What's Driving an Epidemic? The Spread of Syphilis Along an Interstate Highway in Rural North Carolina

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ABSTRACT

Objectives. The purpose of this study was to determine whether county syphilis rates were increased along Interstate Highway 95 (I-95) in North Carolina during a recent epidemic.

Methods. Ecological data on syphilis cases, demographic data, highway data, and drug activity data were used to conduct a cross-sectional and longitudinal study of North Carolina counties from 1985 to 1994. Crude and adjusted incidence rate ratios (IRRs) were determined by means of standard and longitudinal Poisson regression models adjusted for sociodemographic factors and drug use.

Results. Ten-year syphilis rates in I-95 counties greatly exceeded rates in non–I-95 counties (38 vs 16 cases per 100 000 persons) and remained higher after adjustment for race, age, sex, poverty, large cities, and drug activity (adjusted IRR = 2.05, 95% confidence interval [CI] = 1.84, 2.28). Syphilis rates were stable until 1989, when rates increased sharply in I-95 counties but remained stable in non–I-95 counties. Increased drug activity in I-95 counties preceded the rise in syphilis cases.

Conclusions. A better understanding of the relationship between highways and the spread of sexually transmitted diseases may guide future prevention interventions. (*Am J Public Health.* 1999;89:369–373)

After years of decline, syphilis rates surged in the United States during the mid-1980s and reached a high in 1990 of 20.3 cases per 100 000 population.[1] During this national epidemic, syphilis rates rose first in large urban areas, especially along the East Coast and in the South.[2] By the late 1980s, syphilis rates in some rural areas surpassed urban rates.[3] This was the trend in North Carolina, where a surprising concentration of high syphilis rates was noted in rural counties along Interstate Highway 95 (I-95) (Figure 1). This highway connects New York City and Miami, areas where the syphilis epidemic had peaked earlier.

The high rates of syphilis in counties along I-95 prompted speculation that factors associated with this highway may have contributed to the spread of syphilis into rural North Carolina. It is known that sexual contact between long-distance truck drivers and local prostitutes has contributed to the heterosexual spread of HIV in several nations,[4–8] but such an association has not been investigated in the United States in a systematic manner. Drug trafficking and distribution may be focused along interstate highways,[9] and sexual behaviors associated with drug use could lead to an increase in sexually transmitted diseases such as syphilis.[10–13] Alternatively, the association of I-95 with higher syphilis rates may simply reflect the characteristics of the population in eastern North Carolina, an economically depressed rural region where access to health care services is limited and a high proportion of the population is Black.[14] These sociodemographic factors are inexplicably associated with higher syphilis rates.[15]

The objectives of this study were to determine whether county syphilis rates were increased along I-95 when adjustments were made for county sociodemographic factors and to compare patterns of change in syphilis rates with changes in demographics and drug use over time.

Methods

Data Collection and Sources

Annual syphilis data (1985–1994) were obtained for each of the 100 North Carolina counties from the North Carolina Department of Environment, Health and Natural Resources. Data for each case included the person's age, sex, race, stage of syphilis, county of residence, and year of report. Cases of primary and secondary syphilis in persons 10 years and older were selected for this analysis. Thus, cases of congenital or late syphilis and cases in people younger than 10 years were excluded.

County sociodemographic data, including population statistics, urban–rural distinctions, and economic data, were obtained from LINC (Log Into North Carolina), an on-line database containing census information and annual intercensal estimates. Data on county population 10 years and older were collected for each year (1985–1994) and subdivided by sex, race (White or non-White), and age. Percentages of the population who were female, non-White, and young adult (aged 20–35 years) were calculated for each county. The presence or absence in the county of a large city (population > 100 000) was noted. Data on county economics included the percentage of persons living in poverty (1990).

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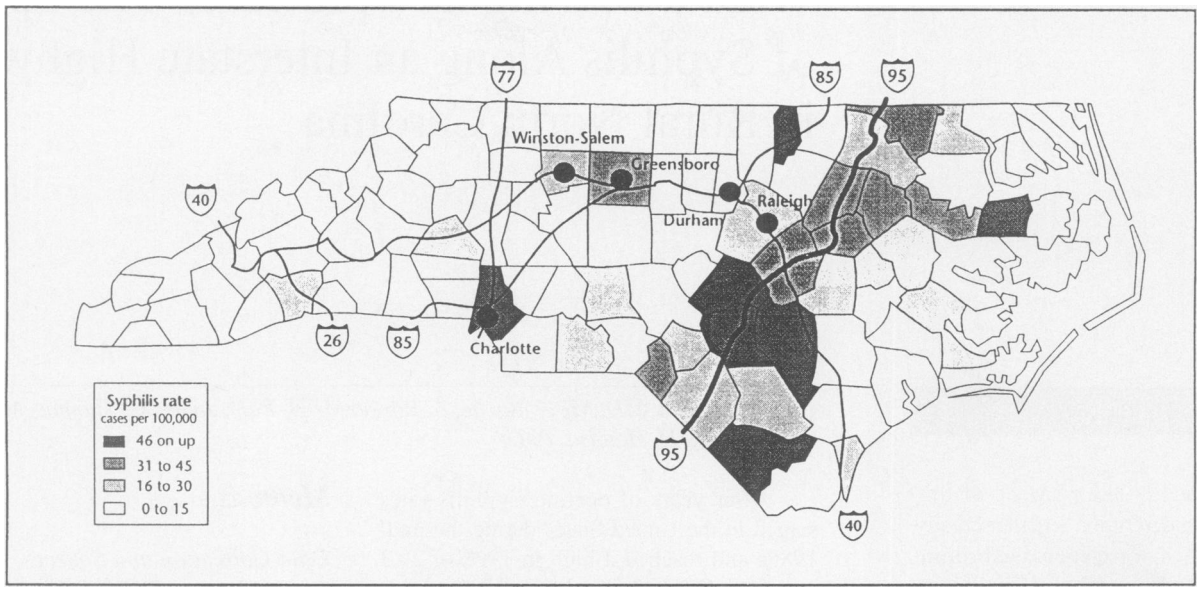

FIGURE 1—Syphilis rates (cases of primary and secondary syphilis per 100 000 persons aged 10 years and older): North Carolina counties, 1989.

Highway transportation data for each county, including the geographic proximity of an interstate highway and the number of highway exits, were determined directly from the North Carolina official 1994 highway map. The North Carolina Department of Transportation provided the total interstate highway mileage within each county. To estimate county drug activity, the number of persons admitted to drug and alcohol rehabilitation centers was abstracted from LINC (1985–1994) and the number of cocaine- and heroin-related arrests was taken from annual published state crime statistics (1985–1994).[16]

Definitions

A county was considered to be exposed to an interstate highway if the highway passed through the county or if the county could be accessed by road from the interstate highway in fewer than 5 miles. The 5 counties containing large cities (population >100 000) were considered separately; no such cities were located in counties along I-95. Annual syphilis rates for groups of counties were defined as the total number of primary and secondary syphilis cases within a given year divided by the total population 10 years and older within those counties. Ten-year syphilis rates were defined as the mean annual number of primary and secondary syphilis cases over the 10-year period (1985–1994) divided by the mean annual population for the group of counties.

A 10-year average syphilis rate was calculated for counties along each of the 5 interstate highways in North Carolina (highways I-26, I-40, I-77, I-85, and I-95). For each highway, syphilis rates were determined for counties having high, medium, and low numbers of highway exits, interstate miles, and exits per mile (exit density).

For the remainder of the analyses, each county was classified into 1 of 3 mutually exclusive groups: I-95 counties, non–I-95 counties, and counties with large cities. Syphilis rates for each county classification were computed for individual years (1985–1994) and as a 10-year average. Rates were determined for the entire study population and separately for each sex and race category. Within each county classification, annual median values were determined for the percentages of the population who were non-White, female, and aged 20 to 35 years, as well as for rates of drug arrests and admissions to drug and alcohol rehabilitation centers. The patterns of change in syphilis rates and the other county-level variables were examined over the 10-year period.

Regression Analysis

The crude incidence rate ratio (IRR) between each county-level variable and syphilis rates over the 10-year period was determined by Poisson regression.[17] Exposure to I-95; percentages of the population who were non-White, aged 20 to 35 years, female, and below poverty level; presence of a large city; and drug arrest rate were each examined as a predictor of syphilis rates. Then the relationship of I-95 to county syphilis rates was determined, with adjustment for all of the other predictor variables. A longitudinal random-effects Poisson regression model was used to adjust for calendar time because the data represented repeated annual county measures over the 10-year period.[17] Finally, standard multivariable Poisson regression was used to determine the adjusted annual relationship of I-95 to county syphilis rates specifically for each year (1985–1994).

Results

Of the 100 North Carolina counties, 11 were classified as I-95 counties, 84 as non–I-95 counties, and 5 as counties with large cities. Compared with non–I-95 counties, I-95 counties had a higher percentage of non-Whites and of young adults aged 20 to 35 years, in addition to a higher drug arrest rate (Table 1). Counties with large cities were different from the other 2 county classifications in that they had the highest percentages of young adults, the highest drug arrest rates, and the lowest percentages of persons below the poverty level (Table 1).

The 10-year average syphilis rate in North Carolina during the period was 24 cases per 100 000 persons. Excluding the 5 counties containing large cities, 10-year syphilis rates in counties along highways I-95, I-85, I-77, I-40, and I-26 were 38, 15, 15, 17, and 5 cases per 100 000 persons, respectively. Thus, counties along I-95 were the only interstate-highway counties with

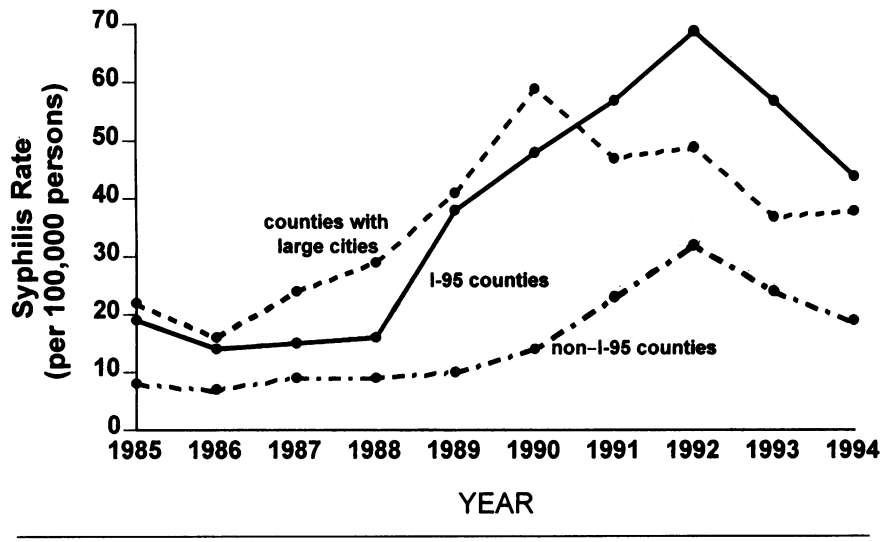

FIGURE 2—Syphilis rates in 3 groups of North Carolina counties, 1985–1994.

syphilis rates above the state average. There was no consistent relationship between county syphilis rates and miles of interstate highway, number of exits, or exit density (data not shown).

The 10-year average syphilis rate in I-95 counties (38 cases per 100 000 persons) was similar to the rate seen in counties with large cities (37 cases per 100 000 persons) but significantly higher than the rate in non–I-95 counties (16 cases per 100 000 persons). For each stratum of race and sex, syphilis rates were consistently higher in I-95 counties than in non–I-95 counties.

Between 1985 and 1994, North Carolina syphilis rates increased first in counties with large cities, next in I-95 counties, and finally in the rest of the state (Figure 2). Annual syphilis rates in I-95 and non–I-95 counties were fairly similar until 1989, when rates more than doubled in I-95 counties (from 16 to 38 per 100 000 persons), whereas they remained stable in non–I-95 counties (16 per 100 000 persons). For each year after 1989, rates remained higher in I-95 counties than in non–I-95 counties. Similar trends in rates over time were noted in each sex and race category (data not shown).

In crude longitudinal analyses over the 10-year period, county exposure to I-95 was associated with a significantly increased risk of syphilis (IRR = 1.73, 95% confidence interval [CI] = 1.60, 1.86). Other risk factors associated with county syphilis rates included presence of a large city, percentage of the population who were non-White, percentage of the population who were female, percentage of the population living below poverty, and the drug arrest rate (Table 2). In multivariable analysis over the 10-year period, controlling for county-level race, sex, age, and poverty percentages, large cities, and drug arrests, counties along I-95 experienced syphilis rates twice as high as those in non–I-95 counties (adjusted IRR = 2.05, 95% CI = 1.84, 2.28) (Table 2). The multivariable analysis suggested that many of the crude incidence rate ratios were confounded. The adjusted incidence rate ratio for I-95 was actually higher than the crude incidence rate ratio, probably as a result of the inclusion of counties with large cities in the adjusted model. Also, percentage female and percentage below the poverty level had a direct relationship with syphilis rates in the crude analysis but an inverse relationship in the adjusted model. This likely represents joint confounding between several of the independent variables.

Over the 10-year period, the percentages of the population who were non-White, female, and young adult changed very little. In contrast, drug arrests related to cocaine or heroin varied significantly over time. The pattern of arrest rates was remarkably similar to the pattern of syphilis rates, increasing dramatically in I-95 counties from 1987 to 1989, just prior to the increase in syphilis rates in these counties. Between 1987 and 1989, drug arrests in I-95 counties doubled (from 268 to 543 arrests per 100 000 persons), while arrests in non–I-95 counties increased by only 25% (from 295 to 368 arrests per 100 000 persons). Admissions to drug and alcohol rehabilitation centers also increased sharply in I-95 counties in 1987 (from 59 to 86 admissions per 100 000 persons), while there was little change in non–I-95 counties (from 67 to 68 admissions per 100 000 persons).

TABLE 1—Demographic Characteristics of North Carolina Counties, 1985–1994

	I-95 Counties (n = 11)	Non–I-95 Counties (n = 84)	Counties With Large Cities (n = 5)
Total population, 1990	810 766	3 419 211	1 287 048
	Median (IQR)	**Median (IQR)**	**Median (IQR)**
Female, %	53 (52–53)	52 (51–53)	53 (52–53)
Aged 20–34, %	28 (26–30)	26 (24–28)	33 (30–35)
Non-White, %	35 (31–52)	18 (6–33)	27 (24–27)
Below poverty level, %	20 (14–24)	15 (11–20)	10 (10–11)
Drug arrests[a]	393 (202–526)	252 (160–368)	609 (444–941)
Drug/alcohol treatment[a]	44 (16–67)	17 (7–38)	103 (52–227)

Note. IQR= interquartile range (25th–75th percentile).
[a]Rate per 100 000 persons aged 10 years and older.

Discussion

Ecological analyses examining the relationship of group characteristics to disease rates are important because individual risk behaviors alone have been unable to explain the distribution of sexually transmitted diseases in a population.[15,18] Group characteristics such as access to condoms, presence of pharmacies, access to health care, or prevalence of disease in a community can all affect sexually transmitted disease rates.[15,19,20] Use of crack cocaine or other drugs may influence not only the individual but the social dynamics of a community or neighborhood.[21] Similarly, the presence of a large interstate highway may affect an entire community through travel-related businesses or the highway's influence on the cost or availability of certain products, such as drugs.

This analysis suggests that populations in rural counties along I-95 were more vulnerable to syphilis than residents of other counties during a recent epidemic. The sudden rise in syphilis rates along I-95 in 1989 prompted the search for some external factor associated with I-95 that could account for this dramatic increase.

It was important to first eliminate county demographic differences as the

TABLE 2—County-Level Factors Associated With Syphilis Rates in North Carolina, From a Longitudinal Analysis of 1985–1994 Data

Covariate	Crude IRR[a]	95% CI	Adjusted IRR[b]	95% CI
I-95	1.73	1.62, 1.84	2.04	1.84, 2.28
Presence of large city	1.83	1.73, 1.92	2.20	1.94, 2.48
Percentage non-White[c]	1.03	1.02, 1.03	1.04	1.03, 1.04
Percentage female[c]	1.09	1.07, 1.11	0.86	0.84, 0.89
Percentage aged 20–35 y[c]	0.95	0.94, 0.95	0.90	0.89, 0.91
Percentage below poverty level[c]	1.02	1.01, 1.02	0.95	0.94, 0.96
Drug arrest rate[d]	1.10	1.10, 1.11	1.01	1.00, 1.01

Note. IRR = incidence rate ratio; CI = confidence interval.
[a]Crude rate ratios are adjusted for year but not the other covariates.
[b]Adjusted rate ratios include each of the other listed terms in the model.
[c]The incidence rate ratio represents the risk of syphilis given a 1% county-level increase.
[d]The incidence rate ratio represents the risk of syphilis given an increase in county drug arrests of 100 per 100 000 person-years.

explanation for the observed syphilis rates. Counties along I-95 have higher percentages of Blacks and young adults than non–I-95 counties, and they are characterized by significant areas of poverty.[14] These sociodemographic factors are each associated with higher syphilis rates.[15] Race does not affect risk for any known biological reason, but Black populations often have a younger age distribution and higher rates of poverty than White populations. Furthermore, membership in a specific ethnic group strongly influences the potential pool from which one chooses sexual partners and will increase the likelihood of contracting syphilis once the disease is introduced into that population. This analysis suggests that the presence of I-95 played a role in the high county syphilis rates independently of demographic and economic factors. In addition, there was no evidence of a sudden change in these demographic characteristics that could account for the dramatic increase in cases in 1989. Since demographic variables did not appear to explain the differences, other explanations were considered.

One possible explanation proposed that syphilis could be spread along highways through contact between truck drivers and local commercial sex workers. This mechanism is felt to have contributed to the heterosexual spread of HIV into rural areas of Africa, India, and Asia. In these locations, long-distance truck drivers had a high prevalence of HIV infection (27%–51%), reported frequent visits to local prostitutes, and rarely used condoms.[4–8,22] In addition, geographic patterns suggested that HIV infection was first introduced into rural communities along the main roads in these areas.[7]

In the United States, the transmission of syphilis between prostitutes and truck drivers has been documented since the 1960s, when the diary of a prostitute infected with syphilis was used to identify 168 long-distance truck drivers who had been exposed.[23] More recently, risky sexual behavior has been described (anecdotally) within interstate rest areas and truck stops in the southeastern United States.[24,25] However, there are no data available on the sexual risk behaviors of US truck drivers, and it remains unclear whether this population could be contributing substantially to the spread of syphilis or other sexually transmitted diseases in the United States. Many of the large truck stops in North Carolina actively discourage solicitation by prostitutes, and rest areas are patrolled by the state police 24 hours a day, so it is unlikely that the excess rates can be attributed to these facilities. Ethnographic interviews we conducted at truck stops in one I-95 county yielded no evidence of significant interactions between truck drivers and prostitutes in the county (data not shown). However, the absence of prostitutes at truck stops does not mean an absence of interaction between truck drivers and prostitutes at other locations.

An alternative or additional explanation is that cocaine distribution along I-95 led to the existence of cocaine markets in these rural counties. In the 1980s, cocaine was imported into the eastern United States primarily through Miami and New York City, both of which lie along I-95.[26] Cocaine distribution outside of these large metropolitan areas appeared to jump first to other urban areas and then out from these areas along major interstate highways.[9] The emergence of a cocaine market in a community increases risky behaviors such as higher numbers of sexual partners and less frequent condom use, owing in part to the exchange of sex for drugs.[10–13,27] Syphilis that is already present in the community, or that is introduced from outside, then finds conditions favorable for transmission. Thus, the association of I-95 with syphilis may have occurred indirectly through the dissemination of cocaine markets into rural areas and the associated deterioration of the affected communities.

Other potential explanations include measurement error, which could have occurred if syphilis was reported more accurately in rural counties or counties with public sexually transmitted disease clinics.[28] While differential reporting may affect comparisons between counties for a given year, changes in reporting are unlikely to affect observed disease trends over a longer period. In addition, there may have been incomplete control for confounding, because we used proxy measures for domains that could not be directly measured. For example, drug arrests and admissions to drug treatment centers may themselves be influenced purely by political trends in law enforcement policy and social norms of tolerance for drug use. Changes in community social norms related to condom use or sexual behavior could also influence syphilis rates, but such changes are unlikely to occur suddenly and differentially in some counties relative to others. Finally, new travel patterns among the local populations could explain the findings if residents of I-95 counties traveled to areas of high disease prevalence and brought infections back with them.

It is not possible to demonstrate which of these factors was specifically responsible for the increase in syphilis along I-95, but cocaine distribution along the highway seems most likely. Two estimates of drug activity, drawn from different sources, each suggest a substantial increase in drug activity along I-95 just prior to the increase in syphilis cases. The data are consistent with other reports linking use of crack cocaine with the spread of syphilis into rural areas.[29] While the data clearly suggest a link between cocaine use, syphilis rates, and I-95, they do not allow a detailed understanding of the true, complex relationship between these factors. Clearly, our understanding of these relationships would be significantly enhanced by the use of other research methods, such as ethnographic studies. It is interesting that North Carolina syphilis rates began to decline in 1992, while cocaine arrests remained high, suggesting that an epidemic of a treatable infectious disease may be easier to curtail than epidemics of drug abuse. The decline in syphilis rates may have resulted from changes in sexual behavior, from increased public health efforts, or from partial acquired immunity to syphilis among the population.[30]

In summary, this analysis suggests that counties along some interstate highways are particularly vulnerable to the spread of syphilis, especially if the highway connects

areas of high disease prevalence. Counties along these highways may thus benefit from additional resources to fight epidemics in future outbreaks. This conclusion will be strengthened if such trends are confirmed in other geographic locations and among other sexually transmitted diseases. A better understanding of the cause of the association may allow the design of specific interventions to prevent the spread of syphilis in counties along interstate highways. Such county-level interventions should complement individual risk reduction strategies as we move toward the ultimate goal of elimination of syphilis. □

Contributors

R. L. Cook collected and analyzed the data and wrote the paper. R. L. Cook, R. A. Royce, and J. C. Thomas each participated in planning and designing the study and interpreting the findings. B. H. Hanusa and R. A. Royce supervised data analysis. All 4 authors contributed to writing and revising the manuscript and are guarantors for the integrity of the research.

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