The Fall After the Rise: Tuberculosis in the United States, 1991 Through 1994

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ABSTRACT

Objectives. Factors associated with decreases in tuberculosis cases observed in the United States in 1993 and 1994 were analyzed.

Methods. Changes in case counts reported to the national surveillance system were evaluated by dividing the number of incident cases of TB reported in 1993 and 1994 by the number of cases reported in 1991 and 1992 and stratifying these ratios by demographic factors, AIDS incidence, and changes in program performance.

Results. Case counts decreased from 52 956 in 1991 and 1992 to 49 605 in 1993 and 1994 (case count ratio = 0.94, 95% confidence interval [CI] = 0.93, 0.95). The decrease, confined to US-born patients, was generally associated with AIDS incidence and improvements in completion of therapy, conversion of sputum, and increases in the number of contacts identified per case.

Conclusions. Recent TB epidemiology patterns suggest that improvements in treatment and control activities have contributed to the reversal in the resurgence of this disease in US-born persons. Continued success in preventing the occurrence of active TB will require sustained efforts to ensure appropriate treatment of cases. (*Am J Public Health.* 1998;88:1059–1063)

Introduction

In 1993, the resurgence of tuberculosis (TB) observed in the late 1980s and early 1990s reversed. The number of reported patients in 1993 decreased by 5% (in comparison with 1992), and another decrease of almost 4% was recorded in 1994 (as compared with 1993).[1,2]

Recent longitudinal studies from several areas have demonstrated prompt declines in drug resistance and case counts after introduction of directly observed therapy as a standard of treatment.[3–5] However, there have been no systematic presentations of data from a variety of program areas quantitatively assessing the association between changes in the performance of tuberculosis control programs and decreases in case counts. To determine whether improvements in TB control programs correlated with the recent decline in TB incidence in the United States, we analyzed data from the national reporting systems for AIDS and TB, as well as information from the program management reports of the TB control programs in the United States.

Methods

Surveillance Data

We compared the TB case counts from the 2 years with the largest number of reported cases since 1985 (1991 and 1992) with totals from 1993 and 1994. The data used to calculate AIDS rates were derived from the national surveillance system for AIDS.[6] AIDS and TB registries are managed separately at the Centers for Disease Control and Prevention.[7]

For each program area (described subsequently), we calculated age-specific, race-specific, and country-of-origin-specific (foreign born or US born) AIDS case rates using 1990 census data as the denominators.[8] We then aggregated the TB cases into 4 groups of equal size (i.e., quartiles) based on AIDS rate cut points of 0 through 5.7, 5.8 through 10.2, 10.3 through 25.8, and greater than 25.8 AIDS cases per 100 000 population. Using data from the 1990 census, we also sorted the TB cases into quartiles based on the percentage of all persons living in poverty in each demographic and program area group (quartile boundaries were 0%–12.9%, 13.0%–14.7%, 14.8%–20.4%, and 20.5% or higher).[8,9]

Program Areas

We derived information on indicators of program performance from biannual reports of aggregate data submitted from 1991 through 1994. These data are not stratified by demographic characteristics such as age or country of origin. Area-specific indicators were computed for 103 consistent reporting jurisdictions (a listing of areas is available on request from the authors).[10]

Four indicators were available from the program management reports: (1) proportion of patients completing therapy in 12

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months, (2) proportion of sputum culture–positive patients who converted to negative 3 months after initiating therapy, (3) number of identified contacts for each TB case patient, and (4) proportion of eligible contacts who completed at least a 6-month course of preventive therapy with isoniazid. We used log-linear regression models to estimate the magnitude of improvement separately for each indicator and area. The calendar year of the program management report was entered as the independent variable in a regression analysis in which the value of the program indicator was the dependent variable. The corresponding regression coefficient for the completion of curative or preventive therapy and conversion of sputum equaled the natural logarithm of the odds ratio for the year-to-year success rate in terms of each of these indicators.[11] For number of contacts, the regression coefficient equaled the natural log of the average annual relative increase in the number of contacts identified per case patient. Changes in program performance were assessed by assigning case patients from each area to 4 equal, scored groups (i.e., ranked quartiles) after the areas had been sorted by the values of the regression coefficients.

Statistical Analysis

We calculated ratios of case counts to evaluate changes in reported cases by dividing the total number of cases reported in 1993 and 1994 by the total number of cases reported in 1991 and 1992. Confidence intervals for the case count ratios associated with detailed demographic factors were estimated via a simple approximation to the Poisson probability distribution.[12] The homogeneity test described by Fleiss[13] was used in testing variability in the ratios of the case counts across subgroups. Trends in the relative magnitude of the decrease in case counts associated with ordinal variables were assessed with the Mantel extension test.[12]

Only aggregate data on program performance were available for each area. Therefore, we used SUDAAN PROC RATIO to estimate the values of the ratios of the case counts for the ranked quartiles of program performance. This procedure involved the use of Taylor's series estimation procedures to adjust for the variability in ratios between areas within the quartile categories of program improvement and the correlation between cases within areas.[14] *P* values for trends were computed by means of using log-linear modeling of the area-specific ratios of case counts weighted by the inverse of the variance of the log of these parameters. We conducted a multivariable analysis using Poisson regression to assess whether associations between changes in program indicators and TB incidence were confounded by differences in the distributions of demographic factors and AIDS incidence between areas.[12] This approach yielded point estimates for the case count ratios essentially identical to those found using PROC RATIO, so we present only the results of the univariate analysis.[14]

Results

Demographic Factors

The ratios of case counts comparing the number of cases reported in 1993 and 1994 with the number reported in the previous 2-year period were essentially identical for culture-positive and culture-negative patients (Table 1). The largest decreases (i.e., smallest case count ratios) occurred in the 15- to 44-year age group; there was no significant change in the number of cases in children less than 15 years of age (Table 1).

There were clear differences by race/ethnicity group and region of the country in the magnitude of the case count ratios. Among race/ethnicity groups, Whites and Blacks showed the largest decreases in ratios, and the reductions in the 2 groups were similar in magnitude (Table 1). Of the study regions, the Northeast showed the largest decrease in case counts. Since about 13% of the cases in the entire country occurred in New York City during the period of study and the case count ratio for this area indicated a very large decrease, we recomputed the ratio for the Northeast after excluding New York City from the calculations (Table 1). The regional differences remained significant in this analysis (*P* for homogeneity: <.001), with the Northeast having the smallest case count ratio.

Although socioeconomic status is generally accepted as a major determinant of TB risk, we found no evidence of a definite trend in the magnitude of the change in case counts with increasing levels of poverty (Table 1).[15] However, there was a definite relationship between AIDS incidence rates and declines in TB cases. The smallest case count ratio was observed for areas with the highest AIDS incidence (Table 1).

There was a 5% (i.e., case count ratio = 1.05; see Table 1) increase in the number of patients who reported being foreign born, whereas there was an 11 % decrease in the number of US-born patients (Table 1). Since the focus of this analysis was on the correlates of decreases in case counts, we restricted our subsequent analysis to US-born patients.

Program Performance Indicators

There was sufficient information in the program management data from at least 94% of the areas to compute changes in the indicators for completion of therapy, conversion of sputum, and number of contacts identified per case patient (Table 2). Only 91 of the areas (comprising 77.2% of the cases) had sufficient information to compute an indicator for preventive therapy (Table 2). The aggregated analysis of the available national data indicated improvement for all of the measures during the 4-year period. However, there was substantial variation from area to area in the trends for these indicators, as evidenced by the wide range in values displayed in Table 2.

The case counts were then assembled into 4 equal-sized groups on the basis of the magnitude of the program indicator. There was a general trend of decreasing case count ratios with increasing improvement in program performance for every indicator except completion of preventive therapy for contacts (*P* for trend for preventive therapy: .15) (Figure 1). However, there was a great deal of variation in the magnitude of the decrease between areas within the fourth quartile for completion of therapy. This resulted in a very wide confidence interval and a nonsignificant *P* value for trend. Adjustment by age, race, poverty level, and AIDS incidence in Poisson regression models did not materially change any of the results. In comparison with the association with the relative change in program indicators, there was no significant association between the absolute level of the indicators and the trends in US-born case counts for any of the program indicators (data not shown).

Discussion

Our analysis demonstrates that the largest decreases in US-born patients with TB cases during 1993 and 1994 generally occurred in areas that have reported greater increases in completion of therapy, conversion of sputum, and numbers of contacts per case patient. We used statistical procedures to account for the variability between areas within categories of program performance. Our finding that the overall decreases in case counts were most strongly associated with improvements in conversion of sputum further supports the biologic plausibility of the present results, since this indicator most

TABLE 1—Trends in Tuberculosis Morbidity by Demographic Factors, 1991–1994

Factor	No. of Reported Patients 1991/92	No. of Reported Patients 1993/94	Case Count Ratio (95% Confidence Interval)	Homogeneity[a] (*P*)	Trend (*P*)
Culture-positive cases only	42 815	39 678	0.93 (0.91, 0.94)	...	...
Age group, y					
<5	2 082	2 073	0.99 (0.94, 1.06)	<.001	.25
5–14	1 291	1 321	1.02 (0.95, 1.10)		
15–44	24 679	22 427	0.91 (0.89, 0.92)		
45–64	12 798	12 386	0.97 (0.94, 0.99)		
≥65	12 106	11 398	0.94 (0.92, 0.97)		
Race or ethnic group					
Non-Hispanic White	15 345	13 536	0.87 (0.85, 0.89)	<.001	...
Non-Hispanic Black	19 183	17 466	0.90 (0.88, 0.92)		
Asian	7 049	7 677	1.08 (1.04, 1.11)		
Hispanic	10 728	10 298	0.95 (0.93, 0.98)		
Native American	651	623	0.95 (0.85, 1.06)		
Sex					
Male	34 505	32 240	0.93 (0.92, 0.95)		
Female	18 451	17 365	0.94 (0.92, 0.96)	.38	...
Country of origin status					
Foreign born	14 268	15 007	1.05 (1.03, 1.08)	<.001	...
US born	38 688	34 598	0.89 (0.88, 0.91)		
Region of the United States					
Northeast	13 910	11 960	0.86 (0.84, 0.88)	<.001	...
Midwest	6 018	5 804	0.96 (0.93, 1.00)		
South	19 549	19 045	0.97 (0.95, 0.99)		
West	13 479	12 796	0.95 (0.93, 0.97)		
New York City	7 493	6 230	0.83 (0.80, 0.86)	<.001[b]	...
Northeast without New York City	6 417	5 730	0.89 (0.86, 0.93)		
Percentage of persons living in poverty					
Low	13 205	12 499	0.95 (0.92, 0.97)	<.001	.13
Low intermediate	13 433	12 886	0.96 (0.94, 0.98)		
High intermediate	13 119	11 813	0.90 (0.88, 0.92)		
High	13 199	12 407	0.94 (0.92, 0.96)		
AIDS rate (cases per 100 000 persons)					
Low (<5.7)	13 062	12 737	0.97 (0.95, 0.99)	<.01	<.001
Low intermediate (5.7–10.1)	12 895	12 595	0.98 (0.95, 1.00)		
High intermediate (10.2–25.8)	13 134	12 707	0.97 (0.94, 0.99)		
High (>25.8)	13 865	11 566	0.83 (0.81, 0.86)		
Total	52 956	49 605	0.94 (0.93, 0.95)	...	...

[a]Test of homogeneity for ratios of case counts across subgroups.
[b]Value for test of homogeneity between regional ratios of case counts with New York City excluded.

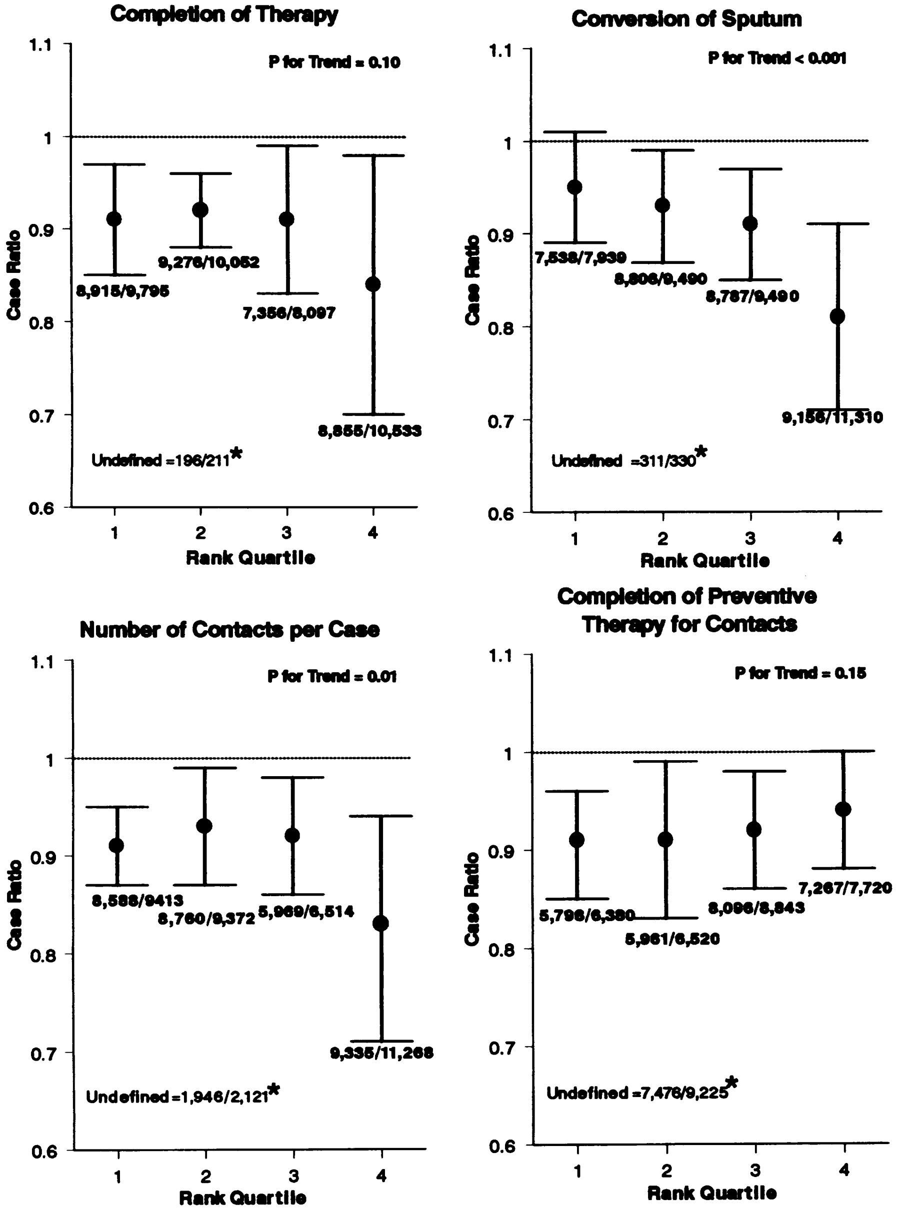
directly assesses the clinical outcome associated with infectiousness.[16]

The large decline in areas with high AIDS rates supports the hypothesis that improvements in measures to control recent transmission are the primary determinants of declines in TB incidence. HIV co-infected individuals are susceptible to swift progression from asymptomatic TB infection to active disease.[17] Investigations conducted in San Francisco and New York during the early 1990s that used restriction-fragment-length polymorphism suggested that significant numbers of cases in these areas resulted from recently transmitted *Mycobacterium tuberculosis* infection in HIV co-infected persons.[18,19] Therefore, since ongoing transmission of TB rapidly becomes manifested as active disease in communities with large numbers of individuals with HIV co-infection, decrements in TB case counts should be

TABLE 2—Completeness of Program Performance Data, 1991–1994

Program Performance Indicator	Areas, No. (%)	US-Born Patients, No (%)	Value of Indicator[a] (Range)
Completion of therapy	102 (99.0)	72 879 (99.4)	1.17 (0.32 to >10^9)
Conversion of sputum	98 (95.1)	72 645 (99.1)	1.15 (0.07 to 12.93)
Preventive therapy for contacts	91 (88.3)	56 585 (77.2)	1.05 (0.05 to >10^{10})
Contacts per case patient	97 (94.1)	69 219 (94.4)	1.05 (0.66 to 10.80)

Note. There were a total of 103 reporting areas with 102 561 patients defined for this analysis. Shown are the number of areas with adequate information submitted to CDC (in order to compute changes in program performance) and the number of cases reported from the areas with adequate program data.
[a]For completion of therapy, conversion of sputum, and preventive therapy, values represent the odds ratio of success from one year to the next from 1991 through 1994 for each of the indicators. The indicator for contacts per case patient is the average annual relative change in the number of contacts per patient. The tabulated values are for all areas combined. The range boundaries are the extreme, area-specific values. Values greater than 1 indicate improvement, whereas values less than 1 indicate decreasing performance.



Note. The period-specific totals used to compute the ratios are displayed for each quartile, with the 1993 and 1994 counts as numerators and the 1991 and 1992 counts as denominators. Ranked quartiles are scored from 1 (least improvement) to 4 (greatest improvement).
*Undefined = areas with insufficient data to estimate reliable trends for program indices.

FIGURE 1—Adjusted ratios of case counts (solid circles) and 95% confidence intervals (vertical bars) for 4 equal-sized groups ranked by improvement in terms of completion of therapy, conversion of sputum, increases in number of contacts per case patient identified, and improvement in proportion of infected contacts completing preventive therapy.

most pronounced in communities with high AIDS rates when transmission is effectively controlled by promptly identifying and successfully treating infectious TB patients.[3] In the present study, similar to the analysis by Chaulk et al., the success associated with improving treatment and control programs appeared independent of the poverty level of the area.[5]

We could not address the contribution of the prevention of nosocomial transmission to declines in TB, since comprehensive, systematically collected data on TB infection control programs in hospitals were not available for this analysis.[20,21] Studies from individual hospitals and population-based data from New York City have documented the effectiveness of these procedures, in combination with more potent therapies for patients with multidrug-resistant TB, in reducing nosocomial transmission.[22-24] These accounts, as well as the results of our analysis, intimate that the contribution of nosocomial transmission is abating.

Despite the overall decreases in case counts, the number of foreign-born patients continued to increase. Factors that influence the risk of TB among immigrants include the prevalence of TB in the country of origin, duration of residence in the United States after immigration (longer residence imparting lower risk), efficiency of the local health department in tracking persons identified as "probable" TB patients via the overseas screening process, and the quality of the screening and treatment program in the country of origin.[25-27] Assessments in specific program areas in the United States have revealed that the relative importance of each of these factors differs substantially from one area to another.[27] However, studies using a variety of approaches suggest that a preponderance of TB cases in foreign-born individuals result from reactivation of infections acquired in the country of origin.[18,19,27] Therefore, since the indicators available for our analysis focused on control of active transmission rather than screening for latent infection, and because there was no evidence of a decrease in case counts in foreign-born individuals, we concentrated our analysis on trends in US-born case patients.

The finding that case counts for US-born children have not decreased is also disturbing. A pediatric TB patient's young age necessarily implies that the illness is the result of rapid progression of a recent infection rather than reactivation of latent infections acquired in the distant past.[28] Studies from New York City and San Diego indicate that much of the contemporary TB in US-born children in these communities was probably acquired from exposure to foreign-born adults in their households.[29,30] Since information on household contacts is not collected in the surveillance system, it was not possible to estimate the indirect contribution of TB in the foreign-born population to the incidence of pediatric TB in the US-born population.

Studies that use aggregated information (e.g., program management reports) to examine factors associated with the epidemiology of any disease must be interpreted with caution. Unmeasured influences, as well as misclassification, can result in "ecologic fallacies."[31] However, our general results suggest that improvements in TB control programs have been effective, even in the era of HIV. In addition, recent reports indicate that the downward trend continued in 1995 and

1996.[32,33] Future explorations of epidemiologic trends should be greatly augmented by the reporting of individual TB patient treatment information and HIV status, instituted as part of the expansion of TB surveillance in 1993.[34]

Similar successes in the control of TB and other communicable diseases have frequently been followed by withdrawals of support and commitment on the part of policymakers.[35,36] Dwindling resources for TB prevention and control in the early 1970s promoted the decay of local TB control programs and set the stage for the disease's subsequent resurgence. A recapitulation of these mistakes could be disastrous and ultimately more expensive than maintaining adequate levels of support.[3] □

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