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Tuberculosis outbreak in a Texas prison, 1994

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SUMMARY

In 1994 a Texas prison containing a population of mentally retarded inmates experienced a large tuberculosis outbreak. Fifteen cases of tuberculosis were identified (8 confirmed by positive cultures for *Mycobacterium tuberculosis*) and more than 100 inmates became infected. The culture-confirmed patients were infected with an identical strain of tuberculosis as demonstrated by polymerase chain reaction (PCR) based DNA fingerprinting technique. The prison followed standard tuberculosis infection control policies, but these controls were inadequate to prevent tuberculosis transmission in this special population. Two hundred and thirty inmates (119 inmates showing evidence of new tuberculosis infection or active disease and 111 healthy controls) were enrolled in the investigation. Inmate cell assignments, job duties, and educational classes were identified and medical chart reviews were conducted on all inmates. Tuberculosis transmission was associated with residing on the D Wing of the prison (OR = 25·84, $P < 0·01$), attending school in Classroom A (OR = 8·34, $P = 0·01$) and working on the prison utility work crew (OR = 2·52, $P < 0·01$). The index case in the outbreak had been prescribed 6 months of isoniazid (INH) chemoprophylaxis in 1988.

BACKGROUND

Tuberculosis is a bacterial disease caused by *Mycobacterium tuberculosis*. This bacteria is transmitted from person to person by a respiratory route. The lungs are the primary site of infection. There are two stages of the disease: the acquisition of infection, and the development of clinical illness.

In many countries, children are routinely vaccinated with bacille Calmette-Guerin (BCG) to protect against tuberculosis. BCG is not routinely used in the United States due to the low prevalence of tuberculosis infection in the general population and the debate over the efficacy of BCG in preventing active cases of disease. BCG vaccination also interferes with tuberculin skin tests by causing false positive skin test reactions among certain vaccinated individuals. Public health officials in the United States prefer to preserve the Mantoux tuberculin skin test as an effective screening tool to detect persons recently infected with tuberculosis so preventive therapy may be offered.

Currently, the best method for identifying infected persons is an intradermal skin injection of purified protein derivative (PPD) of *M. tuberculosis*. Induration at the injection site is evidence of infection. The

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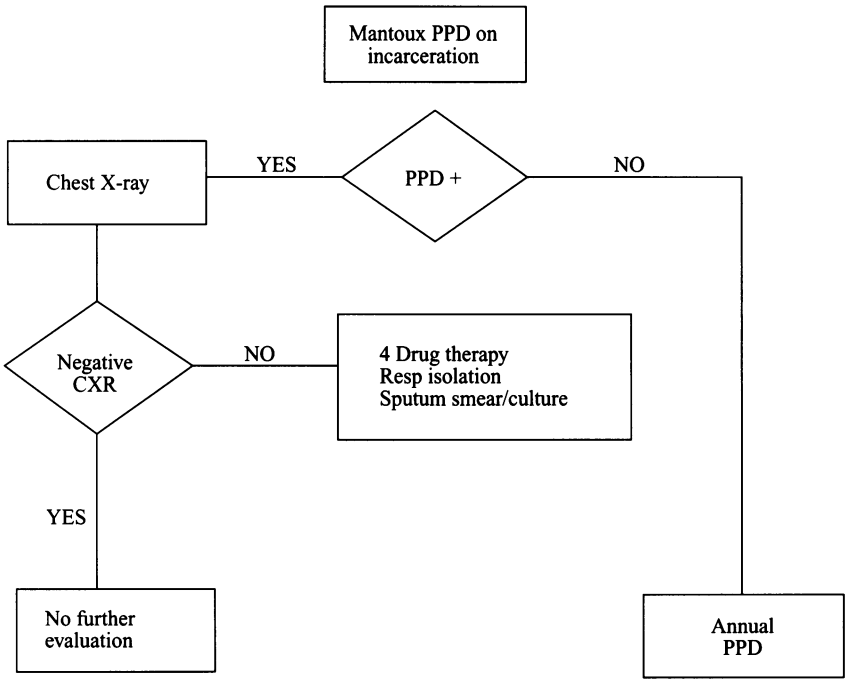

Fig. 1. TDCJ tuberculosis screening practices during outbreak period.

size of induration is arbitrary and varies between age groups and immunologic status. The Texas Department of Health (TDH) and the Texas Department of Criminal Justice (TDCJ) regard indurations of 10 mm or greater to be positive skin tests. Most infected persons never develop clinical illness. The time from acquisition of infection to clinical illness varies from a few weeks to several decades in those persons who do develop active disease.

Prisons and jails have long been recognized as high-risk environments for tuberculosis transmission [1–7]. Recent outbreaks in correctional facilities in New York and California have involved multi-drug resistant strains of tuberculosis [8–10]. During the first 6 months of 1994, a Texas Department of Criminal Justice facility in East Texas experienced the largest tuberculosis outbreak recorded for a Texas prison. All patients identified in this outbreak were inmates or employees assigned to the Mentally Retarded Offenders Program (MROP) of the Texas Department of Criminal Justice. Prison A is a medium security prison located in northeast Texas. The average daily census for the facility ranges from 2500–3000 inmates. The MROP inmates were housed together in four wings on the southern end of the prison. There are approximately 700 MROP inmates incarcerated at any given time.

Inmates in the TDCJ system all receive a Mantoux PPD intradermal skin test upon incarceration, unless they have a documented prior positive PPD test result. Inmates who receive a negative result on their baseline PPD receive annual follow-up PPD skin tests during the month that contains their anniversary date of incarceration. An inmate is considered PPD positive if his reaction induration is 10 mm or greater. All skin test converters are offered a 6-month course of INH prophylaxis. Inmates diagnosed with pulmonary tuberculosis are placed in AFB respiratory isolation and treated with a standard four-drug anti-tuberculosis therapy. An isolation room is a single-patient room in the infirmary or prison hospital where the air in the cell maintains negative pressure relative to the rest of the building by venting the air directly to the outside. Isolation rooms must experience a minimum of 6 complete air changes per hour in existing facilities and 12 complete air changes per hour for newly constructed or renovated rooms [11]. During the outbreak period, inmates with positive PPD results and an initial negative chest radiograph received no further evaluation (Fig. 1). In 1995, TDCJ revised the follow-up procedure to require an annual CXR for positive PPD reactors (Fig. 2).

In 1993, 2137 inmates were given PPD skin tests in prison A and 36 (1·7%) experienced PPD conversions. During the first 5 months of 1994, 1101 inmates received PPD skin tests and 34 (3%) experienced conversions. Additionally, four inmates were diagnosed with active pulmonary tuberculosis from 5 April to 2 May 1994. All four inmates were assigned to the Mentally Retarded Offenders Program. The

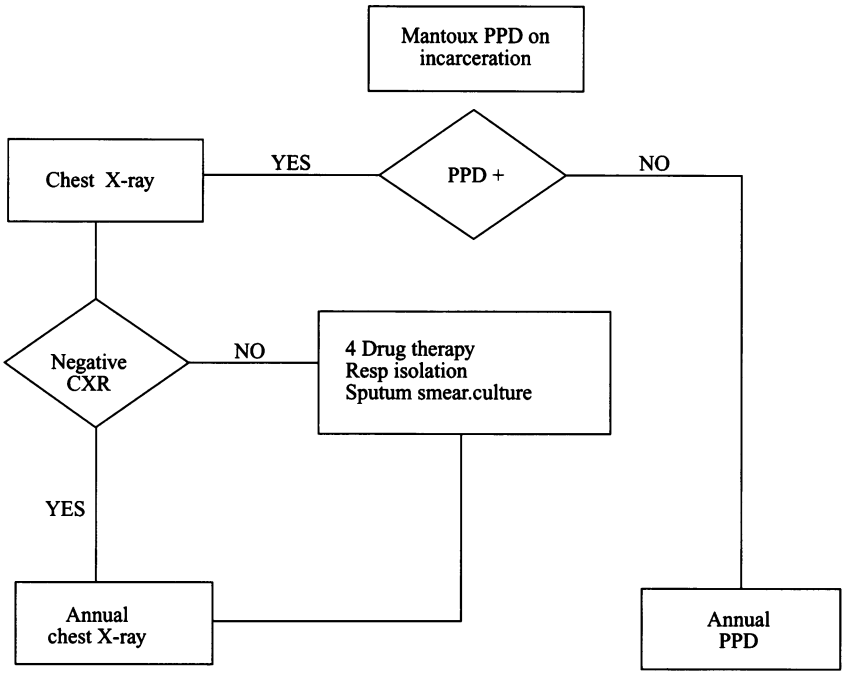

Fig. 2. Revised TDCJ tuberculosis screening practices after the outbreak period.

increase in the number of PPD converters and the identification of MROP inmates with active pulmonary tuberculosis led the public health nurse to screen all MROP inmates for evidence of recent infection.

METHODS

Texas Department of Health staff from the Infectious Disease Epidemiology and Surveillance Division and the Preventive Medicine Department of the Texas Department of Criminal Justice collected the data for this investigation. The sources of data were as follows: computerized administrative records of TDCJ; records from the special education programme for MROP inmates in prison A; and medical chart reviews of all inmates enrolled in the study. The following information was collected: name; TDCJ number; date of birth; date of incarceration; date of incarceration at prison A; race/ethnicity; history of chemical dependency; tuberculosis history; history of diabetes or other underlying health problems; the last two PPD skin test results and dates of those PPD tests; whether the inmate had been tested for human immunodeficiency virus (HIV) infection; HIV test results; whether the inmate had been placed on INH or any other medications in 1994; and the dates and results of any chest X-rays the inmate received in 1994. Information was also collected about the jobs the inmate held within the prison; the classes the inmate attended in the prison school and who taught them; and the prison wing and cell assignments the inmate had from 1 January to 30 June 1994.

Tuberculosis control practices used in the facility were reviewed and compared with established guidelines for the prevention of tuberculosis transmission in institutions. After completing the epidemiological data analysis, environmental tuberculosis control experts from the TDH Tuberculosis Elimination Division investigated areas associated with tuberculosis transmission. The investigation included testing the number of air changes occurring in the areas implicated epidemiologically, as well as studying air flow patterns and the relative contribution of fresh and recirculated air in those areas. These evaluations were conducted in order to establish whether a structural defect in the prison or the environmental control systems could help explain the large number of persons infected in this outbreak.

All laboratory cultures and acid-fast bacilli (AFB) smear results were processed and validated at the TDH laboratory. Positive culture isolates are routinely tested for sensitivity and resistance to first-line anti-tuberculosis medications. *Mycobacterium tuberculosis* isolates were typed by polymerase chain reaction (PCR) DNA fingerprinting process as described by Haas [12]. The DNA fingerprints were compared to each other and to that of a reference strain (H37Rv).

A case-control study to determine risk factors for tuberculosis infection and progression to active pulmonary tuberculosis was initiated in October 1994. A case was defined as an MROP inmate prescribed INH in 1994 who: experienced a PPD skin test conversion; developed culture-confirmed pulmonary tuberculosis; or had a prior history of tuberculosis infection with an abnormal or unstable chest X-ray between 1 January and 30 June 1994. Controls were randomly chosen from among the inmates tested in May and June 1994 and screened negative for recent infection. All inmates in the study were incarcerated in the prison for at least 56 days prior to 1 May 1994. Fifty-six days was the shortest period of time an inmate was incarcerated in the prison before demonstrating a PPD skin test conversion. Fifteen inmates were paroled prior to initiation of INH treatment and were excluded from the case-control study.

Data analysis was conducted using Epi Info, the statistical software package developed by the Centers for Disease Control for epidemiologic investigations. A probability of 0·05 or less was chosen as the measure of statistical significance, and χ^2 was used to test for significance when variables were dichotomous.

RESULTS

Six hundred and eighty-six MROP inmates were evaluated from 2 May to 16 June 1994, for signs of recent tuberculosis infection. Four hundred and forty-nine inmates received PPD skin tests and 237 inmates received chest X-rays (CXR). The screening process identified 109 PPD converters and 10 additional inmates with prior positive PPDs whose CXR was abnormal. Of 686 inmates at risk of becoming infected with *Mycobacterium tuberculosis* during the outbreak period, 119 (17%) showed evidence of recent infection. Fourteen inmates and one prison employee progressed to active pulmonary tuberculosis (Fig. 3). The one employee was a school teacher who taught special education programmes for MROP inmates; the index case in this outbreak was one of his students. The employee was the final case in the outbreak. He was diagnosed with culture-positive tuberculosis in late September 1994. The case rate of 2040/100000 in this outbreak greatly exceeds the case rate for the general population of Texas (approximately 14/100000) [13].

The surrogate measure used to define which inmates met the case definition in the case-control study was whether or not they had been prescribed INH as a treatment for active tuberculosis or as a prophylaxis due to recent tuberculosis infection. In the screening conducted in 1994, 119 inmates showed evidence of recent tuberculosis infection. Fifteen inmates were paroled before preventive therapy was prescribed, and these were lost to follow-up. One hundred and four inmates were prescribed INH and therefore enrolled as cases in the case-control study.

The prison provided TDH personnel a list of 567 MROP inmates who were screened negative for recent tuberculosis infection in the summer of 1994. In an effort to enroll approximately one control per case 111 inmates were randomly chosen from this list as controls. Eighteen controls were dropped because they were not in the prison for a minimum of 56 days before 1 May 1994. Another 33 controls were dropped from the analysis after a review of their medical records disclosed a prior history of tuberculosis infection. These inmates were judged to be less susceptible to new infection than inmates without a prior history of tuberculosis infection. One hundred and sixty-four inmates were included in the final data analysis (104 cases and 60 healthy controls). The mean age in both groups was 32 years (range: 21–60).

The study population was 79% African American, 14% Hispanic, and 7% Caucasian. There were no significant differences between cases and controls with regard to race or ethnicity. Eight (53%) of the 15 cases of pulmonary tuberculosis identified in this outbreak were AFB culture-positive for *Mycobacterium tuberculosis*; two were AFB smear positive as well. The remaining seven cases were diagnosed in inmates having a positive PPD or prior history of PPD conversion and an abnormal or unstable CXR during the outbreak period. Eighty-nine inmates were prescribed preventive INH therapy, and the 15 inmates with active pulmonary tuberculosis were all prescribed a standard four drug therapy (isoniazid, rifampin, ethambutol, pyrazinamide). All culture isolates were sensitive to all first-line anti-tuberculosis medications tested.

Polymerase chain reaction (PCR) DNA fingerprinting of culture isolates demonstrated that all inmates were infected with the same strain of *Mycobacterium tuberculosis*. Figure 4 shows PCR DNA fingerprints of nine *M. tuberculosis* isolates recovered from Prison A inmates in lanes 2–6 and 8–11. The fingerprint of a reference strain of *M. tuberculosis* (H37Rv, ATCC No. 27294 from the American Type Tissue Collection, Rockville, MD) is in lane 12. Water, used as a negative control, is in lane

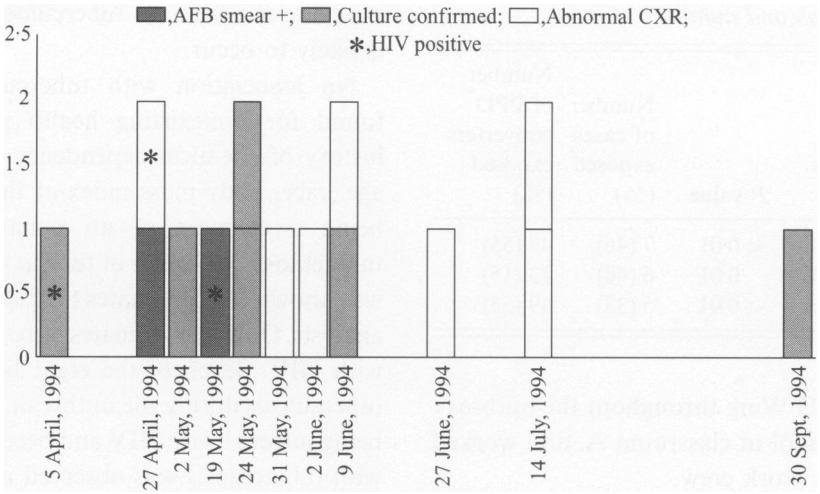

Fig. 3. Epidemic curve. Prison TB cases, 1994.

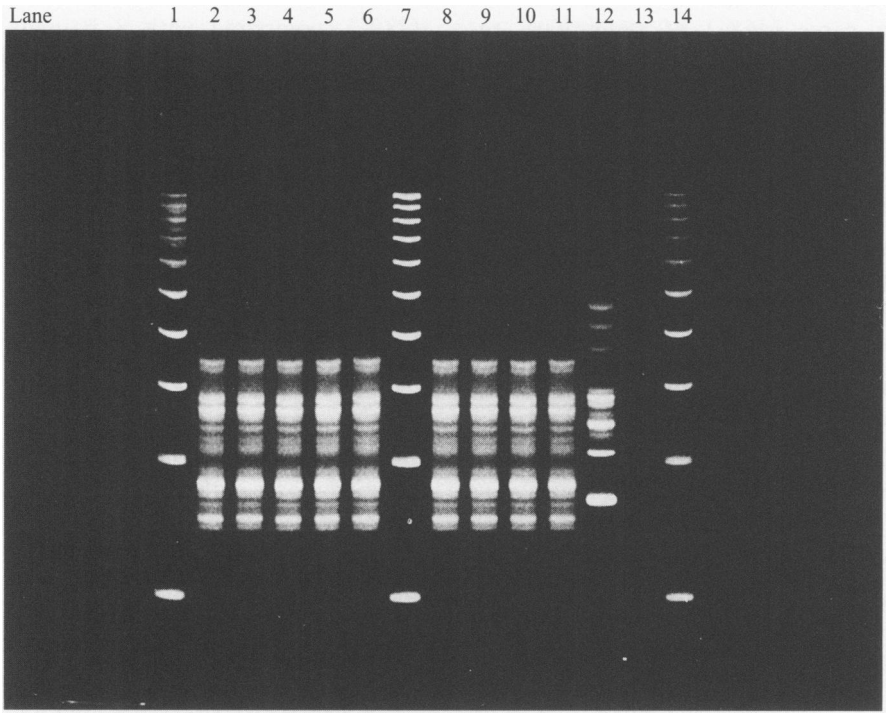

Fig. 4. PCR DNA Fingerprint analysis of the outbreak strain of tuberculosis. Isolates from prison outbreak patients are located in lanes 2–6 and 8–11. A reference strain of tuberculosis is loaded in lane 12 as a positive control; lane 13 contains water as a negative control. Lanes 1, 7 and 14 contain 100 bp sized fragments of DNA. All the prison inmate isolates have an identical DNA fingerprint, indicating a common source of exposure for all patients.

13. A 100 bp DNA size ladder (Superladder-Low 100 BP ladder, GenSura Laboratories, Inc., Del Mar, CA) was loaded into lanes 1, 7 and 14.

Three areas in the prison were significantly associated with inmates receiving INH. All were areas associated with the presumed index case in this outbreak. The index case had a history of prior tuberculosis infection in 1988, and had been prescribed a 6-month course of INH prophylaxis in 1988 as a result of his positive PPD skin test. He was diagnosed with AFB smear and culture positive tuberculosis in late April 1994. He was HIV seronegative by both ELISA and Western Blot HIV antibody tests. Although current TDCJ policy is to evaluate positive PPD reactors with an annual CXR to detect signs of progression to active tuberculosis, this patient went 43 months without an evaluation, according to a review of his medical record. The index

Table 1. *Prison areas and numbers of cases*

Prison area associated with TB transmission	Odds ratio	*P* value	Number of cases exposed (%)	Number of PPD converters exposed (%)
D Wing	25·84	< 0·01	7 (46)	49 (55)
Classroom A	8·34	0·01	6 (40)	13 (15)
Utility crew	2·52	< 0·01	5 (33)	49 (55)

case resided on the D Wing throughout the outbreak period, attended school in classroom A, and worked on the prison utility work crew.

Inmates living on the D Wing were over 25 times more likely to experience tuberculosis infection than inmates living on other wings (OR = 25·84, $P < 0·01$) (Table 1). Seven cases (46%) of pulmonary tuberculosis and 49 (55%) PPD converters show an association with the D Wing, including the index case. Structurally, the D Wing is no different from any other area in the prison. The only difference between the D Wing and other cell wings in prison A concerns the type of inmate assigned to the wing. Inmates living on the D Wing have a history of mental illness and other psychological problems in addition to their mental retardation.

Attending school in classroom A (OR = 8·34, $P = 0·01$) and working on the prison utility work crew (OR = 2·52, $P < 0·01$) were also significantly associated with tuberculosis infection. There were five inmates and one employee (the teacher) in classroom A who developed pulmonary tuberculosis in 1994. The utility work crew is a group of inmates who handle light duty chores in the prison. Several MROP inmates, including the index case, were assigned to this work group.

TDH's Tuberculosis Elimination Division performed an environmental evaluation of the D Wing and the prison school after these areas were implicated epidemiologically. A series of large attic fans draws air from the D Wing upward through the unit, and the air vents directly to the outside through louvres near the roof. The placement and size of exhaust vents on the unit made precise measurement impossible, although it is estimated that the unit experiences at least 26 air changes per hour. The classrooms investigated in the prison school averaged eight air changes per hour. There is no evidence that a breakdown in environmental control measures was responsible for the outbreak. If individuals have prolonged and repeated exposure to infectious tuberculosis patients, infection is likely to occur.

No association with tuberculosis infection was found for pre-existing health problems, having a history of chemical dependency or substance abuse, age, race, body mass index at time of incarceration, being a cellmate of an inmate with pulmonary tuberculosis, or length of time at prison A. HIV status was known for 60 inmates (37%) included in the data analysis. Only eight inmates were known to be infected with HIV. Seven of the eight became infected with tuberculosis during the outbreak. An association with being infected with HIV and becoming newly infected with tuberculosis was observed in our study but was not statistically significant (OR 4·03, $P = 0·17$). HIV status was known for 11 of the 15 cases of pulmonary tuberculosis. Eight of the 11 were HIV negative (73%), compared with 3 patients who were HIV positive (27%). The index case in this outbreak was HIV negative.

DISCUSSION

In previous prison tuberculosis outbreaks, HIV infection contributed significantly to tuberculosis transmission [2–3, 8–10]. The Texas outbreak was unusual in that HIV infection was not significantly associated with either tuberculosis infection or active disease. However, HIV-TB co-infection among inmates alerted prison medical staff to the possibility of a tuberculosis outbreak. Three inmates infected with HIV developed pulmonary tuberculosis during this outbreak. They represented three of the first five cases identified, and they all developed active disease before 19 May 1994. The co-infected inmates thus served as a sentinel population, identifying a problem of tuberculosis transmission within the facility for the medical staff.

The fact that the outbreak occurred among MROP inmates both aided medical personnel in containing the outbreak and prevented them from quickly recognizing the problem of tuberculosis transmission in the prison. MROP inmates transfer to other facilities far less often than inmates in the general TDCJ population. This aspect contained the outbreak to one prison and, indeed, to one section within the prison. Once the outbreak was identified in late April 1994, it was relatively easy to screen the inmates as a group and intervene to interrupt tuberculosis transmission in the facility. Since general population inmates are routinely transferred in the TDCJ system,

recognizing and containing the outbreak would have been more difficult had it occurred among general population inmates. Determining the extent of new infections also would have been more difficult. At the same time, MROP inmates are less capable than other inmates of raising an appropriate level of concern among their medical care givers or alerting staff to significant changes in their health status. This problem prevented medical staff from recognizing the outbreak earlier, allowing a large number of inmates to become infected.

TDCJ's Infection Control Manual Tuberculosis Protocol follows established guidelines designed to prevent tuberculosis transmission in institutional settings [14–15]. The PPD testing programme enabled the public health nurse for the prison to identify a significant increase in the prison's PPD conversion rates and to identify four active cases of pulmonary tuberculosis early in 1994. This action led to screening all MROP inmates and allowed the outbreak to be brought under control quickly once the problem was recognized. However, the infection control policy manual was changed twice between 1988 and 1994 while the index case was incarcerated, and the inconsistencies between policies allowed the patient to go without a comprehensive evaluation for more than 3 years. The old TDCJ policy concerning inmates with documented PPD skin test reactions greater than 10 mm required no annual evaluation provided the initial chest radiograph was normal and INH prophylaxis had been prescribed. The index case in this outbreak was in the prison for 6 years and known to be a positive reactor from the time of his initial screening. A 6 month course of INH was prescribed initially, but it is doubtful the patient took the medication. He received a follow-up CXR for 2 years, and then went without any evaluation for 43 months. The TDCJ protocol for follow-up evaluations of inmates with positive PPD skin tests was strengthened after the 1994 outbreak. The new policy provides for annual CXR evaluation of all positive reactors for signs of progression to active disease, even for patients who have been prescribed INH prophylaxis.

Molecular epidemiology contributed significantly to our understanding of this outbreak. All *M. tuberculosis* isolates cultured from the inmates and the employee had identical PCR DNA fingerprints. This established that a single strain of *M. tuberculosis* was responsible for the outbreak. The MROP inmates collectively experienced high rates of prior substance abuse, homelessness, and a history of prior incarceration. It was important to determine whether the 1994 tuberculosis cases were related to a common source or if they represented a group of people previously infected with several different strains, simultaneously progressing to disease. Molecular epidemiology proved that this was a common-source outbreak initiated by a single individual progressing to active disease.

The majority of tuberculosis transmission in this outbreak occurred on the prison's D Wing. This area housed a special population of inmates who were both mentally ill and mentally retarded. To our knowledge, this is the first documented tuberculosis outbreak among a mentally retarded population. The fact that the outbreak originated among this group of inmates with a dual diagnosis of mental retardation and mental illness may explain why cases were not recognized more quickly and why so many inmates became infected in such a short period of time. Institutionalized persons who are both mentally ill and mentally retarded may not be as capable as others of making medical personnel aware of their illnesses, and may represent a population in need of greater attention from authorities involved in tuberculosis control.

The association of tuberculosis infection with a particular classroom is not unusual. School-based tuberculosis outbreaks have been described in Italy, England, Ireland, and the United States [16–21]. The only prison employee to develop pulmonary tuberculosis in 1994 was the teacher in this class. We were unable to determine the number of newly-infected prison employees associated with this outbreak because PPD testing for TDCJ employees is voluntary, and baseline PPD skin test data for employees were unavailable.

This outbreak is significant because it reinforces the need for medical staff treating institutionalized patients to follow established infection control protocols consistently. The outbreak also alerts us to be vigilant for signs of progression to active disease among positive PPD reactors, even if they have been prescribed INH prophylaxis in the past. Finally, mentally ill and mentally retarded patients with tuberculosis infection represent a population in need of careful routine evaluations on an annual basis for signs they are progressing to active disease. The potential for widespread tuberculosis transmission among special populations emphasizes the need to recognize signs of tuberculosis transmission quickly in prisons and other institutions.

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