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Transmission of *Mycobacterium tuberculosis* in a Tennessee Prison, 2002-2004

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An outbreak investigation was conducted in a Tennessee prison to determine the extent of *Mycobacterium tuberculosis* transmission and prevent additional tuberculosis (TB) cases. Inmates, staff, visitors, and community contacts were screened. TB disease was diagnosed for eight inmates, including one after release and three people in the community, including two young children. In addition, 59 contacts (47 inmates, 4 staff members, and 8 additional persons in the community) were newly diagnosed with latent TB infection (LTBI). Failure to recognize TB symptoms, delays in TB diagnosis, inconsistent LTBI treatment, and prolonged congregation of inmates with infectious TB propagated this outbreak. Prison incarceration provides an important opportunity to diagnose and treat LTBI and thus prevent TB disease transmission to the community.

Keywords: tuberculosis; prisons; disease outbreaks; genotype; correctional health care

During the past decade, multiple tuberculosis (TB) outbreaks have been reported in correctional facilities (Bergmire-Sweat et al., 1996; Centers for Disease Control and Prevention [CDC], 2000, 2005a; Jones, Craig, Valway, Woodley, & Schaffner, 1999; Koo, Baron, & Rutherford, 1991; Pelletier et al., 1993; Stead, 1978; Valway et al., 1994). Contributing factors have included inadequate screening for TB disease or latent TB infection (LTBI; MacNeil et al., 2005), delays in diagnosis or isolation of TB cases (McLaughlin et al., 2003; Valway et al., 1994), frequent inmate transfers (Ijaz et al., 2004; Lobato, Roberts, Bazerman, & Hammett, 2004; Valway et al., 1994), recidivism (White, Tulsky, Menendez, Goldenson, & Kawamura, 2005), lengthy incarceration (March et al., 2000), and congregation of HIV-infected inmates (McLaughlin et al., 2003; Mohle-Boetani et al., 2002). Inadequate TB control efforts in correctional settings may propagate ongoing transmission of *Mycobacterium*

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tuberculosis among inmates and staff and into the surrounding community (CDC, 2005a; Jones et al., 1999; MacNeil et al., 2005; Stead, 1978; Valway et al., 1994).

In 2003, 7% of reported TB cases in Tennessee were in persons who were incarcerated at diagnosis—nearly double the proportion reported from correctional facilities in this state and nationally during the previous 5 years (CDC, 2004). A single prison in western Tennessee was an important contributor to this increase, with five TB cases reported in 2003. An outbreak investigation was initiated by the CDC and the Tennessee Department of Health in early 2004 to determine the extent of *M. tuberculosis* transmission and to prevent additional TB cases.

Methods

Setting

The outbreak prison was a privately managed medium-security state facility with an average daily census of approximately 2,000 male inmates. Most inmates (approximately 63%) were White, 36% were Black, and 1% belonged to other racial groups; the inmates' mean age was 34 years.

Epidemiological Investigation

State TB surveillance data were reviewed to identify persons with TB who were incarcerated in the outbreak prison during 2003 or 2004. Medical records of these patients were reviewed to abstract data on sociodemographics, past diagnoses or treatment of TB or LTBI, tuberculin skin test (TST) and chest radiograph (CXR) results, clinical characteristics, and bacteriological findings. Patients were interviewed regarding prior *M. tuberculosis* exposures, incarceration history, onset and type of TB symptoms, their prison locations, and names of close contacts. Initial contact investigation data gathered by the local health department and Tennessee Department of Corrections were reviewed. Genotyping results for inmates with positive *M. tuberculosis* cultures were determined by spoligotyping (CDC, 2005a; Cowan, Diem, Brake, & Crawford, 2004; Gori et al., 2005), mycobacterial interspersed repetitive units analysis (Cowan et al., 2005; Cowan, Mosher, Diem, Massey, & Crawford, 2002), and restriction fragment length polymorphism techniques (van Embden et al., 1993).

Outbreak patients were defined as patients who had *M. tuberculosis* isolates with matching genotypes or those who had culture-negative TB and were known to have had contact with one or more patients having the outbreak strain. Each patient's infectious period was defined as beginning 3 months before either the onset of symptoms or the first positive acid-fast bacilli sputum smear result, whichever was earlier, and ending when the patient's TB was considered noninfectious (the earlier date of either initiation of airborne infection isolation or of antituberculosis treatment). For patients with negative acid-fast bacilli sputum smear results, the infectious period was defined as beginning 1 month before symptom onset date. Prison inmate tracking system data were reviewed to determine inmate housing locations and transfers within the prison and to other facilities during each patient's infectious period. Persons residing in the same prison housing area as a TB patient during that patient's infectious period were considered *known inmate contacts.* For each known inmate contact, the duration of residence with a patient with infectious TB was determined and defined as overlap days. Cumulative overlap days were calculated as the sum of a single contact's overlap days with each TB patient. Staff work assignments and visitor logs during each outbreak patient's infectious period were also reviewed to identify potential staff and visitor contacts.

Follow-Up Screening for TB and LTBI

To identify persons who may have been exposed to inmates with infectious TB and who still required TB screening, lists of inmates, staff members, and visitors were compared with the initial contact investigation data and with annual prison TST logs for inmates and staff. To ensure that all exposed inmates and staff still at the prison had been adequately screened, prisonwide TB screening (including symptom review and TST for those with prior negative TST results) was repeated 3 months after the last patient's infectious period ended. Two subsequent prisonwide screenings were performed to ensure that ongoing *M. tuberculosis* transmission had been terminated.

Health department staff sent letters to known inmate contacts who had been released from the prison to inform them of possible *M. tuberculosis* exposure and the need for TB screening. For inmates who had been transferred to other state prisons, letters were sent to the infection control nurse at the inmate's new facility requesting that TB screening be performed. For inmates released to the community, letters were sent to their last known address.

Identification of Missed Opportunities to Prevent *M. tuberculosis* Transmission

Prison TB control procedures at the time of the outbreak were reviewed and compared with current national guidelines for the prevention and control of TB in correctional facilities (CDC, 1996). Missed opportunities to prevent transmission of *M. tuberculosis* were identified so that revised correctional TB policies and procedures consistent with national guidelines (CDC, 2005b, 2005c, 2006) could be implemented locally and at other correctional facilities in Tennessee.

Results

Outbreak Patients

Seven pulmonary TB cases were reported by the prison during 2003 and 2004, and an additional former inmate with TB was reported by the local health department a few months after his release. Of these eight corrections cases, seven were considered outbreak patients, five had pan-susceptible *M. tuberculosis* isolates with matching genotypes, and two had culture-negative TB but were known contacts of other inmate cases. The eighth inmate was diagnosed with TB in March 2004 but had a nonmatching genotype. All seven outbreak patients were male. Six were Black and one was White. The median age was 34 (range 24-58) years. Each outbreak patient was tested for HIV; one was infected. Four outbreak patients reported drug or alcohol abuse.

After the onset of symptoms of the first outbreak case, three of the seven outbreak patients were found to have TST conversions but had not received LTBI treatment. Two outbreak patients had past positive TST results, one had a documented history of isoniazid treatment in 2001 at another correctional facility by directly observed therapy (DOT; i.e., a health care provider watched the patient swallow each dose of medication), and one reported that while incarcerated in 1990 he was given pills to self-administer for LTBI treatment. One outbreak patient had previous TB disease and had completed 12 months of treatment in 1998; however, no isolate was available from that prior episode to determine if his recurrence was with the same *M. tuberculosis* strain. A seventh outbreak patient who was infected with HIV had a negative TST result.

The overlap between the infectious periods and incarceration dates for the seven outbreak patients is shown in Figure 1. One asymptomatic patient (Inmate G) was found to

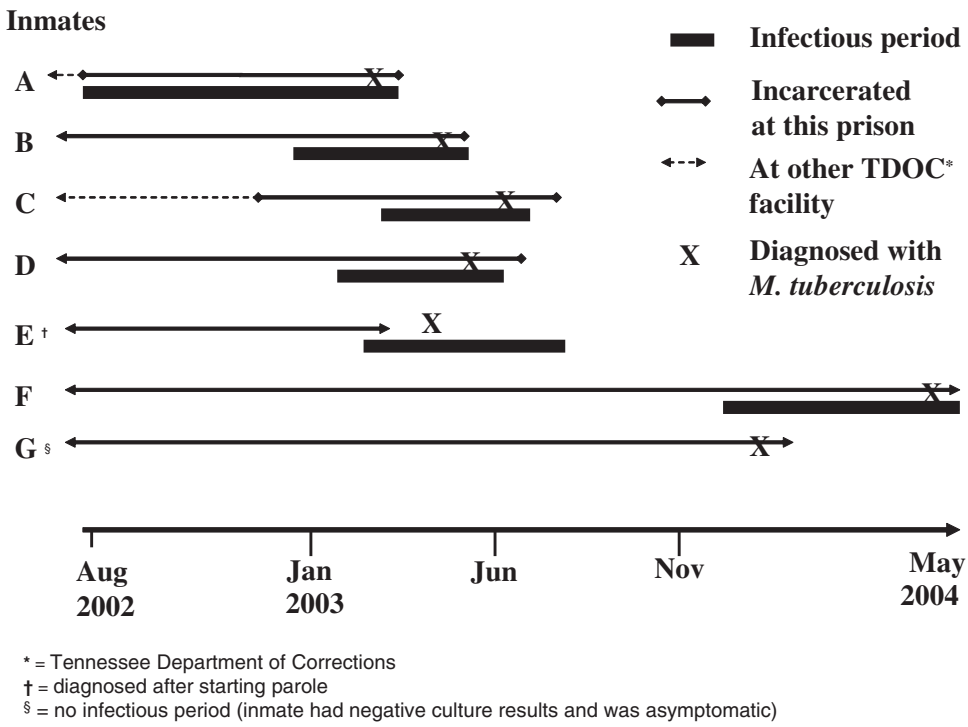

Figure 1. Infectious periods of outbreak TB patients and incarcerations.

have an abnormal CXR result consistent with TB when he was evaluated for a positive TST result during a routine annual prison TB screening. The duration of infectiousness for the six symptomatic patients ranged from 25 to 147 days, with a median of 113 days.

The patient with the longest infectious period (Inmate A, see Figure 1) visited the prison infirmary at least six times complaining of productive cough, fever, chills, night sweats, and weight loss. He was treated symptomatically for cough on the first three visits; he was prescribed amoxicillin on his fourth visit, and on his fifth visit, he was treated with ibuprofen for back pain because of excessive coughing. A CXR was performed 5 months after the inmate initially complained of symptoms and had a 26-pound weight loss. When his CXR findings were described as consistent with TB, the inmate was removed from the general prison population. However, during his infectious period before diagnosis he had been assigned to five different residential units.

Five outbreak patients resided in the same housing unit with at least one other outbreak patient. Prison residential units had separate ventilation systems, but inmates were confined to their cells only from 9 p.m. to 6 a.m. Outbreak patients congregated with other inmates in central common areas for classes, religious services, food service jobs, gym activities, and card games.

Contacts: Inmates, Staff, and Visitors

A total of 988 known inmate contacts were identified during the outbreak investigation. A review of the initial prison contact investigation data revealed that only 257 (26%) of the 988 known inmate contacts had been fully evaluated (i.e., TST for those with prior negative TST results and symptom review for those with past positive TST results); 86 (33%) had past

Table 1. Tuberculin Skin Test (TST) Results for Known Inmate Contacts by Cumulative Overlap Days

Cumulative Overlap Days	Number of Inmate Contacts Tested (n = 594)	TST Conversions n = 47 (8%)	Relative Risk (95% Confidence Interval)
1 to 42 days	456	8 (1%)	
≥43[a] days	138	39 (28%)	16.1 (7.7-33.7)

a. The median number of cumulative overlap days between inmate contacts and outbreak patients.

Table 2. Tuberculin Skin Test (TST) Results for Inmates and Staff Evaluated as Potential Contacts During Follow-Up Prisonwide TB Screenings

	First Screening[a]		Second Screening[b]		Third Screening[c]	
Variable	Inmates	Staff	Inmates	Staff	Inmates	Staff
Number of contacts evaluated	1,941[d]	339	1,702	401	1,783	401
Past positive TST result[e]	314 (16%)	27 (8%)	37 (2%)	0 (0%)	91 (5%)	1 (<1%)
Negative TST result	1,604 (83%)	308 (91%)	1,654 (97%)	401 (100%)	1,692 (95%)	400 (99%)
Documented TST conversion	23 (1%)[f]	4 (1%)[f]	11 (<1%)[f]	0 (0%)	0 (0%)	0 (0%)

a. Three months after the last infectious period ended (i.e., August 2004).
b. Seven months after the last infectious period ended (i.e., December 2004).
c. Eleven months after the last infectious period ended (i.e., April 2005).
d. In addition to 988 known inmate contacts, 953 inmates who did not reside in the same prison housing area as a TB patient were also evaluated at the prison.
e. Persons with past positive TST results received a chest radiograph.
f. Percentage is number of persons with TST conversions divided by number of persons tested. First screening: inmates (23/1,627), staff (4/312); second screening: inmates (11/1,665), staff (0/401); third screening: inmates (0/1,692), staff (0/400).

positive TST results, and 40 (23%) of the 171 known inmate contacts who had been skin tested initially had a documented TST conversion.

After three subsequent prisonwide screenings were completed and follow-up test results were obtained for known inmate contacts who had been released or transferred to other facilities, 698 (71%) of 988 were fully evaluated; 104 (17%) had past positive TST results, and a total of 47 (8%) of the 594 known inmate contacts who received skin tests had TST conversions. (During the subsequent screenings, seven additional known inmate contacts with TST conversions were identified.) Inmate contacts who spent ≥43 (the median number) cumulative overlap days with a TB patient during the infectious period were more likely to have a TST conversion (relative risk [RR] = 16.1; 95% confidence interval = 7.7-33.7; see Table 1).

Staff and visitor contacts also were screened. A total of 98 staff members identified as contacts were evaluated during the initial contact investigation; four (4%) employees (a nurse, counselor, utility officer, and transportation officer) had TST conversions, and 94 (96%) still had negative TST results 3 months after exposure. During their infectious periods, two outbreak patients had a total of 16 visitors at the prison. Of those, 12 (75%) were located and evaluated, and no new TST conversions were recorded. No other outbreak patients had visitors while contagious.

Table 2 shows TST results for all inmates (not only known inmate contacts) and staff who were evaluated as potential contacts during the three follow-up prisonwide TB screenings. In the first two follow-up screenings, TST conversions were noted for 34 inmates (including seven known inmate contacts) and four staff members. During the third follow-up screening,

no new TST conversions were recorded among inmates or staff, and thus, the prison TB screening policy reverted to an annual schedule. No additional TB cases were detected during the follow-up screenings at the prison.

M. tuberculosis Transmission to the Community

Of the seven outbreak patients identified during the investigation, one developed TB after release (Inmate E, see Figure 1); none of his contacts had positive TST results. However, after the outbreak investigation was completed, an additional former inmate developed culture-positive cavitary TB with the outbreak strain, more than a year after release. He was identified through a source-case investigation for an 8-month-old infant with TB meningitis whose disease was also caused by the outbreak strain. In total, 11 (31%) of the former inmate's 35 identified community contacts had positive TST results, and two additional cases of TB were diagnosed among them, including another child.

TB Control Policies at the Time of the Outbreak

TB screening on entry into the Tennessee Department of Corrections system (i.e., at hire for staff and intake for inmates) was performed using a single TST. However, baseline and subsequent annual screenings for TB symptoms were not well documented in inmates' medical records, and TST results were not reviewed systematically to detect increases in TST conversion rates. Inmates with positive TST results were evaluated for TB disease with a CXR and physician examination; however, the evaluation was at times delayed. Many inmates with LTBI were not treated, and DOT was not available for those who were treated. HIV testing was voluntary.

Patients suspected of having TB were housed in the general prison infirmary during their evaluation because the prison did not have an airborne infection isolation room. Established procedures for notifying the health department about TB suspects and cases did not exist; therefore, contact investigations were delayed. The prison did not have a designated person or team assigned to TB infection control at the time of the outbreak, and although correctional staff received training on infection control on hire, ongoing TB training was not routinely offered.

Discussion

Failure to recognize TB symptoms, delays in TB diagnosis, inconsistent LTBI treatment, and prolonged congregation of inmates with infectious TB propagated this outbreak. *M. tuberculosis* transmission also occurred outside the prison when a former inmate was diagnosed with TB after release, and three people in the community, including two young children, developed TB disease. These findings exemplify the potentially dire consequences of lapsed TB control measures within a prison and their impact on the health of the general population.

Several other investigations have demonstrated transmission of *M. tuberculosis* from a correctional facility to the surrounding community (Ijaz et al., 2004; Jones et al., 1999; MacNeil et al., 2005; McLaughlin et al., 2003; Stead, 1978). One study in Memphis indicated that 43% of persons with TB in that city had been previously incarcerated in one urban jail (Jones et al., 1999). In 2004, more than 2 million persons were incarcerated in the United States (Bureau of Justice Statistics, n.d.), and the LTBI prevalence among inmates has been shown to be as high as 25% (CDC, 2006). In addition, correctional facility inmates have relatively high rates of HIV infection, which substantially increases the risk of developing TB disease in those with LTBI (CDC, 2005a, 2006). The combined impact of these factors thus poses a substantial risk to the general public.

The likelihood of transmission of *M. tuberculosis* in prisons can be minimized by the effective use of administrative TB infection control measures and early identification and treatment of persons with TB and LTBI (CDC, 2005a, 2005b). TB control measures include (a) designating responsibility for TB infection control to one person or group of persons for each correctional facility; (b) promptly transferring persons suspected of having infectious TB to airborne infection isolation; (c) providing TB training and education to employees, with specific focus on prevention, transmission, and symptoms; and (d) screening inmates and staff for TB and LTBI on entry into the facility, annually thereafter, and immediately following a known exposure (CDC, 2005b, 2005c). TB screening should include questions about TB symptoms and a baseline diagnostic test for LTBI (either two-step TSTs or an interferon-gamma release blood test; CDC, 2005b). Persons with LTBI who are eligible for treatment should receive 9 months of isoniazid to prevent TB disease, and those with TB disease should complete 6 to 9 months of a multidrug antituberculosis regimen. The average length of prison incarceration is long enough for most inmates to complete TB or LTBI treatment before release, and the supervised setting should facilitate the use of DOT (CDC, 2006). For persons released prior to treatment completion, provisions should be made by the health department to ensure their continuity of care (CDC, 2006).

This investigation demonstrates the usefulness of molecular epidemiology (i.e., genotyping) to define the extent of an outbreak. Many states, including Tennessee, perform universal genotyping on isolates from all patients with positive *M. tuberculosis* culture results. Genotype clustering of TB cases has been shown to correlate with recent transmission rather than reactivation of LTBI (CDC, 2005d; Small et al., 1994). Close monitoring of genotyping data to identify TB clusters in conjunction with surveillance for new TB cases or TST conversions can thus enable early recognition of increasing TB incidence.

The findings in this investigation are subject to the following limitations: Because baseline two-step skin testing was not performed for inmates at this prison, a positive TST result may represent remote rather than recent infection. For persons infected with HIV, a TST measurement of ≥5 mm is considered a positive result; because HIV status was not known for all those with a TST result of 5 mm to 9 mm, those with undiagnosed HIV infection would have been falsely classified as negative. In addition, not all inmate contacts were located or fully evaluated.

In response to this investigation, the Tennessee Department of Corrections and the Tennessee Department of Health have incorporated many positive changes, including strengthened collaboration between the two agencies, new procedures for timely reporting of suspected TB cases to the health department, appropriate use of airborne infection isolation, maintenance of TB infection control measures according to national guidelines, and provision of ongoing training to prison staff to promptly identify and report persons suspected of having infectious TB. Additionally, genotyping data and TST conversion rates are now routinely monitored.

In conclusion, without an effective TB infection control program, prisons can be reservoirs of TB, and therefore, these settings provide an important opportunity to diagnose and treat LTBI (Bandyopadhyay, Murray, & Metersky, 2002; MacNeil et al., 2005; Pelletier et al., 1993; White et al., 2002). Public health staff and correctional officials should collaborate to ensure effective use of TB control measures and appropriate treatment of patients on release to prevent *M. tuberculosis* transmission within prisons and to the community.

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