The Evolving Epidemiology of Chlamydial and Gonococcal Infections in Response to Control Programs in Winnipeg, Canada

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ABSTRACT

Objectives. The purpose of this study was to describe and compare the transmission dynamics of chlamydia and gonorrhea in Winnipeg, Manitoba, Canada, and to assess implications for control programs.

Methods. Chlamydia and gonorrhea surveillance case reports (1988 through 1995) and contact-tracing reports (1991 through 1995) were examined.

Results. High incidence rates of both chlamydia and gonorrhea clustered in geographic core areas characterized by low socioeconomic status. A decline in the number of reported cases of chlamydia (61%) and gonorrhea (64%) occurred between 1988 and 1995. For chlamydia, the decline was most prominent in non–core area cases, while for gonorrhea it was similar in core and noncore areas.

Conclusions. Chlamydia and gonorrhea appear to be evolving through different epidemic phases, with chlamydia transmission, in response to a newly introduced control program, becoming more core dependent and gonorrhea transmission becoming more sporadic in the face of a sustained control effort. Focused control programs, based on an understanding of the transmission dynamics of chlamydia and gonorrhea, may make their elimination a feasible goal. (*Am J Public Health.* 1998;88: 1496–1502)

Bacterial sexually transmitted diseases (STDs) remain an important public health problem worldwide.[1,2] Most bacterial STDs are curable with relatively short courses of antimicrobials and have therefore become the focus of major disease control efforts.[3]

STD control strategies should be based on a sound understanding of the population-level transmission dynamics of STD pathogens. Previous theoretical and empirical findings have provided valuable insight into the transmission dynamics of STDs.[4–12] These findings have identified the importance of core groups in the spread of STDs within populations. The theoretical underpinning of the core group concept is derived from the basic reproductive number, which defines the ecologic success for any infectious disease as the average number of secondary infections arising from infected individuals in a fully susceptible population.[5] The basic reproductive number is the product of 3 population parameters: transmissibility of the disease, contact rate between infective and susceptible individuals, and duration of infectivity. Only when the basic reproductive number is greater than 1 does an infectious agent successfully spread in a population. Estimates from various populations demonstrate that the average rate of partner change (contact rate) in most segments of the population is not sufficient to sustain STDs.[12] Instead, subpopulations with higher rates of partner change (core groups) are required for the spread and maintenance of STDs in the entire population.

Various approaches have been used to identify STD core groups. At the individual level, members of a core group can be defined according to risk behaviors such as rate of partner change.[4,10] However, identifying individuals within core groups can be difficult for public health practitioners and unfairly stigmatizing for individuals. Therefore, spatial analyses have been used to define geographic "core areas" within which STD transmission rates are highest.[8,9] These geographic core areas are hypothesized to contain a higher proportion of the core group members and thus provide a rational target for focusing control efforts.[1,7,13] However, Wasserheit and Aral point out that the characteristics and roles of core groups in STD transmission evolve under the influence of control programs.[14] Furthermore, they suggest that these changes unfold in a stereotypic pattern and that control programs should be responsive to such changes.

In this paper, we analyze the epidemiology of *Chlamydia trachomatis* (chlamydia) and *Neisseria gonorrhoeae* (gonorrhea) infection in Winnipeg, Canada. By examining the role of geographic core area populations in the spread of these 2 STDs over time, we provide evidence suggesting that the epidemiology of chlamydia and gonorrhea has evolved in response to control programs, as proposed by Wasserheit and Aral.[14]

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Methods

Descriptive Epidemiology

Manitoba is a province in Canada with a population of approximately 1.14 million. Winnipeg, with a population of close to 660 000, is the only major city in the province. All cases of chlamydia and gonorrhea are notifiable to the provincial health department by both physicians and laboratories under the Public Health Act. Since laboratories in the province routinely report all positive diagnostic tests for chlamydia and gonorrhea, few laboratory-confirmed cases are unreported. In Winnipeg, specially trained public health nurses interview and conduct contact tracing for most persons infected with chlamydia or gonorrhea.[15] Sexual contacts of those with chlamydia and gonorrhea are also notifiable to the provincial health department. As a means of computing the incidence of chlamydia and gonorrhea by geographic location, the province was divided into 322 geographic sites defined by preexisting administrative boundaries (288 rural municipalities for non–Winnipeg residents and the 34 postal areas for Winnipeg residents). The average annual incidence of chlamydia and gonorrhea per 100 000 population was computed on the basis of all reported cases. Incidence rates were directly standardized for age and gender to the total 1991 Manitoba population. Product–moment correlation coefficients were used to assess the geographic relationship between chlamydia and gonorrhea rates. Chi-square tests were used to assess the statistical significance of differences in proportions. SAS (version 6.12; SAS Institute Inc, Cary, NC) was used in performing all statistical analyses.

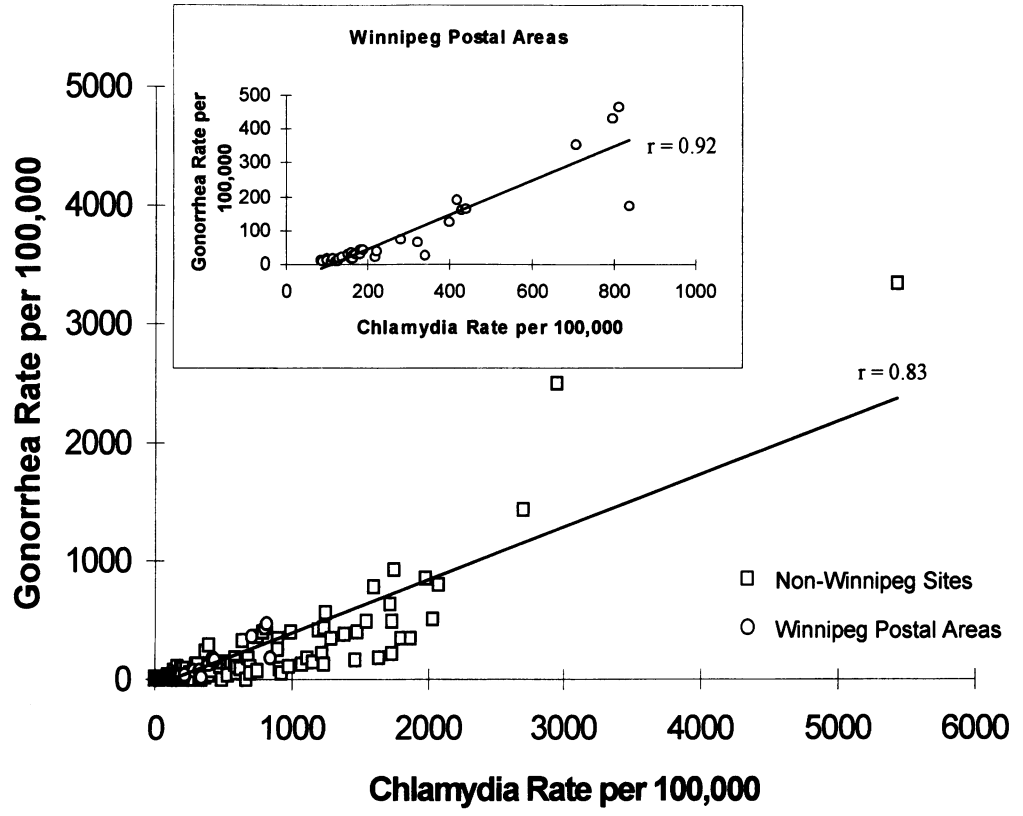
Winnipeg Risk Areas

Winnipeg was divided into 3 geographic risk areas ("core," "adjacent," and "peripheral") separately for chlamydia and gonorrhea. This was done empirically by aggregating postal areas based on their average annual incidence rates between 1991 and 1995 and visually estimating the break points from the distribution curves (see Figure 3a, 3c). Data from the 1991 Census of Canada were used to estimate unemployment rates, mean household incomes, language usually spoken at home, mobility status, and population density for the Winnipeg postal areas (Statistics Canada, Microdata Release File). The incidence of other selected communicable diseases was derived from the provincial notifiable disease registry.

Results

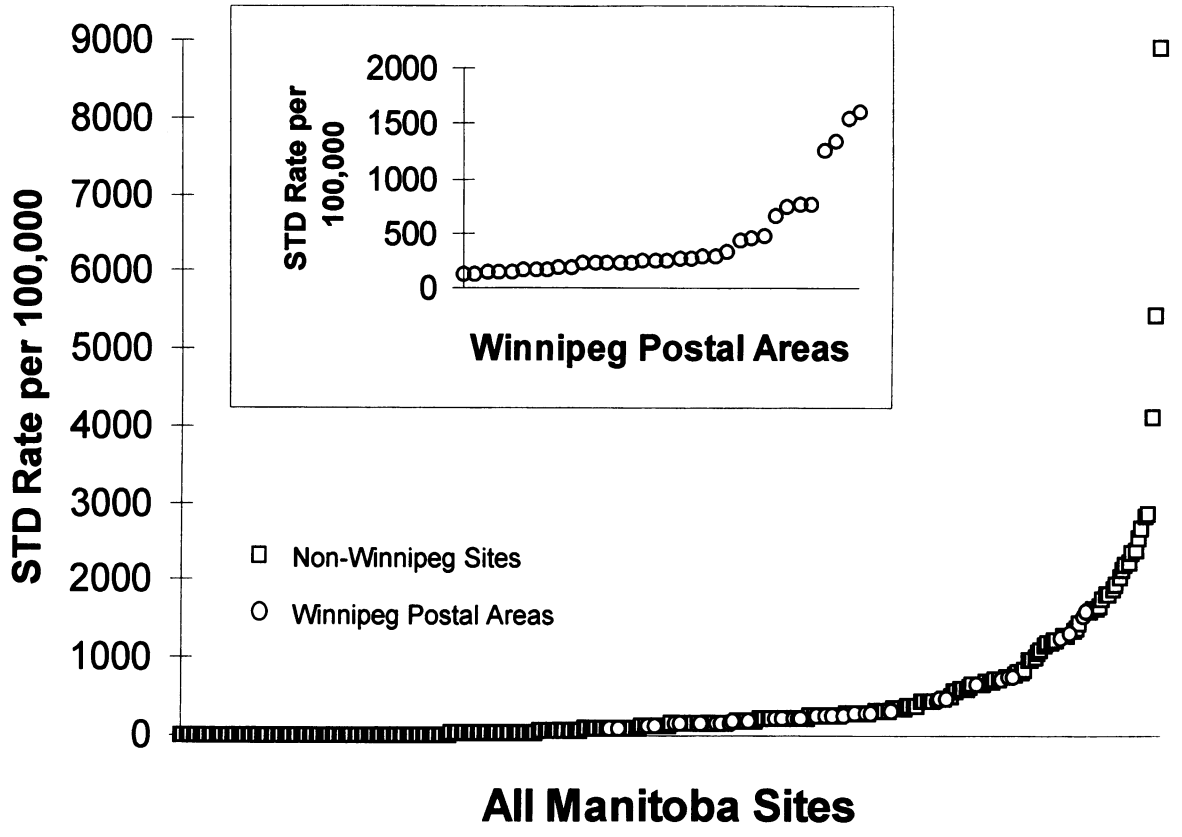
STD Incidence Rates by Geographic Site

Figure 1 shows that chlamydia and gonorrhea incidence rates were highly correlated at both the provincial and urban levels (Manitoba, $r = .83$, $P < .001$; Winnipeg, $r = .92$, $P < .001$). Because chlamydia and gonorrhea rates were so highly correlated, we pooled the data and analyzed the spatial distribution of incidence in the province and in the city of Winnipeg. Figure 2 shows the remarkable geographic variation in chlamydia and gonorrhea incidence rates. From 1991 through 1995, the average annual incidence of chlamydia and gonorrhea ranged from 0 to almost 9000 per 100 000 population in differ-



Note. Manitoba sites are the municipalities outside of Winnipeg and the postal areas within Winnipeg. The inset shows the scatterplot for the Winnipeg subset of the Manitoba sites.

FIGURE 1—Scatterplot of average annual age- and sex-standardized incidence rates of chlamydia and gonorrhea, by Manitoba geographic site, 1991 through 1995.



Note. Manitoba sites are the municipalities outside of Winnipeg and the postal areas within Winnipeg. The inset shows the Winnipeg subset of the Manitoba sites.

FIGURE 2—Average annual age- and sex-standardized incidence rates of chlamydia and gonorrhea (combined), by Manitoba geographic site, 1991 through 1995.

ent Manitoba geographic sites. This was also true within the city of Winnipeg, where the variation in incidence ranged by more than 13-fold from 119 to 1600 per 100 000 (Figure 2 inset).

To better define factors associated with the geographic heterogeneity in STD incidence, we restricted further analysis to cases in Winnipeg, since most Manitoba STD cases occur in Winnipeg and most non-Winnipeg cases occur in remote northern regions of the province. Both chlamydia and gonorrhea incidence rates differed greatly by postal area in Winnipeg, but, as Figure 3 demonstrates, there was substantial geographic congruence between chlamydia and gonorrhea risk areas. For chlamydia, 4 postal areas had similar high incidence rates (range: 887 to 1047 per 100 000) and were thus designated core; 7 postal areas had intermediate rates (range: 350 to 547 per 100 000) and were designated adjacent, and the remaining 23 were designated peripheral (range: 106 to 275 per 100 000). For gonorrhea, 3 postal areas were designated core (incidence range: 443 to 584 per 100 000), 5 were designated adjacent (incidence range: 157 to 238 per 100 000), and 26 were designated peripheral (incidence range: 8 to 94 per 100 000). The chlamydia core postal areas included all 3 gonorrhea core postal areas along with 1 postal area designated as adjacent for gonorrhea. The chlamydia adjacent areas included the remaining 4 gonorrhea adjacent postal areas and 2 additional adjacent areas designated as peripheral for gonorrhea.

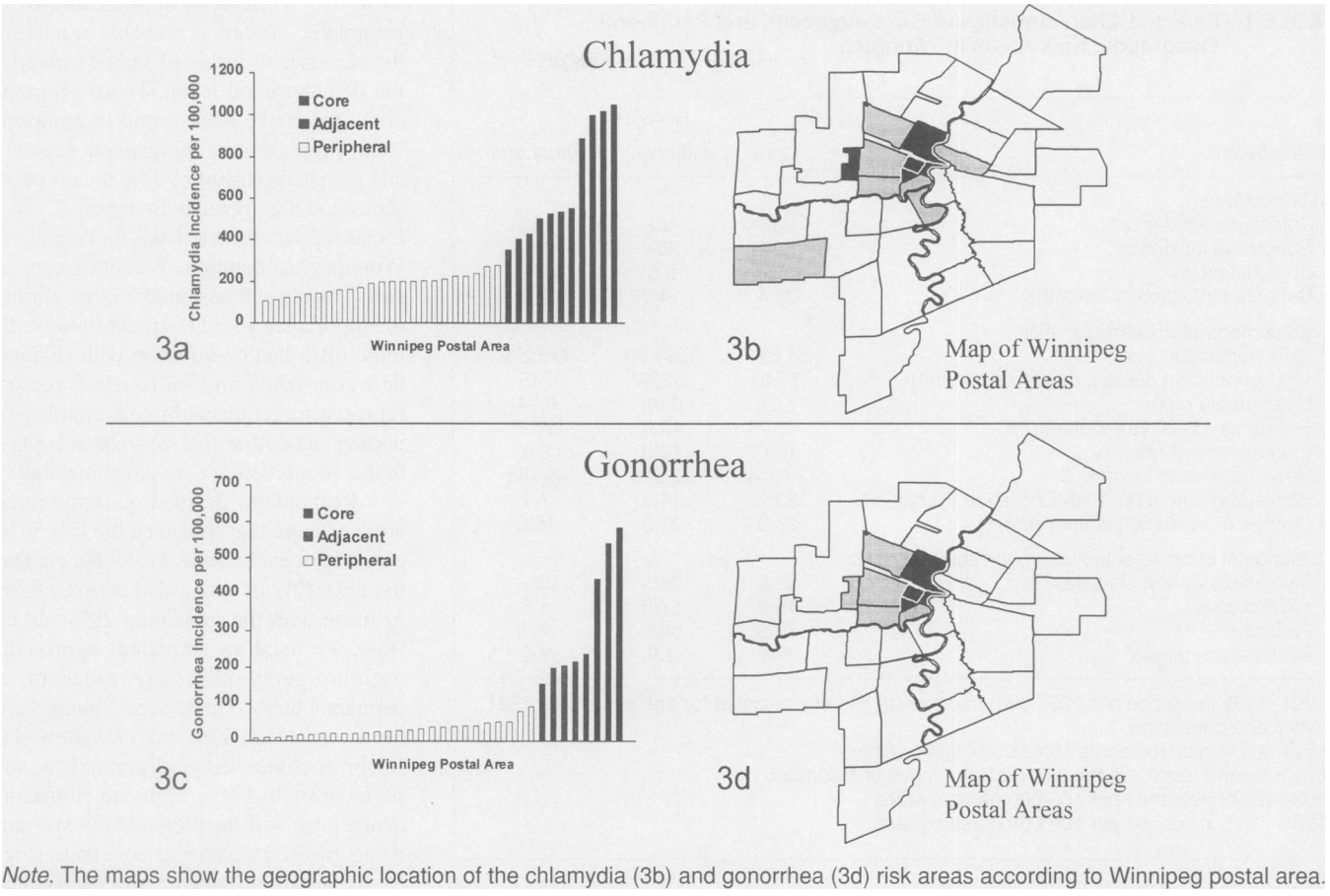
Characteristics of STD Risk Areas

The chlamydia risk areas were used to describe the sociodemographic characteristics of the Winnipeg risk areas, since the gonorrhea core areas and adjacent areas were a subset of those for chlamydia. The core risk areas contained only 8% of the Winnipeg population (Table 1). The adjacent areas contained 20%, and the peripheral areas contained the remaining 72%. Notably, case patients from core areas in 1991 were more likely to have a repeat infection within 1 year (20.4%) than were case patients from the adjacent (14.2%) or peripheral (9.2%) areas. As well, a higher proportion of core area patients (7.5%) than patients from the adjacent (5.5%) or peripheral (2.5%) areas had concomitant infection with chlamydia and gonorrhea.

The core areas differed demographically from the noncore areas. There was a higher population density in the core areas, as well as a higher percentage of male residents. The core areas also had a higher proportion of persons who did not speak either English or French (Manitoba's 2 official languages) at home and were characterized by greater residential mobility than the adjacent or peripheral areas. The core area was characterized by higher unemployment rates and lower mean household incomes than the adjacent and peripheral areas. The incidence of other communicable diseases was also higher in the core areas. This difference was most evident for salmonellosis, shigellosis, and tuberculosis.

STD Trends in Winnipeg

Between 1988 and 1995, there was a substantial decline in the number of reported cases of both chlamydia (61%) and gonorrhea (64%) in Winnipeg (Figure 4). For



Note. The maps show the geographic location of the chlamydia (3b) and gonorrhea (3d) risk areas according to Winnipeg postal area.

FIGURE 3—Incidence of chlamydia (3a) and gonorrhea (3c), by postal area of residence and geographic risk area (core, adjacent, and peripheral), 1991 through 1995.

chlamydia, the most substantial declines were seen in the peripheral (67%) and adjacent (59%) areas, with a smaller decline seen in the core areas (50%). As a result, there was a significant increase in the proportion of chlamydia cases occurring in the core areas, from 20% to 26% ($P < .001$).

In contrast to the trends for chlamydia, the decline in core area cases of gonorrhea (67%) was similar to that observed in the peripheral areas (68%). The smallest decline in gonorrhea cases was seen in the adjacent areas (55%). As a result, the proportion of gonorrhea cases occurring in the core areas did not change appreciably between 1988 and 1995 (39% vs 36%; $P = .24$).

Mixing Patterns Among Case Patients and Contacts

The postal areas of residence were known for 60.2% of the named sexual contacts in 1991 and for 60.9% in 1995. As shown in Table 2, for all Winnipeg chlamydia index case patients, there was a significant increase in the proportion naming at least 1 core area contact, from 22.1% in 1991 to 27.4% in 1995 ($P < .01$). This increase was seen among both noncore and core case patients.

In contrast, there was an overall reduction in the proportion of gonorrhea index case patients naming a core area contact, from 42.6% in 1991 to 38.1% in 1995 ($P = .34$). This decline was due to a substantial reduction in the proportion of non–core area case patients who named a core area contact (from 31.4% to 20.5%; $P < .05$). As was observed for chlamydia, the proportion of core area gonorrhea patients naming a core area contact increased, but this increase was not statistically significant (57.7% to 64.3%; $P = .38$).

Discussion

The importance of core groups in STD transmission dynamics is widely acknowledged, although their centrality to STD epidemiology has been difficult to empirically demonstrate.[13,14] Theoretical models have shown that without the presence of core groups, newly introduced STDs will generate short infection chains that ultimately extinguish themselves.[4,5] Rothenberg and Voigt have shown that the likelihood that a strain of penicillinase-producing *N gonorrhoeae* will persist in a community is largely determined by how rapidly it initially spreads.[11] Such observations suggest that entry of a sexually transmitted agent into a core group is an important determinant of its ecological success.

One potentially practical method of targeting control efforts at core groups is that of identifying geographic areas with high rates of STD transmission, which are likely to contain higher proportions of core group members. In the present study, we have shown that there is substantial geographic variation in the incidence of chlamydia and gonorrhea in the province of Manitoba and in the city of Winnipeg. Geographic diversity in STD incidence has also been reported from other North American populations such as those of upstate New York[9]; Colorado Springs[8]; King County, Washington[16]; Dade County, Florida[17]; Miami, Fla[18]; and North Carolina.[19] The concept of identifying core groups geographically has been explored previously for both chlamydia and gonor-

TABLE 1—Selected Characteristics of Core, Adjacent, and Peripheral Geographic Risk Areas in Winnipeg

Characteristic	Risk Area		
	Core	Adjacent	Peripheral
STD incidence			
Chlamydia incidence[a]	986	468	183
Gonorrhea incidence[a]	523	204	33
Co-infection, %	7.5	5.5	2.5
Repeated infection (12 months), %	20.4	14.2	9.2
Sociodemographic characteristics			
1991 population size	51 631	128 480	473 279
1991 population density, residents per km^2	3740	3224	745
Male:female ratio	1.02	0.95	0.94
Residents 15–24 years of age, %	13.7	13.2	14.6
Unemployment rate,[b] %	16.0	12.0	8.0
Mean household income, $	27 074	32 518	49 456
Home language other than English or French,[c] %	23.7	14.2	7.1
Change of residence in past year, %	26.3	21.3	15.6
Incidence of other selected communicable diseases			
Salmonellosis and shigellosis[d]	52.9	36.5	20.2
Tuberculosis[e]	45.0	17.0	4.6
Pertussis[d]	73.9	50.8	66.0
Bacterial meningitis[d]	5.2	2.9	3.5

[a]1991–1995 incidence per 100 000 person-years, directly adjusted for age and sex to 1991 Manitoba population.
[b]Male and female residents 15 years of age or older.
[c]English and French are the 2 official languages of Manitoba.
[d]1991–1995 incidence per 100 000 person-years.
[e]1988–1995 incidence per 100 000 person-years.

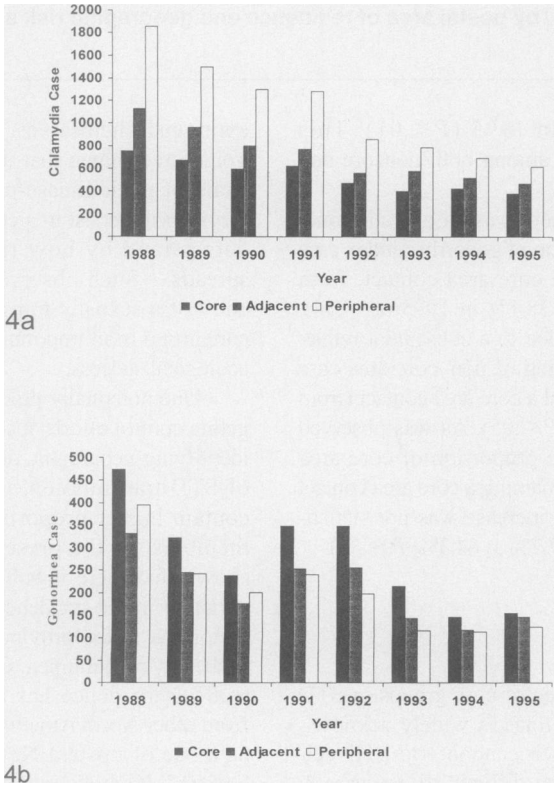


FIGURE 4—Annual number of reported cases of chlamydia (4a) and gonorrhea (4b), by Winnipeg risk area, 1988 through 1995.

rhea.[8–10,20] Potterat et al. have shown that geographic clustering probably results from the existence of localized sexual networks at the neighborhood level.[8] These geographic core areas have been found to comprise a small proportion of the general population and are characterized by low socioeconomic status and high population density.[8,9,18,20] We found similar characteristics for core areas in Winnipeg. In addition, Winnipeg core area case patients demonstrated 2 other attributes of importance to STD epidemiology: they more often had co-infection with chlamydia and gonorrhea and more often reported repeated infection within 12 months, supporting the notion that core areas contain a higher proportion of core group members.

Rothenberg defined geographic core areas as those that contained the first 50% of cases, adjacent areas as those that contained the next 30% of cases, and peripheral areas as those with the remaining 20%.[9] In contrast, we used an empirical approach to defining geographic core, adjacent, and peripheral areas. There were 2 main reasons for this approach. First, our data showed that for both chlamydia and gonorrhea, some postal areas had very high and similar incidence rates and therefore clearly warranted being grouped together as core areas (Figure 3). Expansion of the core areas according to Rothenberg's method would have resulted in the aggregation of postal areas with very dissimilar infection rates. Second, we wanted to study and contrast the relative size and influence of the core areas for chlamydia and gonorrhea epidemiology over time. Appropriate incidence cutpoints to distinguish adjacent from peripheral areas were less clear, especially for chlamydia.

We observed a clear geographic congruence in Winnipeg between areas with similar chlamydia and gonorrhea incidence rates, with the chlamydia core and adjacent areas being only slightly expanded in relation to those for gonorrhea. This differed from the 1988 findings of Zimmerman et al. in Colorado Springs, where the chlamydia core and adjacent areas were observed to be somewhat different from those for gonorrhea.[20] The difference between the 2 studies may be due in part to their interpretation of Rothenberg's definition of geographic core, adjacent, and peripheral areas. It could also reflect an earlier epidemic phase for chlamydia in Colorado Springs at that time.

Although the existence of relatively small and geographically contiguous core areas with high rates of both chlamydia and gonorrhea transmission offers a feasible focus for STD control efforts, the nature and influence of these areas may change in response to such efforts. Brunham and Plum-

TABLE 2—Percentages of Winnipeg Chlamydia and Gonorrhea Index Case Patients Naming at Least 1 Sexual Partner Who Resided in the Core Areas in 1991 and 1995

	1991, % (95% CI)	1995, % (95% CI)
Chlamydia		
Noncore	11.4 (9.8, 13.0)	15.0 (11.3, 18.8)
Core	59.8 (55.0, 64.4)	63.2 (54.1, 71.6)
All cases	22.1 (20.3, 23.9)	27.4** (23.4, 31.4)
Gonorrhea		
Noncore	31.4 (26.1, 37.1)	20.5* (12.4, 30.8)
Core	57.7 (50.8, 64.5)	64.3 (50.4, 76.6)
All cases	42.6 (38.2, 47.1)	38.1 (30.0, 46.7)

Note. CI = confidence interval.
*$P < .05$ vs 1991.
**$P < .01$ vs 1991.

mer previously postulated that control efforts serve to concentrate STDs in ever more sexually active populations that are less accessible to public health control programs.[7] Wasserheit and Aral expanded this concept and suggested that the epidemiology of STDs would change in a predictable pattern in response to disease control activities.[14] In support of these notions, we found important differences between chlamydia and gonorrhea suggesting that these 2 diseases are indeed in different epidemic phases. Using the nomenclature of Wasserheit and Aral, we suggest that the chlamydia epidemic has moved from phase II/II′ ("hyperendemic") to phase III ("decline") and that the gonorrhea epidemic has moved from phase III ("decline") toward phase IV ("endemic").

The incidence of both chlamydia and gonorrhea has declined dramatically over the past several years in Winnipeg. While gonorrhea remains more concentrated in the core areas than does chlamydia, the recent decline in gonorrhea cases has been evenly distributed among core and noncore areas, with the proportion of cases arising from the core areas actually decreasing slightly. In contrast, chlamydia has become more focused in the core areas over time. This difference probably reflects the more recent introduction of a chlamydia control program. Whereas gonorrhea control activities have been in place since the 1970s, the chlamydia control program was not implemented until the mid-1980s. Early in the control program, chlamydia cases were more likely to have been prevalent infections and to exist in non–core group populations. As prevalent infections were eliminated, a greater proportion of cases became concentrated in core groups, and these were more likely to be incident cases. As well, prior to the introduction of a control program, the long duration of chlamydia infectiousness may have allowed chlamydia to persist in populations with lower rates of partner change. However, the availability of diagnostic and treatment services would shorten the duration of infectiousness and should concentrate the epidemic in core groups with higher rates of partner change and less contact with the health care system.

Further evidence of differences in the epidemic phase of chlamydia and gonorrhea is found in geographic patient–contact mixing patterns. Our data indicate that gonorrhea is more core dependent than chlamydia, since a greater proportion of all gonorrhea patients named at least 1 sexual contact who resided in the core areas (Table 2). Subsequent to the introduction of a control program, chlamydia appears to have become more core dependent, with a greater proportion of patients naming at least 1 contact residing in a core area in 1995 than in 1991 (Table 2). In contrast, the proportion of gonorrhea patients naming at least 1 core area contact has declined. While gonorrhea patients residing in the core areas remain most likely to name a core area contact, there has been a significant decline in the proportion of non–core area gonorrhea patients naming a core area contact. This finding may indicate that the steady decline in gonorrhea incidence in both the core and noncore areas has begun to disrupt the spread between sexual networks in different geographic parts of the city. In commenting on the role of social networks in the spread of HIV, Rothenberg et al. pointed out that such segmentation of networks may be important in interrupting disease transmission.[21]

Our findings have important implications for STD control strategies in other jurisdictions. As Wasserheit and Aral have advocated, the nature and content of control efforts should respond to changes in the epidemiology of STDs caused by the effects of a control program.[14] For instance, in Winnipeg, as chlamydia continues to become more core dependent, prevention efforts should be increasingly targeted toward the geographic core areas. Since the core areas have characteristics such as socioeconomic disadvantage and high mobility, success will probably depend on a firm understanding of the local community and the implementation of effective community development processes that are multisectoral in nature. The higher incidence of other communicable diseases in the core areas also suggests that the social, economic, and demographic characteristics of these areas are associated with greater transmission of both non-STDs and STDs. Availability and use of health services may be one determinant of the greater infectious disease burden in these areas. Thus, it is important that health services in core areas, including those for STD control, be made as accessible as possible through measures such as flexible operating hours and the acceptance of clients without appointments.

Gonorrhea appears to be in a different epidemic phase than chlamydia in Winnipeg. Therefore, different control strategies are indicated. Since gonorrhea continues to be concentrated in the core areas, control efforts should also be focused there. However, if gonorrhea incidence continues to decline and geographic segmentation continues, it will become increasingly difficult to target core groups geographically. Instead, efforts may need to be redirected more toward aggressive interruption of the spread of infection within specific sexual networks rather than specific geographic areas. These activities may include enhanced public health efforts in contact tracing and epidemiologic treatment of contacts. They may also require the acquisition of more detailed knowledge regarding the characteristics of social and sexual networks.

We acknowledge that there are many possible biases inherent in passive surveillance systems such as those used for the reported STD rates in Manitoba. In particular, reporting patterns may differ according to residence or socioeconomic status.[22,23] With respect to assessment of patient–contact mixing patterns, patients are probably more likely to remember or name contacts who live near them. However, we believe that routinely collected STD disease surveillance data can be more effectively analyzed than at present and that they can be used to guide control strategies through the evolving phases of STD epidemics. The use of applied epidemiologic research, together with new tools such as network analysis and molecular epidemiology, will further enhance control efforts and may make elimination of bacterial STDs from many populations a feasible public health goal. □

Acknowledgments

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References

1. Over M, Piot P. Human immunodeficiency virus infection and other sexually transmitted diseases in developing countries: public health importance and priorities for resource allocation. *J Infect Dis*. 1996;174(suppl 2):S162–S175.
2. Piot P, Islam MQ. Sexually transmitted diseases in the 1990s. Global epidemiology and challenges for control. *Sex Transm Dis*. 1994;21(suppl 2):S7–S13.
3. O'Reilly KR, Piot P. International perspectives on individual and community approaches to the prevention of sexually transmitted disease and human immunodeficiency virus infection. *J Infect Dis*. 1996;174(suppl 2):S214–S222.
4. Yorke JA, Heathcote HW, Nold A. Dynamics and control of the transmission of gonorrhea. *Sex Transm Dis*. 1978;5:51–57.
5. May RM, Anderson RM. Transmission dynamics of HIV infection. *Nature*. 1987;326:137–142.
6. Anderson RM, May RM. Epidemiological parameters of HIV transmission. *Nature*. 1988;333:514–519.
7. Brunham RC, Plummer FA. A general model of sexually transmitted disease epidemiology and its implications for control. *Med Clin North Am*. 1990;74:1339–1352.
8. Potterat JJ, Rothenberg RB, Woodhouse DE, Muth JB, Pratts CI, Fogle JS. Gonorrhea as a social disease. *Sex Transm Dis*. 1985;12:25–32.
9. Rothenberg RB. The geography of gonorrhea: empirical demonstration of core group transmission. *Am J Epidemiol*. 1983;117:688–694.
10. Garnett GP, Anderson RM. Contact tracing and the estimation of sexual mixing patterns: the epidemiology of gonococcal infections. *Sex Transm Dis*. 1993;20:181–191.
11. Rothenberg RB, Voigt R. Epidemiologic aspects of control of penicillinase-producing *Neisseria gonorrhoeae*. *Sex Transm Dis*. 1988; 15:211–216.
12. Brunham RC. Core group theory: a central concept in STD epidemiology. *Venereology*. 1997;10:28–31.
13. Thomas JC, Tucker MJ. The development and use of the concept of a sexually transmitted disease core. *J Infect Dis*. 1996;174(suppl 2): S134–S143.
14. Wasserheit JN, Aral SO. The dynamic topology of sexually transmitted disease epidemics: implications for prevention strategies. *J Infect Dis*. 1996;174(suppl 2):S201–S213.
15. Orr P, Sherman E, Blanchard JF, Fast M, Hammond G, Brunham RC. The epidemiology of *Chlamydia trachomatis* in Manitoba, Canada. *Clin Infect Dis*. 1995;19:876–883.
16. Rice RJ, Roberts PL, Handsfield HH, Holmes KK. Sociodemographic distribution of gonorrhea incidence: implications for prevention and behavioral research. *Am J Public Health*. 1991;81:1252–1258.
17. Zenilman JM, Bonner M, Sharp KL, Rabb JA, Alexander ER. Penicillinase-producing *Neisseria gonorrhoeae* in Dade County, Florida: evidence for core-group transmitters and of the impact of illicit antibiotics. *Sex Transm Dis*. 1988;15:45–50.
18. Hamers FF, Peterman TA, Zaidi AA, Ransom RL, Wroten JE, Witte JJ. Syphilis and gonorrhea in Miami: similar clustering, different trends. *Am J Public Health*. 1995;85:1104–1108.
19. Thomas JC, Schoenbach VJ, Weiner DM, Parker EA, Earp JA. Rural gonorrhea in the southeastern United States: a neglected epidemic? *Am J Epidemiol*. 1996;143:269–277.
20. Zimmerman HL, Potterat JJ, Dukes RL, et al. Epidemiologic differences between chlamydia and gonorrhea. *Am J Public Health*. 1990;80: 1338–1342.
21. Rothenberg RB, Potterat JJ, Woodhouse DE. Personal risk taking and the spread of disease: beyond core groups. *J Infect Dis*. 1996; 174(suppl 2):S144–S149.
22. Rothenberg RB, Bross DC, Vernon TM. Reporting of gonorrhea by private physicians: a behavioral study. *Am J Public Health*. 1980;70:983–986.
23. Curtis AC. National survey of venereal disease treatment. *JAMA*. 1963;186:46–59.