Transmission of *Mycobacterium tuberculosis* From Medical Waste

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Context Washington State has a relatively low incidence rate of tuberculosis (TB) infection. However, from May to September 1997, 3 cases of pulmonary TB were reported among medical waste treatment workers at 1 facility in Washington. There is no previous documentation of *Mycobacterium tuberculosis* transmission as a result of processing medical waste.

Objective To identify the source(s) of these 3 TB infections.

Design, Setting, and Participants Interviews of the 3 infected patient-workers and their contacts, review of patient-worker medical records and the state TB registry, and collection of all multidrug-resistant TB (MDR-TB) isolates identified after January 1, 1995, from the facility's catchment area; DNA fingerprinting of all isolates; polymerase chain reaction and automated DNA sequencing to determine genetic mutations associated with drug resistance; and occupational safety and environmental evaluations of the facility.

Main Outcome Measures Previous exposures of patient-workers to TB; verification of patient-worker tuberculin skin test histories; identification of other cases of TB in the community and at the facility; drug susceptibility of patient-worker isolates; and potential for worker exposure to live *M tuberculosis* cultures.

Results All 3 patient-workers were younger than 55 years, were born in the United States, and reported no known exposures to TB. We did not identify other TB cases. The 3 patient-workers' isolates had different DNA fingerprints. One of 10 MDR-TB catchment-area isolates matched an MDR-TB patient-worker isolate by DNA fingerprint pattern. DNA sequencing demonstrated the same rare mutation in these isolates. There was no evidence of personal contact between these 2 individuals. The laboratory that initially processed the matching isolate sent contaminated waste to the treatment facility. The facility accepted contaminated medical waste where it was shredded, blown, compacted, and finally deactivated. Equipment failures, insufficient employee training, and respiratory protective equipment inadequacies were identified at the facility.

Conclusion Processing contaminated medical waste resulted in transmission of *M tuberculosis* to at least 1 medical waste treatment facility worker.

JAMA. 2000;284:1683-1688 www.jama.com

MYCOBACTERIUM TUBERCULOSIS is usually transmitted when persons with pulmonary tuberculosis (TB) aerosolize bacteria by coughing, sneezing, speaking, or singing.[1] Susceptible persons inhale the aerosolized bacteria, which then can implant deep within the lung and establish infection. However, novel methods of transmission have been reported, for example, nosocomial infections resulting from the use of poorly cleaned, contaminated bronchoscopes[2,3]; infections due to the aerosolization of bacteria during vigorous wound[4] irrigation; disposal of peritoneal dialysate[5]; and autopsy[6,7] and embalming procedures.[8] To our knowledge, transmission of *M tuberculosis* as a result of processing medical waste has not been documented.

In 1997, Washington State had a TB incidence rate of 5.4 cases per 100 000 persons,[9] which was less than the national TB incidence rate of 7.4 cases per 100 000 persons.[10] Furthermore, multidrug-resistant TB (isolates resistant to at least isoniazid and rifampin) is uncommon in Washington State. Five or fewer cases have been reported annually during 1992-1997.[9] This report

For editorial comment see p 1701.

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summarizes an investigation of 3 TB cases reported from May through September 1997. All 3 patients lived in a county (population approximately 67 000) in Washington State that had a history of 3 or fewer cases of TB per year for the past decade,[9] and the patients had been employed as workers in a medical waste treatment facility. Our investigation sought to identify the source of the infections and to determine if exposure to medical waste resulted in the transmission of *M tuberculosis*.

METHODS

Investigation of Patient-Workers

We interviewed each patient-worker and reviewed their medical records to determine their previous exposures to TB and to verify their histories of tuberculin skin tests. We reviewed the state TB registry for 1996 and 1997 to identify other cases of TB in the community. We also matched the current and former (1996-1997) employee rosters of the medical waste treatment facility to the state TB registry to identify other employees diagnosed with TB.

Laboratory Investigation of Patient-Worker Isolates

We submitted *M tuberculosis* isolates from each of the patient-workers for susceptibility testing. Laboratory records and specimen handling methods were reviewed for all laboratories involved in processing the isolates to identify potential laboratory cross-contamination or mislabeling of specimens.[11] Representative isolates from each patient-worker underwent DNA fingerprinting using IS*6110*-based restriction fragment length polymorphism, according to published standards.[12] *M tuberculosis* isolates resistant to isoniazid, rifampin, and streptomycin collected from patients after January 1, 1995, from the catchment region of the medical waste facility (medical waste was received from Oregon, Washington, Idaho, and British Columbia) also underwent DNA fingerprinting. The DNA fingerprints from the patient-worker isolates were cross-matched with the Centers for Disease Control and Prevention, National Tuberculosis Genotyping and Surveillance Network regional laboratory database of *M tuberculosis* isolates.

To identify *M tuberculosis* drug-resistant mutations, regions of the RNA polymerase β subunit (*rpob*) gene and the entire pyrazinamidase (*pncA*) gene were amplified using polymerase chain reaction. The resulting amplicons were sequenced using an ABI 373XL automated DNA sequencer (Applied Biosystems, Inc, Foster City, Calif). The pan-susceptible strain *M tuberculosis* H_{37}Rv was used as a control. The sequences of the patient-worker isolates and the control strain were compared with the published sequences of these genes using the Sequence Navigator software (version 1.0.1; Applied Biosystems, Inc).

Investigation of Patient-Worker Contacts

We interviewed the household, social, and coworker contacts of the patient-workers and reviewed their medical records. All contacts underwent tuberculin skin test screening with 5 units of purified protein derivative.[13] Persons who had recent contact with a patient-worker underwent a second skin test 3 months after the last exposure. We defined a positive skin test result as 5 mm or larger induration and a tuberculin skin test conversion as an increase in induration of 5 mm or more compared with a negative test result within the previous 2 years.[13]

Environmental Investigations of the Medical Waste Treatment Facility

The Washington State Department of Labor and Industries Division of Industrial Safety and Health, Olympia, Wash, performed a safety and health evaluation of the facility and, subsequently, the National Institute for Occupational Safety and Health (NIOSH) evaluated the potential for occupational exposure to *M tuberculosis* from processing the medical waste. The investigators conducted walk-through surveys of the facility, interviewed employees, observed work practices, reviewed the facility's work and safety policies and procedures, met with local health care providers, reviewed employee medical records, and photographed and videotaped the plant's methods and procedures.[14,15] In addition, in their evaluation, the NIOSH team used a variety of environmental sampling methods to assess the potential for aerosolization of medical waste during processing.[14]

Investigation of Clinical Laboratory Waste Disposal Methods

To determine if worker exposure to live *M tuberculosis* cultures was possible, we conducted a telephone survey of all clinical laboratories in Washington State approved to perform acid-fast bacilli (AFB) testing. Personnel at each laboratory were questioned about types of diagnostic testing performed, current and past laboratory waste decontamination procedures, and waste disposal methods.[16]

RESULTS

Patient-Worker Investigation

All 3 patient-workers were white, US born, between the ages of 28 and 52 years old, and seronegative for the human immunodeficiency virus (HIV). All 3 worked at the medical waste treatment facility, for various amounts of time between 1992 and 1997. None of them had known exposures to any other persons with active TB, and none of the 3 had documented results of prior tuberculin skin tests. The first patient-worker identified (patient-worker 1) worked at the medical waste treatment facility for 4.5 years. Patient-worker 1 reported a productive cough in December 1996 and was evaluated for pneumonia in April 1997. Infiltrates and cavitary lesions were seen on chest radiograph, smears of sputum samples contained numerous AFB, and sputum cultures grew isoniazid-resistant *M tuberculosis*. Patient-worker 1 did not report other risk factors for TB infection.

Patient-worker 2 worked at the facility for 6 months. Patient-worker 2 described the onset of cough and fever

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during November and December 1996. After hearing of patient-worker 1's diagnosis, patient-worker 2 sought a tuberculin skin test in June 1997 and the results were positive (>15 mm). Chest radiographs revealed infiltrates, smears of sputum samples were positive for AFB, and sputum cultures grew *M tuberculosis* that was sensitive to all drugs tested. Patient-worker 2 had a history of incarcerations in a county jail and a psychiatric hospitalization but had not had previous tuberculin skin tests.

Patient-worker 3 worked at the medical waste facility for 2.5 years after reporting the onset of a productive cough at the end of July 1997. Patient-worker 3 was screened as an employee contact of patient-workers 1 and 2 and in August 1997, had a positive tuberculin skin test result (17 mm). The chest radiograph showed bilateral apical densities. Smears of sputum samples did not reveal AFB, but sputum cultures grew *M tuberculosis* that was resistant to isoniazid, rifampin, and streptomycin. Patient-worker 3 did not recall exposure to patients with active TB other than patient-workers 1 and 2. He had a history of substance abuse and underwent inpatient substance abuse treatment several years before but was not screened for TB at that time.

All 3 patient-workers were residents of the community for more than 7 years. The only cases of TB reported from the county for 1997 were these 3 patients. None of the former employees of the facility had been reported as having a case of TB.

Laboratory Investigation

After review of laboratory records and procedures of the 5 laboratories involved in processing the *M tuberculosis* isolates from the 3 patient-workers, no evidence of laboratory cross-contamination or mislabeling of isolates was found. The laboratory characteristics of isolates from each patient-worker are summarized in TABLE 1. The isolates from the 3 patient-workers showed different antimicrobial resistance patterns (Table 1), and their DNA fingerprints were distinct from one another (FIGURE). No isolates with matching fingerprints were identified from the National Tuberculosis Genotyping and Surveillance Network regional database.

Table 1. Laboratory Characteristics of *Mycobacterium tuberculosis* Isolates From Medical Waste Workers

Patient-Worker No.	Isolate Antimicrobial Resistance Pattern	DNA Fingerprint Characteristics
1	Isoniazid	19 bands*
2	None	15 bands
3	Isoniazed, rifampin, streptomycin	11 bands

*Bands refer to the number of IS*6110* hybridizing fragments in the restriction fragment length polymorphism pattern.

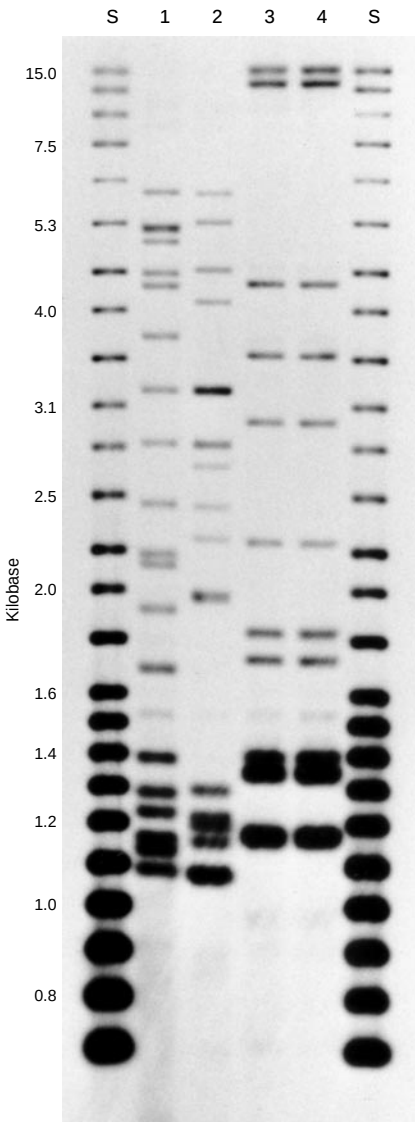
We identified 10 *M tuberculosis* isolates from the medical waste processing facility's catchment region with resistance patterns that matched the isolates from patient-worker 3 (ie, resistant to isoniazid, rifampin, and streptomycin. One regional isolate had a DNA fingerprint pattern that was identical to that from patient-worker 3 (Figure). Approximately 96% of rifampin-resistant *M tuberculosis* isolates possess a mutation within an 81–base pair region of the *rpob* gene.[17] The isolate from patient-worker 3 and the matching regional isolate both had the same mutation in codon 516 (GAC → GTC) resulting in the substitution of valine for aspartic acid. This particular mutation is found in approximately 6% of rifampin-resistant isolates.[17] The entire *pncA* gene was sequenced, and both isolates had the same silent mutation in codon 38 (GCG → GCC). Silent mutations do not change the amino acid sequence of the translated protein and are rarely seen in *M tuberculosis*.[18]

Patient-Worker Contact Investigation

We performed tuberculin skin tests for all patient-worker contacts (TABLE 2). No household contacts had positive tuberculin skin test results. One social contact had a positive skin test result; this contact had not had previous tuberculin skin tests but had a history of substance abuse. A follow-up chest radiograph showed no abnormalities.

All 29 employees (7 clerical and 22 waste workers) of the medical treatment facility were screened as co-

Figure. DNA Fingerprinting Analyses of *Mycobacterium tuberculosis* Isolates



S indicates molecular weight standard. DNA fingerprints of isolates from patient-worker 1 (lane 1), patient-worker 2 (lane 2), patient-worker 3 who had multidrug- resistant tuberculosis (lane 3), and patient with multidrug-resistant tuberculosis from the facility catchment region (lane 4).

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Table 2. Investigation of the Contacts of Medical Waste Workers Infected With Tuberculosis*

	No./Total (%)			
	Coworker Contacts			
Patient-Worker	Clerical Workers	Waste Workers	Household and Close Social Contacts	Total No. of Contacts per Patient-Worker
1	2/7 (29)	11/22 (50)	0/10 (0)	13/39 (33)
2†	. . .	. . .	0/7 (0)	0/7 (0)
3‡	0/5 (0)	0/9 (0)	1/17 (6)	1/31 (3)
Total	2/7 (29)	11/22 (50)	1/34 (3)	14/77 (18)

*No. of contacts with tuberculin skin test results greater than 5 mm divided by the No. of contacts tested. Ellipses indicate no contacts.
†Coworker contacts were included in patient-worker 1 contact investigation.
‡Coworker contacts for patient-worker 3 were also tested as contacts for patient-workers 1 and 2.

worker contacts of patient-workers 1 and 2 (Table 2). Ten workers had a positive skin test result, and an additional 3 had skin test conversions; 4 of these 13 workers had previous risk factors for TB. None of the 10 workers with positive tuberculin skin test results had had prior skin tests. All contacts with positive skin test results had normal chest radiographic findings.

Medical Waste Treatment Facility

The medical waste treatment facility began operating in January 1992. The facility received waste from hospitals, clinical laboratories, and medical and dental clinics in Oregon, Washington, Idaho, and British Columbia. The facility did not require incoming waste to be decontaminated prior to receipt and processing; the packaging and interstate shipping of the waste met published guidelines[19] and legal requirements.

The treatment facility is a 13 500-square-foot building with an 800-square-foot, 2-story steel-walled containment room located in the center of the plant floor where the processing equipment is located.[14,20] The containment room is designed to operate under negative air pressure relative to the plant floor. Waste workers perform their duties at various locations around the plant floor or in the containment room. A second-floor office space provides a work area for clerical staff.

Containers of waste are manually unloaded from delivery trucks onto a conveyor that delivers them to the in-feed station of the processing equipment. Containers are manually emptied into the in-feed chute and placed on another conveyor to be washed with steam or hot chlorinated water. The processing equipment shreds the waste and blows it through the system with fans, filling vessels with approximately 225 kg of waste. Shredded waste is compacted in the vessels by a hand-operated hydraulic press. The vessels are then manually capped and guided to a conveyor that delivers them to a radiofrequency oven that decontaminates the waste using a heating process referred to as "electrothermal deactivation." Processed vessels exit the containment room and are probed to determine a core temperature. Vessels not reaching a core temperature of at least 194°F (90°C) are returned to the oven for reheating. Processed waste is then hauled from the facility by truck to a landfill.

The 3 patient-workers performed different tasks, but they worked in close proximity to one another in the facility; all workers shared a common break room. Patient-worker 1 washed containers after they were emptied. Patient-worker 2 emptied containers into the processing equipment at the in-feed station and also provided assistance to patient-worker 3 numerous times throughout the day. In accordance with the facility's task-specific personal-protective equipment policy, respiratory protection was not required for the positions of patient-workers 1 and 2. Patient-worker 3 operated the hydraulic press within the sealed containment room while wearing a Tyvek suit, impervious shoes and gloves, and a supplied-air hooded respirator. All patient-workers worked with the waste prior to the electrothermal deactivation decontamination step.

Environmental Investigation of the Medical Waste Treatment Facility

A safety flap within the in-feed chute, which was designed to prevent waste from being thrown back onto the plant floor, had been missing for 2 to 5 years.[14,15] Employees reported that when the shredding equipment became clogged, waste particles reversed direction and vented from the in-feed chute onto the plant floor. Employees referred to this occurrence as "blowback." Employees did not consistently shower following their shift, nor did they decontaminate themselves when leaving the enclosed containment room.[14]

Employees did not fully understand the potential health risks (eg, needle injuries and waste spills) associated with exposures to medical waste nor did they report all such occurrences to supervisors.[14] Employees also reported uncertainty about the correct way to don and remove protective clothing, and they did not always wear it appropriately. The airline respirator system used inside the containment room did not meet the requirements for NIOSH approval. Workers reported they had responded to spills without respiratory protection, that they had repackaged contaminated waste, and that the doors between the contained processing equipment and the plant floor were left open during waste processing. The NIOSH evaluation documented the "blowback" phenomenon using smoke tubes and video equipment.[14]

Clinical Laboratory Waste Disposal

All 44 laboratories licensed to process AFB specimens in Washington State were surveyed by telephone. Forty-one laboratories (93%) sent all waste to an off-site medical waste disposal company, including the facility where the 3 patient-workers worked. Three laboratories (7%) incinerated all or nearly all waste on site. Of the 41 laboratories that contracted for

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off-site waste disposal, 21 (51%) performed some decontamination on site. However, 20 laboratories (49%) did not decontaminate laboratory waste, including stocks and cultures, prior to shipment. Nineteen (95%) of these laboratories shipped waste to processing facilities and 1 (5%) to a landfill.[16]

Traceback Investigation

The regional isolate that matched the isolate of patient-worker 3 was from a patient who was foreign-born, had immigrated to the United States in 1994 and had known exposures to multidrug-resistant TB. This patient underwent testing for symptoms consistent with TB in early 1996. At that time, an aspirate specimen collected from a cutaneous lower limb lesion was culture-positive for *M tuberculosis*; lung biopsy and bronchoalveolar wash specimens were AFB smear- and culture-negative. There was no evidence of infectious pulmonary disease.

The laboratory that handled the matching isolate had contracted exclusively with the medical waste treatment facility for waste removal since August 1992. Furthermore, the laboratory did not decontaminate cultures of *M tuberculosis* with growth on solid media prior to discarding them as medical waste. A solid media culture with growth of the matching isolate was discarded in mid-1996 from this laboratory. Specimens from patient-worker 3 were never processed in this laboratory.

Patient-worker 3 and the patient with the matching isolate were interviewed. Personal contact between the 2 patients was not identified; they lived more than 60 miles from one another and had lived within their respective communities for more than 3 years. The patients did not have common workplaces, hobbies, social groups, or medical care providers.

COMMENT

To our knowledge, this report is the first to document transmission of *M tuberculosis* from occupational exposure to infectious medical waste. Five lines of evidence from this investigation support this conclusion.

First, no evidence indicated that transmission to the 3 medical waste workers occurred as a result of exposure to cases occurring in the community. DNA fingerprinting data also excluded the possibility that transmission occurred from one patient-worker to another.

Second, an unusually high percentage (45%) of the coworker contacts of the 3 patient-workers had positive tuberculin skin test results, especially considering there was no evidence that patients transmitted TB to their household contacts.

Third, in Washington State, 49% of laboratories routinely shipped viable *M tuberculosis* cultures to medical waste disposal facilities, including this facility, despite Centers for Disease Control and Prevention recommendations to decontaminate such material prior to disposal.[19]

Fourth, the environmental investigations of the facility support the plausibility of workers being exposed to contaminated waste in ways that put them at risk for infection. One study reported that bacteria (eg, *Bacillus subtilis* var *niger*), particularly dry spores, added to the waste prior to processing were released from equipment during the compaction process.[21] Therefore, all workers in the processing area of the plant may have been exposed to aerosols released from the shredding process.

Finally, an isolate from patient-worker 3 had a DNA fingerprint pattern that was identical to the pattern for an isolate from a patient whose only relationship to this outbreak was exposure to the medical waste stream. That these 2 isolates also share rare mutations increases the likelihood that both patients were infected with the same organism. The patient whose isolate matched patient-worker 3's isolate did not have infectious pulmonary TB, and there was no evidence of contact between them.

A substantial percentage (45%) of the coworker contacts had positive (11-40 mm) tuberculin skin test results. The level of TB infection in this study is 3 to 4 times greater than the prevalence for funeral service industry employees (11.7%),[22] an occupational group previously identified to be high risk for clinically active TB.[23] However, it is unknown to what extent exposure to infectious medical waste played a role in this finding. The 3 persons with documented tuberculin skin test conversions may have been infected by patient-worker 1, who worked for several months while infectious. The coworkers with skin test conversions also had brief contact with patient-worker 2 while potentially infectious. Four of the persons with positive skin test results acknowledged risk factors prior to the outbreak that increased their potential for exposure to TB.

This investigation revealed that infectious laboratory waste (eg, stocks and cultures) are frequently discarded into the solid medical waste stream in Washington State. Our survey was limited to Washington State; this finding may not be true for other states. Medical waste was identified as the source for patient-worker 3's infection only because he was infected with an organism with a rare pattern of drug resistance that limited the number of possible sources. Because multidrug-resistant TB rarely occurred in the treatment facility's catchment region, cultures had been banked since January 1995, permitting comparison of DNA fingerprints from these isolates with the one from patient-worker 3. This approach was not possible for the more common isolates from the other 2 patient-workers.

Documented results of previous tuberculin skin tests were not available for patient-workers 1 and 2 or for their coworker contacts. These results would have allowed estimation of when their exposures occurred. The possibility that these patient-workers developed TB from previous infections cannot be excluded. However, based on the annual incidence of TB in Washington State (5.4 cases/100 000 persons), we would expect 0.0017 cases of TB annually among 32 workers.[9] Therefore, the probability of observing 3 cases in 1 year by chance is less than 0.000001.[24]

The findings of this investigation lead to several recommendations. First, laboratories should review their

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policies and procedures for disposal of viable *M tuberculosis* stocks and cultures. To minimize the risk of infection for medical waste workers, stocks and cultures should be decontaminated by autoclaving or other approved methods prior to disposal, preferably within the laboratory where they are generated.[19] Ideally, medical waste treatment facilities should not accept contaminated laboratory waste. Facilities that do accept contaminated waste should consider deactivation of contaminated stocks and cultures as the first step in processing waste. Engineering controls that prevent employee exposure to potentially infectious waste need to be adopted by medical waste treatment facilities. In addition, medical waste workers need extensive and ongoing safety training. Such training should include general infection control principles, personal protective equipment use, and techniques for responding to waste spills. This training will help employees recognize situations that put them at risk for exposure to potentially viable pathogens. Medical waste workers who are employed at facilities that accept contaminated waste should be considered for routine screening for TB.

Previous Presentations: Portions of this study have been presented at the 48th Annual Conference of the Epidemic Intelligence Service, April 19-23,1999, Centers for Disease Control and Prevention, Atlanta, Ga;and by invitation at the Northwest Occupational Health Conference, October 1998, Seattle, Wash.

Acknowledgment: We thank Donna Osmond, MS, John Kobayashi, MD, MPH, and Richelle Peterson, RN, Washington State Department of Health, Olympia and Seattle; Sheila Bowers, RN, and Susan Bland, RN, Lewis County Health Department, Chehalis, Wash; Mary Miller, RN, and Margaret Cunningham, RN, MSN, MPH, Washington State Department of Labor and Industries.

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