

SPECIAL ARTICLE

THE EPIDEMIOLOGY OF TUBERCULOSIS AMONG FOREIGN-BORN PERSONS IN THE UNITED STATES, 1986 TO 1993

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Abstract Background. One third of the world's population is infected with *Mycobacterium tuberculosis*, and in the developed countries immigration is a major force that sustains the incidence of tuberculosis. We studied the effects of immigration on the epidemiology of tuberculosis and its recent resurgence in the United States.

Methods. We analyzed data from the national tuberculosis reporting system of the Centers for Disease Control and Prevention. Since 1986 reports of tuberculosis have included the patient's country of origin. Population estimates for foreign-born persons were derived from special samples from the 1980 and 1990 censuses.

Results. The proportion of persons reported to have tuberculosis who were foreign-born increased from 21.6 percent (4925 cases) in 1986 to 29.6 percent (7346 cas-

es) in 1993. For the entire eight-year period, most foreign-born patients with tuberculosis were from Latin America (43.9 percent; 21,115 cases) and Southeast Asia (34.6 percent; 16,643 cases). Among foreign-born persons the incidence rate was almost quadruple the rate for native residents of the United States (30.6 vs. 8.1 per 100,000 person-years), and 55 percent of immigrants with tuberculosis had the condition diagnosed in their first five years in the United States.

Conclusions. Immigration has had an increasingly important effect on the epidemiology of tuberculosis in the United States. It will be difficult to eliminate tuberculosis without better efforts to prevent and control it among immigrants and greater efforts to control it in the countries from which they come. (N Engl J Med 1995; 332:1071-6.)

THE decades-long decline in the incidence of tuberculosis in the United States was reversed during the late 1980s. The resurgence continued into the current decade, and despite a 5.1 percent relative decline from 1992 to 1993, the number of reported cases in 1993 was 14 percent higher than in the nadir year of 1985.¹ A limited number of studies have examined the effects of increases in immigration on the recent epidemiology of tuberculosis in the United States.²⁻⁶ A study by Powell et al. from 1977 to 1979 found that foreign-born persons accounted for 15 percent of the reported cases of tuberculosis in the 11 areas studied.² The national surveillance data show that the proportion of diagnosed cases of active tuberculosis in which the patient was foreign-born increased from 22 percent in 1986 to almost 30 percent in 1993.¹

The increasing contribution of foreign-born persons to the incidence of tuberculosis has been noted in a number of developed countries with substantial levels of immigration.⁷⁻¹⁴ However, there have been no comprehensive epidemiologic studies in the United States of the incidence rates of tuberculosis among foreign-born residents. Previous analyses have presented only frequency counts or estimates of rates for a limited number of subgroups of the foreign-born population.^{2-5,15} Accurate estimates of incidence rates are needed to develop cost-effective strategies for the prevention, control, and ultimate elimination of tuberculosis.¹⁶ Therefore, we have investigated the recent influence of immigration on the epidemiology of tuberculosis using data from the national reporting system for tuberculosis and from

U.S. Census Bureau surveys of the foreign-born population.

METHODS

Cases

All 50 states and the District of Columbia mandate the reporting of persons with clinically active tuberculosis to local or state health authorities.¹⁷ The data used in this analysis were derived from the standardized case reports forwarded to the Centers for Disease Control and Prevention (CDC) by these local or state authorities.¹ Since 1986 all reports have included data on the patient's country of origin. All patients with newly diagnosed disease must be reported, regardless of their legal residency status, so long as they consider the community their home or plan to remain in the country for at least 90 days.¹⁸ The patient's legal residency status, if it is ascertained, is not forwarded to the CDC.

The U.S. Census Bureau definition was used to classify persons as foreign-born.¹⁹ Anyone born in the United States or a territory of the United States, as well as anyone born in a foreign country but having at least one American parent, was categorized as native to the United States, or U.S.-born. Persons not meeting the criteria for the native designation were considered foreign-born.

Information on the date of immigration was incomplete for 24 percent of the foreign-born persons reported as having tuberculosis. Excluding patients with incomplete information would have resulted in gross underestimations of the incidence rates. Therefore, since age and world region of origin correlated strongly with length of residence for patients with complete information, means for length of residence were imputed to those with missing dates on the basis of their ages and world regions of origin.

Population

The population estimates used in this analysis were derived from a 5 percent sample of all U.S. households surveyed as part of the censuses conducted in 1980 and 1990.²⁰ We calculated intercensal estimates using linear interpolations between the 1980 and 1990 censuses. Estimates beyond 1990 were developed by linear extrapolation. The sampling frame for the decennial estimates contained single households as well as group quarters, including homeless shelters, correctional facilities, camps for migrant workers, and military in-

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stallations. Data were collected by the U.S. Census Bureau regardless of residency status, so legal immigrants as well as undocumented persons are included in these estimates. Data on the number of legal immigrants, as well as estimates of the number of illegal immigrants and residents, were obtained from reports published by the Immigration and Naturalization Service.²¹

Census data may undercount certain minority subpopulations, possibly resulting in inflated disease-rate estimates for the foreign-born population.^{22,23} However, published estimates of census undercounts suggest that for broad population groupings on a national level the magnitude of these biases would have no substantial effect on our major findings.^{19,23}

Regions of Origin

To obtain precise rate estimates, we categorized the foreign countries of origin in eight groups according to geography and economic development, using a scheme devised by the World Bank.²⁴ The groups are sub-Saharan Africa; India; mainland China; other Asian countries (excluding India, China, Japan, and countries of the former Soviet Union); Latin America and the Caribbean; the Middle Eastern crescent; the formerly socialist economies of Europe, including the countries of the former Soviet Union as well as the eastern European countries with formerly communist economies; and the established market economies, including Canada, Western Europe, Australia, New Zealand, and Japan.

Statistical Analysis

All rates were adjusted for age by the direct method, with the distribution in the 10-year age intervals in 1990 used as the standard.²⁴ Standard errors for age-adjusted rate ratios were estimated with a simple approximation to the Poisson probability distribution.^{25,26} We present 99 percent confidence intervals because of the design effect associated with the complex sampling procedures used to derive the population estimates.^{20,25,27} Pearson correlation coefficients were calculated with two-sided P values.

We used logistic regression to assess the effects of adjustment for multiple covariates other than age.²⁸ We present the results from the model containing only main effects.²⁹

RESULTS

From 1986 through 1993, 195,186 persons were given a diagnosis of tuberculosis and were reported to the CDC. Only 1.2 percent of the reports had incomplete information about the country of origin or age and were excluded from our analysis. The proportion of patients reported to have tuberculosis who were classified as foreign-born increased from 21.6 percent (4925) in 1986 to 29.6 percent (7346) in 1993. The estimated rates of tuberculosis among foreign-born persons also increased (Fig. 1). From 1986 to 1989 the average annual rate in the foreign-born population was 27.1 per 100,000 persons. After 1989 the number of documented immigrants increased greatly. This increase included previously illegal long-term residents who were allowed to adjust their residency status under provisions of the Immigration Reform and Control Act of 1986. Immigrants adjusting their status were also screened for tuberculosis as part of this special admission process. From 1990 to 1993 the incidence rate of tuberculosis in the foreign-born population increased to 33.6 per 100,000. During the entire eight-year period, the overall rate in the U.S.-born population remained relatively constant at about 8.1 per 100,000.

When people with tuberculosis were stratified ac-

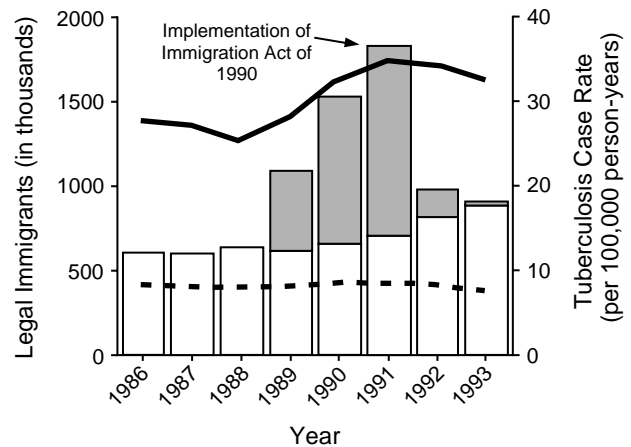


Figure 1. Number of Legal Immigrants According to Year of Admission (Bars) and Tuberculosis Case Rates for U.S.-Born (Broken Line) and Foreign-Born (Solid Line) Persons.

The gray portions of the bars represent the numbers of illegal residents who were granted legal residence status under the provisions of the Immigration Reform and Control Act of 1986. The Immigration Act of 1990 liberalized the screening procedures for tuberculosis in legal immigrants (see the Discussion section). All rates are adjusted for age to the 1990 U.S. population distribution.

ording to age, the largest relative difference between those who were foreign-born and those who were born in the United States was evident among children less than 15 years of age (Table 1). The annual rate among foreign-born children was so great that it exceeded the highest age-specific rate among native persons by 54 percent.

There was substantial heterogeneity in the effect of foreign birth on the rate of tuberculosis across racial and ethnic groups. The greatest difference was noted in the Asian population, whereas there was relatively little difference in the rates between foreign-born and U.S.-born blacks or Hispanics (Table 1).

The incidence of tuberculosis in foreign-born persons residing in the western United States was almost twice the rate among foreign-born persons in the rest of the country (Table 1). In contrast, the highest rates of tuberculosis for U.S.-born persons were in the Northeast. There was little correlation between the state-specific rates for foreign-born persons and those for U.S.-born persons (Fig. 2).

The incidence of tuberculosis in foreign-born persons varied substantially according to the world region of origin (Table 2). People from Asian countries other than India, Japan, mainland China, and countries of the former Soviet Union had the highest rate. Of the 16,643 persons from this region with a diagnosis of tuberculosis, 92.2 percent were from five countries: the Philippines (6286 cases); Vietnam (4941); South Korea (2262); Cambodia (977); and Laos (878). Although the rate of tuberculosis was highest in those from Asia, there were more patients with tuberculosis from Latin

Table 1. Tuberculosis Case Rates in the United States According to Place of Birth and Demographic Variables, 1986 to 1993.*

VARIABLE	U.S.-BORN PERSONS			FOREIGN-BORN PERSONS			RATE RATIO (99% CI)‡
	PERSON-YEARS (IN 100,000s)	CASES	RATE†	PERSON-YEARS (IN 100,000s)	CASES	RATE†	
Total	18,272	144,727	8.1	1579	48,120	30.6	3.7 (3.7–3.8)
Age group (yr)							
<15	4,162	8,812	2.1	119	2,630	27.7	13.2 (12.5–13.9)
15–44	8,473	57,324	6.9	881	27,400	31.0	4.5 (4.4–4.6)
45–64	3,380	38,273	11.3	349	10,161	29.3	2.6 (2.5–2.7)
≥65	2,257	40,318	18.0	230	7,929	35.6	2.0 (1.9–2.0)
Race or ethnic group							
White, non-Hispanic	14,561	57,849	3.8	517	3,841	7.7	2.0 (1.9–2.1)
Black, non-Hispanic	2,236	66,242	34.3	95	4,231	39.9	1.2 (1.1–1.2)
Asian	209	2,031	15.8	356	21,765	68.5	4.3 (4.1–4.6)
Hispanic	1,095	16,001	22.1	602	18,239	32.2	1.5 (1.4–1.5)
Sex							
Female	9,372	47,504	4.9	811	19,318	25.1	5.1 (5.0–5.2)
Male	8,900	97,212	11.9	768	28,798	37.1	3.1 (3.1–3.2)
Region of the U.S.							
Northeast	3,638	36,942	10.3	424	10,142	23.6	2.3 (2.2–2.4)
South	7,102	66,641	9.6	389	9,550	23.4	2.5 (2.4–2.6)
West	3,564	20,560	6.1	617	25,067	42.1	7.1 (6.9–7.3)
Midwest	3,968	20,584	5.2	149	3,361	22.9	4.4 (4.2–4.6)

*Values in some columns do not add up to the totals given because of missing values or values assigned to the classification "other."

†Rates are per 100,000 person-years. All rates are adjusted for age.

‡The rate ratios are adjusted for age. CI denotes confidence interval.

America, and Mexico was the country of origin for 56.8 percent of the 21,115 patients from Latin America.

The length of residence in the United States was strongly related to the rate of tuberculosis among foreign-born persons, with the highest rates occurring in the first five years after arrival. Overall, 55 percent of the tuberculosis cases in the foreign-born population

were diagnosed in the first five years of residence in the United States. Of the 35,399 foreign-born patients whose records contained complete information on the month and year of immigration, 10,478 (29.6 percent) received diagnoses of tuberculosis less than one year after their entry into the United States. The highest average annual rate for the first five years after arrival was among persons from the other-Asian-countries region. In contrast, the rate for recent arrivals from countries with established market economies was lower than the rate for U.S.-born Americans.

We used logistic regression to adjust simultaneously for the potential confounding effects of selected demographic and geographic variables. The major determinants of risk in the foreign-born population were the region of the world from which the person emigrated and the number of years in the United States (Table 3). The rate ratio for the incidence of tuberculosis among foreign-born persons in the western United States as compared with the incidence in foreign-born persons in the rest of the country decreased substantially, from 1.7 to 1.3, after adjustment for other factors.

DISCUSSION

Recent reports from Canada, New Zealand, Britain, and western Europe have documented that immigration from nations where tuberculosis is common has been largely responsible for slowing the decrease in morbidity rates in these developed countries.^{7,10,11,30} In the United States, approximately 8.2 million immigrants were legally granted permanent residence from

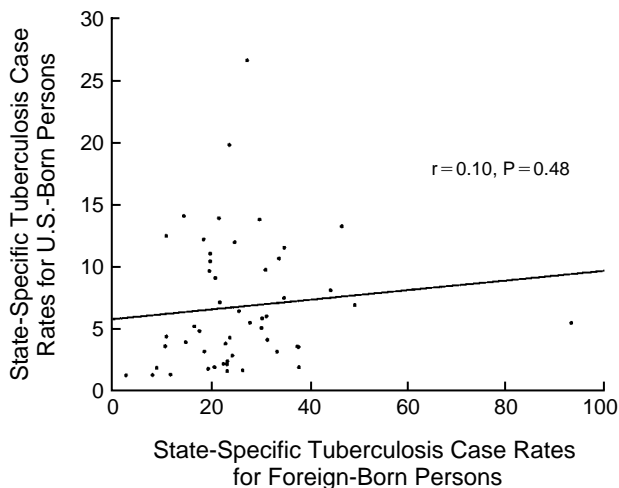


Figure 2. Correlation between State-Specific Tuberculosis Case Rates for Foreign-Born Persons and U.S.-Born Persons in the United States, 1986 to 1993.

All rates are adjusted for age to the 1990 U.S. population distribution. The solid line is the best-fit regression line, and the correlation coefficient was calculated by the Pearson method.

1986 through 1993. There were 3 to 4 million illegal foreign-born residents by the early 1990s.²¹ Therefore, between 1980 and 1990 the foreign-born population in this country increased by over 40 percent.¹⁹ The top five countries of origin during this period were Mexico, the Philippines, Vietnam, China, and Korea.²¹ The tuberculosis incidence rates in these countries are 10 to 30 times greater than the rate in the United States.³¹ Our findings suggest that the increase in immigration during the late 1980s and early 1990s has profoundly affected the recent epidemiology of this disease in the United States.

National tuberculosis rates among people born in the United States did not vary substantially during the period of this study. This general stability obscures the increases in some areas, particularly urban centers with large numbers of persons infected with the human immunodeficiency virus (HIV).³² There are currently only limited national data on the proportion of patients with tuberculosis who are infected with HIV.¹ Focused seroprevalence studies from tuberculosis clinics indicate that foreign-born patients from the countries that contribute the greatest number of immigrants have substantially lower rates of HIV infection than have patients born in the United States.³³ These data, in combination with the legal restriction that makes HIV infection a bar to immigration to the United States, suggest there is little likelihood that HIV coinfection has contributed to recent increases in tuberculosis rates among foreign-born persons.³⁴

The high relative rate of tuberculosis in foreign-born children indicates that there is substantial recent transmission either before or shortly after immigration.³⁵ From our data it is difficult to determine the importance of active transmission within the foreign-born community after immigrants' arrival in the United

Table 3. Age-Adjusted and Multivariable Analysis of Rate Ratios for Tuberculosis among Foreign-Born Persons in the United States According to Selected Variables, 1986 to 1993.

VARIABLE	AGE-ADJUSTED RATE RATIO	MULTIVARIABLE RATE RATIO (99% CI)*
World region of origin		
Established market economies	Reference group	Reference group
Former socialist economies	1.9	1.7 (1.6–1.9)
India	12.7	11.3 (10.3–12.3)
Latin America	8.1	8.0 (7.5–8.5)
Mainland China	9.8	8.2 (7.6–8.8)
Middle East	5.0	4.4 (4.1–4.9)
Other Asian countries†	18.4	16.4 (15.2–17.3)
Sub-Saharan Africa	14.6	13.0 (11.7–14.2)
Region of the U.S. (West vs. all others)	1.7	1.3 (1.2–1.3)
Length of residence in the U.S. (≤5 yr vs. >5 yr)	4.2	3.9 (3.8–4.0)

*The multivariable model contained the following variables: age, sex, world region of origin, region of the United States, and years in the United States.

†This category includes Asian countries other than India, mainland China, Japan, and countries of the former Soviet Union.

States. However, a recent study from San Francisco using the technique of restriction-fragment-length polymorphism concluded that active tuberculosis in foreign-born persons was more likely to result from reactivation of remote infection than from recent transmission in the local community.³⁶ The absence of correlation between state-specific disease rates for the foreign-born and those for the native population suggests that transmission to U.S.-born persons is probably not extensive.

The elevated rates among young foreign-born persons are consistent with the results of studies that report positive tuberculin-skin-test reactions in 35 to 53 percent of young foreign-born persons from Southeast Asia and Latin America.^{36–40} Young foreign-born persons with latent tuberculosis infections represent a growing pool of immigrants in whom active disease will continue to develop unless major efforts are mounted to screen for infection and provide treatment.^{6,16,41}

Several factors explain the finding that the highest rates of tuberculosis among foreign-born persons occur within a few years of their arrival in the United States.^{3,5} First, only immigrants and refugees applying for permanent legal residence are screened for tuberculosis. Persons allowed to change their status from illegal to legal under the provisions of the Immigration Reform and Control Act of 1986 were also screened. Applicants for immigration who have abnormal screening chest radiographs as well as positive smears for acid-fast bacilli on sputum examinations must begin therapy that is effective in converting their sputum smears to negative, and each must obtain a waiver from a responsible health care provider in the United States before he or she can enter or remain in the country.³⁴ Before implementation of the Immigration Act of 1990 (Fig. 1), people with abnormal chest radiographs indicative of active tuberculosis but with negative sputum smears were also required to obtain waivers.⁶ However, the criteria for exclusion were liberalized to

Table 2. Tuberculosis Case Rates According to the Length of Residence in the United States and the World Region of Origin for Foreign-Born Persons in the United States, 1986 to 1993.

WORLD REGION OF ORIGIN	TOTAL NO. OF CASES (%)	RATES*		
		TOTAL	U.S. RESIDENCE ≤5 YR	U.S. RESIDENCE >5 YR
United States	144,727 (75.0)	8.1	—	—
Established market economies	1,733 (0.9)	4.7	6.0	4.7
Former socialist economies of Europe	1,138 (0.6)	11.2	14.9	13.7
India	1,740 (0.9)	55.6	108.2	35.8
Latin America	21,115 (10.9)	33.7	68.4	30.8
Mainland China	2,957 (1.5)	40.6	89.7	30.7
Middle East	1,273 (0.7)	22.1	47.3	15.2
Other Asian countries†	16,643 (8.6)	81.8	207.5	41.1
Sub-Saharan Africa	1,167 (0.6)	58.4	108.9	26.4
Total foreign-born	48,120 (25.0)‡	30.6	66.3	21.7

*Rates are per 100,000 person-years. All rates are adjusted for age to the 1990 U.S. population distribution.

†This category includes Asian countries other than India, mainland China, Japan, and countries of the former Soviet Union.

‡Information on country of origin was missing for 354 foreign-born persons with tuberculosis.

make it easier for overseas immigrants who were considered noninfectious (i.e., whose sputum smears were negative) to receive treatment in the United States. This was done to discourage such persons from receiving suboptimal treatment overseas that could promote the selection of resistant organisms.^{6,34}

Studies in recent Southeast Asian immigrants have found that sputum smears are relatively insensitive in detecting clinically active *Mycobacterium tuberculosis*.^{6,9,42,43} There are currently no federal regulations prescribing follow-up procedures for those with suspicious chest radiographs who have negative sputum smears, although they are reported to local health departments by federal authorities. The number who are actually evaluated is unknown, since many notification forms sent to state and local health departments are never returned to the CDC (Tipple M, Division of Quarantine, CDC: personal communication). Hence, substantial numbers of persons undoubtedly enter the country with active disease but when they later come to the attention of health care workers in the United States they are counted as representing new, previously unidentified cases.^{3,5,6}

A second factor contributing to the high rates among recent arrivals is the decreased risk of tuberculosis with lengthening time after infection.¹² The annual risk of infection in many of the countries of origin is 100 to 200 times the rate in the United States.^{2,12,44,45} Therefore, the rate of disease among immigrants is greatest within the first few years after entry, because they are much more likely to be infected before departure than after their arrival in the United States.

Another reason for high incidence rates among recent arrivals is the more than 20 million nonimmigrant visitors and students and the estimated 200,000 undocumented immigrants who enter the United States every year.²¹ People in these groups do not undergo a prescribed medical evaluation before entry, and some arrive with active disease that is then diagnosed and reported in the United States. The impact of visitors and students and of undocumented residents on the rate of tuberculosis among foreign-born persons is impossible to estimate from our surveillance data. Local health departments are frequently reluctant to inquire about legal status because illegal residents with infectious disease may delay seeking care if they suspect they will be reported to immigration authorities.⁴⁶

Our analyses indicate that improvements are needed in screening immigrants and refugees overseas, as well as in communicating the results of screening examinations to responsible public health and medical officials.^{6,16,47} Physicians in the United States who care for foreign-born persons should be aware that their patients from developing countries are at increased risk for tuberculosis even if they have been medically cleared during the legal immigration process, since that screening focuses exclusively on the identification of highly infectious persons (i.e., those whose sputum smears are positive for acid-fast bacilli). Also, pro-

grams that minimize barriers to appropriate screening and chemoprophylaxis have to be available to foreign-born residents if progress is to be made in the control of tuberculosis.^{6,16,41,47}

Finally, recent reports document that the treatment and control of tuberculosis is one of the most cost-effective health interventions for developing countries.^{24,48} Future success in tuberculosis control in this country will require greater efforts by the United States, in coordination with other countries and international organizations, to upgrade the standards and quality of tuberculosis-control programs in developing countries.^{6,31,49} These endeavors may be most efficiently pursued in Latin America and Southeast Asia, which supply the greatest numbers of immigrants to the United States.

We are indebted to state and local tuberculosis-control officials in health departments throughout the United States who collected and reported the data used in this analysis, and to the surveillance staff at the Division of Tuberculosis Elimination, CDC, who have maintained this information over time; to Dr. Nancy Binkin from the Division of Tuberculosis Elimination for comments on early versions of the manuscript; to Dr. Margaret Tipple from the Division of Quarantine, CDC, for valuable assistance; and to Robert Pratt for his help with the computer programming.

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