SPECIAL ARTICLE

TUBERCULOSIS IN NEW YORK CITY — TURNING THE TIDE

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Abstract *Background. From 1978 through 1992, the number of patients with tuberculosis in New York City nearly tripled, and the proportion of such patients who had drug-resistant isolates of Mycobacterium tuberculosis more than doubled.*

Methods. We reviewed, confirmed, and analyzed data obtained during the surveillance of patients with tuberculosis.

Results. From 1992 through 1994, there was a 21 percent decrease in reported cases of tuberculosis in New York City. An evaluation of the surveillance system revealed very few unreported cases. The number of cases decreased by more than 20 percent among blacks and Hispanics, persons with documented human immunodeficiency virus infection, homeless persons, and patients with multidrug-resistant tuberculosis; in all these groups, tuberculosis is likely to result from recent transmission. In contrast, the number of cases of tuberculosis increased among elderly and foreign-born persons, in whom the disease is likely to result from the reactivation of an infection acquired many years earlier. Enrollment in a program of directly observed therapy, in which health workers watch patients take their medications, increased from fewer than 100 patients to nearly 1300, with more than 32,000 patient-months of observation from 1992 through 1994.

Conclusions. Epidemiologic patterns strongly suggest that the decrease in cases resulted from an interruption in the ongoing spread of M. tuberculosis infection, primarily because of better rates of completion of treatment and expanded use of directly observed therapy. Another contributing factor may have been efforts to reduce the spread of tuberculosis in institutional settings, such as hospitals, shelters, and jails. Expansion of measures to prevent and control tuberculosis and support of international control efforts are needed to ensure continued progress. (N Engl J Med 1995;333:229-33.)

SINCE before the turn of the century, New York City has been a center for both tuberculosis and its control. In 1889, Hermann Biggs of the New York City Department of Health recommended a comprehensive program of tuberculosis control[1] that eventually included systematic surveillance, nursing follow-up of individual patients, public education, isolation of infectious patients, and free laboratory testing of sputum samples. Until the discovery of specific antituberculous medications, these were the only available methods of disease control; even now, all remain important.

Programs to control tuberculosis became victims of their own success. In 1960, New York City had more than 2400 beds for patients with tuberculosis in hospitals and sanitariums and a comprehensive system of treatment.[2] But as the incidence of the disease declined, so did programs to control it. By 1988, the staff of the Bureau of Tuberculosis Control had been reduced to approximately 140, the number of clinics had declined from 24 to 8, and combined public health and chest clinics in municipal and voluntary hospitals had been disbanded.[3] As a result, in 1989 less than half of patients who began treatment were cured. The human immunodeficiency virus (HIV) epidemic, diminished public health efforts to control tuberculosis, rising poverty and homelessness, overcrowded conditions in congregate settings, and immigration from countries with a high prevalence of tuberculosis all led to a resurgence of the disease in the 1980s.[3]

As a result of inadequate treatment, the proportion of patients with drug-resistant isolates of *Mycobacterium tuberculosis* increased. Drug resistance among patients who had never been treated increased from 10 percent in 1983 to 23 percent in 1991.[4] Such resistance increases the likelihood of treatment failure and relapse and greatly complicates the control of the disease.[5] By 1992, the situation in New York City looked bleak. The number of cases of tuberculosis had nearly tripled in 15 years.[6] In central Harlem, the case rate of 222 per 100,000 people exceeded that of many Third World countries.[7] Outbreaks of multidrug-resistant tuberculosis had been documented in more than half a dozen major hospitals, with case fatality rates greater than 80 percent, and health care workers were becoming ill and dying of this disease.[8-11] Nearly one in five patients with tuberculosis in New York City had multidrug-resistant strains, and the proportion of new patients with multidrug resistance had more than doubled in seven years.[4] In the first quarter of 1991, with 3 percent of the country's population, New York City accounted for a remarkable 61 percent of cases of multidrug-resistant tuberculosis in the United States.[12]

Just two years later, however, the city announced a substantial decrease in new cases — a reduction of 15 percent, from 3811 in 1992 to 3235 in 1993. This decline continued through 1994 (to 2995 cases), with the decrease reported over the two-year period exceeding 21 percent; the trend appears to be continuing in 1995. The decrease in 1993 was the first substantial decline in New York City in 15 years, accounting for 42 percent of the decrease in the number of cases of tuberculosis in the nation that year.[13] In this article we analyze the accuracy of reporting of tuberculosis cases, as well as the epidemiologic patterns of and reasons for this decrease.

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METHODS

To confirm the accuracy of surveillance data, we conducted four investigations. First, all mycobacteriology laboratories in New York

City were audited. Second, we reviewed all 1992 and 1993 death certificates that listed tuberculosis as the underlying cause of death. Third, we reviewed the records of all patients reported to the Department of Health for whom no bacteriologic confirmation of disease was available, to see whether they met the clinical case definition of tuberculosis.[14] Fourth, we evaluated the possibility that patients with the acquired immunodeficiency syndrome (AIDS) who also had tuberculosis were being reported to the AIDS surveillance program in New York City, but not to the tuberculosis surveillance system.

Results

The audits of death certificates yielded only two previously unreported cases of tuberculosis. Both were culture-negative, with tuberculosis diagnosed at autopsy, and both were included in the 1994 case count. As a result of intensive review, 382 patients who met the clinical case definition of tuberculosis were included in the 1993 case count, and 515 were included in the 1994 count. The proportion of clinically confirmed cases rose steadily, from 4.2 percent in 1990 to 17.2 percent in 1994. Thus, the decrease in culture-confirmed cases from 1992 to 1994 was even greater — 27.9 percent — than the overall decrease. Because verification of clinically confirmed cases of tuberculosis has improved, in this article we analyze trends among cases with positive cultures only. One hundred forty-nine patients were reported to the AIDS surveillance system as having tuberculosis, but they were not reported to the Bureau of Tuberculosis Control. On review, only one of these patients, who had been cared for at a Veterans Affairs hospital, met the surveillance criteria for tuberculosis. Thus, the decrease in the number of cases does not appear to be an artifact of surveillance.

There are revealing patterns in the decreasing number of cases. Recent evidence based on the analysis of *M. tuberculosis* isolates using restriction-fragment–length polymorphisms suggests that in New York City, San Francisco, and possibly elsewhere, at least one quarter of cases of tuberculosis result from recently transmitted infection.[15,16] Patients likely to have acquired *M. tuberculosis* recently include the poor, some racial and ethnic minorities, patients with multidrug-resistant tuberculosis, and patients with HIV infection or AIDS.[15,16] Foreign-born and elderly patients are substantially less likely than U.S.-born or young patients to be infected with organisms that had been transmitted recently. It can be expected, then, that if the decrease in the number of cases of tuberculosis was real and was the result of improved treatment, the groups most likely to have recently transmitted infections would have the greatest reductions in disease. This is precisely what occurred.

As compared with 1991–1992, the number of culture-confirmed cases in New York City in 1993–1994 decreased by 44 percent among children under the age of 10 years, by 30 percent among adults 20 to 40 years old, by 24 percent among persons with documented HIV infection, by 24 percent among non-Hispanic blacks, and by 21 percent among Hispanics. Even more dramatic were the decreases in the number (44 percent) and proportion (30 percent) of these patients who had multidrug-resistant tuberculosis. In contrast, the number of cases increased by 22 percent among foreign-born persons and by 4 percent among those more than 60 years of age — patients in whom a case of tuberculosis is likely to represent a reactivation of infection acquired years earlier (Table 1). The increase in cases in the Asian population in New York City was observed entirely among foreign-born persons; the number of cases declined slightly among Asians born in the United States.

Discussion

These epidemiologic patterns strongly suggest that the decrease in the number of cases resulted from an interruption of the ongoing spread of *M. tuberculosis* infection. Several programmatic improvements are likely to have contributed.

Directly Observed Therapy

First, public health programs to control tuberculosis have recently expanded, particularly those that provide directly observed therapy, in which patients are observed as they take each dose of their medicine (Fig. 1). With support from the Centers for Disease Control and Prevention as well as the city and state governments of New York, the staff of the Bureau of Tuberculosis Control of the New York City Department of Health increased from 144 to more than 600 between 1988 and 1994; in the same period, the bureau's budget increased from $4 million to more than $40 million. Outreach workers traveled to patients' homes and workplaces, as well as to street corners, bridges, subway stations, park benches, and even "crack dens" in aban-

Table 1. Patients with Culture-Confirmed Tuberculosis in New York City during Two Two-Year Periods.

Variable	1991–1992	1993–1994	Percent Change
	no. of patients		
Age (yr)			
0–9	87	49	−43.7
10–19	138	126	−8.7
20–29	1002	683	−31.8
30–39	2053	1469	−28.4
40–49	1499	1273	−15.1
50–59	671	623	−7.2
≥60	789	824	+4.4
Sex			
Male	4356	3335	−23.4
Female	1883	1712	−9.1
Race or ethnic group			
Non-Hispanic black	3475	2646	−23.9
Hispanic	1627	1293	−20.5
Non-Hispanic white	713	585	−18.0
Asian	424	523	+23.3
Place of birth			
Outside U.S.	1147	1403	+22.3
In U.S.	5092	3644	−28.4
HIV status			
Seropositive	2386	1810	−24.1
Seronegative	908	932	+2.6
Not reported	2945	2305	−21.7
Multidrug-resistant tuberculosis	775	435	−43.9
All patients	6239	5047	−19.1

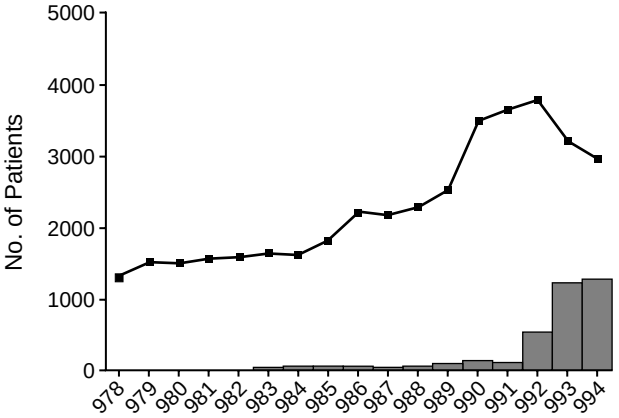

Figure 1. Number of Patients with Tuberculosis in New York City (Solid Line) and Number Receiving Directly Observed Therapy at the End of Each Year (Shaded Bars), 1978 through 1994. Data are from the New York City Department of Health.

doned buildings, to ensure that patients were appropriately treated. By the end of 1994, more than 1200 patients were receiving directly observed therapy, as compared with fewer than 50 in 1983. Most received their therapy through the city Department of Health with federal and local funding, and some were in programs supported by the state Department of Health, Medicaid funds, and funding granted under the Ryan White Care Act.

From January 1, 1992, through December 31, 1994, more than 32,000 patient-months of directly observed therapy were administered. In a typical month during this period, only 3 percent of patients who received the therapy were infectious, as indicated by sputum smears positive for acid-fast bacilli and *M. tuberculosis* on culture. We estimate that, without directly observed therapy, at least 15 to 20 percent of patients would have been infectious. A single infectious patient infects approximately one person per month.[17] Since more than 40 percent of patients with tuberculosis in New York City have HIV infection,[4] many contacts (perhaps 20 percent) who would have become infected with *M. tuberculosis* were also HIV-infected. Among HIV-infected persons with new tuberculosis infections, the rate of progression to active tuberculosis is likely to be at least 30 percent in the first year[18,19]; among HIV-negative patients, it is approximately 3 to 5 percent.[20] On the basis of these figures, directly observed therapy may have prevented at least 4000 tuberculosis infections and at least 800 cases of active tuberculosis by preventing patients from either becoming or remaining infectious.

The proportion of patients who completed treatment increased from less than 50 percent in 1989 to approximately 90 percent among patients with tuberculosis diagnosed in 1994, with most of the improvement occurring from 1992 to 1994. In addition to directly observed therapy and intensive case management, involuntary in-hospital confinement was instituted for the small proportion of patients (approximately 1 percent) in whom all other treatment approaches failed. The most important effect of the detention program was probably as a deterrent; given the credible threat of detention, adherence to directly observed therapy by some patients undoubtedly increased.

Infection-Control Measures

There has also been improvement in infection control. The New York State Department of Health has documented that tuberculosis-control efforts in New York City hospitals improved substantially from July 1992 to July 1994 (Stricof RL: personal communication). Measures carried out at hospitals where an outbreak has occurred can halt the spread of multidrug-resistant tuberculosis.[21] There were 115 cases in 1991 for which there was epidemiologic evidence of nosocomial transmission, 103 cases in 1992, and fewer than 30 cases annually in 1993 and 1994. We recently found that more than 4 percent of all cases of tuberculosis in New York City in April 1991 appeared to have been associated with a hospital stay (unpublished data). Thus, improved infection control is likely to have substantially decreased the number of cases citywide.

A further factor that may have contributed to the decrease in cases is the downsizing of large shelters for single adults. In the 1980s, as many as 50,000 different people passed through shelters for homeless adult men in New York City in a single year, with more than 5000 housed on any given night.[22] In the early 1990s, noncongregate housing began to be provided to homeless patients with AIDS. This policy had the dual effect of removing most patients with tuberculosis from the shelter system and of removing many patients with AIDS — those who are at highest risk for tuberculosis. Also, the large shelters that had housed 800 or more men in a single room in the late 1980s and early 1990s were phased out. This change may have affected the transmission of tuberculosis among the homeless persons who remained in the system, by reducing the opportunities for exposure to the disease as well as decreasing the intensity of such exposure. The number of patients with tuberculosis who were listed on the computerized registry of the shelter system decreased from 748 in 1991 to 293 in 1994.

In addition, improved practices for screening, isolation, and follow-up of incarcerated persons in New York City probably reduced the transmission of *M. tuberculosis* infection. The Rikers Island Correctional Facility holds more than 120,000 prisoners annually and has a daily census of more than 15,000.[23] There were no effective facilities for isolation at Rikers Island until May 1992, when a communicable-disease unit with effective respiratory isolation was constructed. There is evidence that tuberculosis was transmitted among patients incarcerated at Rikers Island in 1985[24]; it is likely that subsequent improvements in screening and isolation to prevent the airborne spread of *M. tuberculosis* reduced such transmission. In 1992, all patients with suspected or confirmed active tuberculosis at Rikers Island were enrolled in a program of directly observed therapy. An expanded outreach program and the use of incentives

increased the proportion of patients who kept follow-up appointments after their release from less than 20 percent to 92 percent (Bailey V, Larkin C: personal communication).

These factors — the use of directly observed therapy and improved infection control in hospitals, shelters for the homeless, and correctional facilities — are related. Programs of directly observed therapy for outpatients greatly reduced the number of infectious patients entering hospitals, shelters, and jails. Improved infection control limited the spread of disease by infectious persons who entered those facilities.

Changes in Treatment Regimens

Other factors may have contributed to the recent decrease in the number of cases of tuberculosis in New York City. In November 1991 the Department of Health recommended an initial regimen of at least four drugs (isoniazid, rifampin, pyrazinamide, and ethambutol) for all patients with active tuberculosis. By July 1993, one survey found that 89 percent of patients with suspected tuberculosis were being treated with at least four antituberculous drugs (Stricof RL: personal communication). This drug regimen not only reduced the likelihood that the treatment of drug-resistant tuberculosis would be ineffective, but also shortened the time required for patients to become noninfectious.[25] Improved laboratory methods, broader use of drug-susceptibility testing, and a higher index of suspicion for the disease (leading to more rapid diagnosis and initiation of treatment) probably all played a part.

The expanded use of preventive therapy in high-risk groups, such as persons with HIV infection, and the use of rifabutin as prophylaxis against disease caused by *M. avium* complex may also have contributed to the decrease. This cannot be demonstrated, however, because there is no systematic monitoring of the number of patients who complete preventive therapy. The chest clinics of the New York City Department of Health provided such therapy to more than 4000 people annually from 1992 through 1994, a substantial increase from prior years.

Finally, the number of severely immunosuppressed HIV-infected persons may have decreased slightly in New York City in recent years.[26] The fact that the number of cases of tuberculosis decreased less rapidly among women — in whom AIDS has been increasing, when a constant case definition is used — suggests that the epidemiologic features of AIDS may have played some part in this change.[27,28] However, even among women 20 to 40 years of age, the number of cases of tuberculosis fell 22 percent.

The decrease in resistance to drugs is perhaps the most convincing evidence linking the reduced numbers of tuberculosis cases with programmatic improvements. The incidence of drug-resistant tuberculosis has been shown to decline with improved rates of completion of treatment and with the use of directly observed therapy,[29,30] but presumably it would not be decreased by either the use of isoniazid prophylaxis or changes in the pattern of the HIV epidemic.

Implications

There is an important and complex lesson to be learned from the rapid decrease in the number of cases of tuberculosis. It had been believed that 90 percent of cases could be attributed to the reactivation of earlier infection,[31] but at least in the era of HIV, 30 percent or more of cases may result from the recent transmission of *M. tuberculosis*.[15,16] It is comparatively easy to prevent transmission by ensuring that patients with recently acquired disease are treated promptly, appropriately, and completely — ideally, with directly observed therapy. But after these cases have been prevented, the challenge becomes much greater. Preventive treatment must be given to many people who are not ill, who are unaware that they are infected, and for whom preventive therapy may be only a low priority; at the same time, effective directly observed therapy and high rates of completion of treatment among patients with active disease must be maintained. Thus, it is critical that control programs continue and expand, or another surge in tuberculosis may well occur.

New York City has not yet controlled tuberculosis. In 1994, 2995 cases were reported, far more than in any other city in the United States. The case rate was more than four times the national average, and there were more patients with multidrug-resistant tuberculosis than in the rest of the country combined. Nevertheless, the recent substantial decrease confirms that this disease can be prevented and cured, even in persons with HIV infection.[32]

The costs of the resurgence of tuberculosis have been phenomenal. From 1979 through 1994, there were more than 20,000 excess cases of the disease in New York City — cases that would not have occurred if previous downward trends had continued. Each case cost more than $20,000 in 1990 dollars, for a total exceeding $400 million.[33] In addition, as many as one third of patients with tuberculosis were rehospitalized because of inadequate follow-up, and thousands of people were hospitalized in order to rule out the diagnosis. There were additional expenditures for renovation at Rikers Island (more than $60 million); the renovation of hospitals; and preventive therapy for those who became infected during the resurgence. Care will be required for those who become ill, some of them with multidrug-resistant disease, in the years and decades to come. These costs easily exceed $1 billion and may reach several times that amount. Thus, despite their cost, efforts to control tuberculosis in the United States are likely to be highly cost effective.

Tuberculosis is a preventable and curable disease, and the war against it can be won. New York City's experience demonstrates that tuberculosis can be controlled even in populations in which immunosuppression is common and the prevalence of drug-resistant organisms is high. The challenge in the years ahead will be to continue to focus on treating the disease and

to expand the use of preventive treatment for people at high risk, such as close contacts of patients with tuberculosis, people with HIV infection, and persons from countries where tuberculosis remains common. Because foreign-born persons account for an increasing proportion of cases in the United States, we need to improve screening and services for immigrants and support international programs to control tuberculosis, which are important, effective, and woefully underfunded.[34,35] By doing so, we can ensure that the recent decrease in incidence becomes not simply a blip on a curve, but the resumption of a consistent drive to eliminate tuberculosis as a serious threat to public health in the United States.

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