the possibility of a large-scale shift in behavioral norms that, in turn, might account for widespread reductions in HIV transmission among New Haven’s injectors. In a

later study, conducted between 1999 and 2001, in which only 105 of 320 (32.8%) IDUs reported ever using the SEP as a source for syringe, 19.5% reported recent unsafe injection (Heimer et al., 2001). Similar trends have been observed in Chicago. Ouellet and colleagues reported dramatic declines in five forms of sharing practice between 1994, when SEPs were being established, and follow-up investigations in 1996 and 1998 (Huo, Bailey, Garfein, & Ouellet, 2005). Most notably, the prevalence of receptive syringe sharing in the six months prior to interview declined from 45.7% at baseline to 19.2% at follow-up. In our study of 289 IDUs in Chicago begun in 1998, only one-fifth were SEP customers and the prevalence of receptive syringe sharing was 17.6% (Bluthenthal et al., 2004).

While it is hard to quantify the role that changes in social norms may have played in decreasing injection-related AIDS in New Haven and Chicago, it could be possible to design studies of newly established SEPs that investigate this. It may turn out that the synergy of increased syringe access through SEPs and customer-mediated actions -- including changing behavioral norms and undertaking secondary exchange -- may overcome low coverage. Conversely, the absence of community-wide changes in risky injection practices may doom some SEPs, regardless of how extensive is their coverage. Coverage is, thus, just one parameter useful in judging the success of a SEP. By itself, it may not be a valuable indicator of SEP effectiveness in preventing disease transmission, but it is important that such estimates are obtained and intelligently used in programme evaluation.

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Figure 1. Monthly tracking records of the New Haven (panel A) and Chicago (panel B) syringe exchange programmes.

Table 1
Citywide Coverage of IDUs by SEPs in New Haven and Chicago

TIME PERIOD	NEW HAVEN			CHICAGO		
	NOV. '90 – JULY '92	AUG. '92 – OCT. '93	NOV. '99 – APRIL '01	JULY '94 – JUNE '97	JULY '97 – DEC. '99	JAN. '00 – DEC. '05
MEAN CUSTOMERS/MONTH	252	162	190	1095	753	1056
MEAN SYRINGES/MONTH	2,432	2,303	2,696	99,478	111,065	177,824
% IDUs SERVED	10.5 ± 2.5	6.7 ± 1.7 ¹	7.9 ± 2.0 ²	3.3 ± 0.4	2.3 ± 0.6 ³	3.2 ± 0.8
% SYRINGE NEED MET	1.2 ± 0.7	1.1 ± 0.2	1.3 ± 0.4	4.2 ± 1.0	4.7 ± 1.2	7.5 ± 1.4 ⁴

¹ Significantly different from the November, 1990 – July, 1992 period (t = 4.74, p < 0.0001).
² Significantly different from the November, 1990 – July, 1992 period, (t = 3.54, p < 0.002).
³ Significantly different from the July, 1994 – June, 1997 period (t = 10.50, p < 0.0001) and the January 2000 – December, 2005 period (t = 10.26, p < 0.0001).
⁴ Significantly different from the July, 1994 – June, 1997 and the July 1997 – December, 1999 periods (t = 9.52, p < 0.0001).

Table 2

Newly Diagnosed AIDS Cases

YEARS	NEW HAVEN		CHICAGO	
	1981-2000	2001-2006	1992-2002	2003-2006
ALL-CAUSE AIDS CASES	1,990	520	14,544	3,320
YEARLY AVERAGE	99.5	86.7	1322.2	830.0
INJECTION-RELATED AIDS CASES	1,198	245	4,424	592
YEARLY AVERAGE	59.9	40.8	402.2	148.0
% ATTRIBUTABLE TO INJECTION DRUG USE	60.2%	47.1%	30.4%	17.6%
CHANGE IN ALL-CAUSE AIDS CASES ¹	12.9%		37.2%	
CHANGE IN INJECTION-RELATED AIDS CASES ²	31.9%		63.2%	
RELATIVE CHANGE IN % ATTRIBUTABLE TO INJECTION DRUG USE ³	21.7%		41.4%	

¹ 1- (average annual number of all-cause cases in later period divided by average annual number of all-cause cases in earlier period).

² 1- (average annual number of injection-related cases in later period divided by average annual number of injection-related cases in earlier period).

³ 1-[(injection related cases in later period/all-cause cases in later period)/(injection related cases in earlier period/all-cause cases in earlier period)].