A Preventable Outbreak of Tuberculosis Investigated through an Intricate Social Network

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In 1998, a city in Indiana reported a 4-fold increase in the number of cases of tuberculosis (TB). An investigation to assess the increase in cases and to identify possible epidemiologic links among persons with TB identified 41 cases of active TB. Epidemiologic links and/or matching DNA fingerprints were identified for 31 patients (76%). The majority of these patients were members of a single social network within the community. Links for most of these patients were identified after multiple interviews with patients and their contacts. TB control activities in the county were limited prior to the identification of the outbreak. At least 24 cases may have been preventable. This outbreak may have been prevented with prompt case identification and effective contact tracing and screening during the years before the outbreak. The use of social networks should be considered in the investigation of outbreaks that involve difficult-to-reach populations. TB control measures should be maintained in areas with historically low TB incidence.

Since the resurgence of tuberculosis (TB) in 1985, numerous outbreaks of TB have been reported in hospitals, prisons, factories, and schools [1–7]. Outbreaks in well-defined settings like these represent controlled environments for implementation of TB control activities, because the site of transmission, as well as the identities of the source case and potentially exposed persons, are known. In contrast, outbreaks of TB in communities may prove to be more challenging for even the most adept TB programs, because source cases may be elusive, contacts may not be identified by cases, and multiple chains and sites of transmission may occur before the outbreak is detected [8, 9]. In addition, discovering epidemiologic links among nonhousehold or social contacts proves difficult, particularly when relationships among patients involve illicit activities. In community outbreaks, novel approaches to TB control, such as the use of social networks, may help both to determine epidemiologic links among cases and to identify high-risk contacts.

In February 1999, we began an investigation of an outbreak of TB in a community in Indiana. The community is an industry-based urban city in northwestern Indiana with a population of 34,000; 75% of the inhabitants are white, 23% are black, and 2% are Asian. The community traditionally had a low TB case rate (6–8 cases per 100,000 population) until 1996, when the TB case rate increased to 15 cases per 100,000 population. Health department officials first noticed an increase in the case rate in late 1997, when the rate increased to 27 cases per 100,000 population. By February 1998, the case rate increased to 57 cases per 100,000 population. The results of DNA fingerprinting of Mycobacterium tuberculosis isolates from several cases were identical. State officials then alerted the local health department to these findings. At the time of the outbreak, local public health personnel had no formal training in TB control or epidemiology. The 4-fold increase in case rates led to serious deficiencies in manpower and re-
sources at the local health department, because personnel duties were suddenly amplified by the urgent need for TB control. To complicate this situation further, the outbreak was associated with transmission at multiple sites, and a definitive source case for the outbreak had not been identified.

The complexities seen in this outbreak are not unique to outbreaks of tuberculosis. For many years, sexually transmitted disease (STD) investigators have encountered similar obstacles in detecting source cases and obtaining critical contact information. The transmission of STDs shares many of the social dynamics involved in TB transmission. However, STD investigators have successfully used social network analysis to identify prominent sources of disease transmission and to control the spread of disease [10]. Because infectious diseases, such as TB, gonorrhea, and HIV, share commonalities in social and clinical barriers (i.e., issues regarding transient and disenfranchised target populations, compliance, and medical follow-up), the social network methods used in STD control should also be suitable for the control of TB transmission.

This report of our investigation highlights the importance of maintaining TB control programs in areas with traditionally low TB case rates and the challenges of TB control when outbreaks involve an intricate social network and multiple sites of transmission.

MATERIALS AND METHODS

Case finding and confirmation. To identify unreported cases of TB and confirm reported cases, we reviewed laboratory mycobacteriology logs for persons with positive M. tuberculosis cultures. We reviewed hospital emergency department rosters for TB suspects and patient admission and discharge TB diagnosis codes for 1996–1998. We also obtained hospital pharmacy listings of persons who were taking antituberculosis medications from 1996 through 1998. We cross-matched these logs and rosters with a listing of persons on the TB registry at the local health department.

Case review. We reviewed medical and health department records of all TB cases from 1996 to June 1999, and we interviewed patients who were available. In addition, we interviewed local physicians, nurses, and health department personnel to obtain additional information regarding treatment of patients and the patients’ epidemiologic links to other outbreak cases. We reviewed directly observed therapy (DOT) logs and pharmacy logs at the health department.

Contact investigation. A TB case was considered to have an epidemiologic link if there was known contact with another TB case or if the case was a member of the identified social network. Interviews were conducted with available cases and family members to establish links between cases and contacts.

Contact tracing records and tuberculin skin test (TST) logs were reviewed.

Laboratory investigation. DNA fingerprinting that used standard IS6110 restriction-fragment length polymorphism was performed on available isolates recovered from cases who had culture-positive TB diagnosed from late 1997 to 1999 [11]. Isolates collected before late 1997 had been discarded and were unavailable for DNA fingerprinting. All fingerprinting was performed by the Michigan Department of Community Health Laboratory in Lansing, which is a member of the Centers for Disease Control and Prevention National Tuberculosis Genotyping and Surveillance Network. Cases were considered to be laboratory linked if isolates had a DNA fingerprint pattern identical to the outbreak strain.

RESULTS

Cases. The number of TB cases per year from 1990 to 1999 is shown in figure 1; 41 TB cases were reported from 1996 through October 1999. Of these, 4 cases were not linked to the outbreak: the isolate recovered from 1 person had a discordant DNA fingerprint, and 3 persons had known source cases outside of the community, but no isolates were available for fingerprinting for these 3 cases. Of the remaining 37 potential outbreak-related cases, 24 (65%) were male, 32 (86%) were black, all had been born in the United States, and the median age was 39 years. Twenty-eight cases (76%) were HIV negative, 2 were HIV positive, and 7 had unknown HIV status.

Thirty-one (84%) of the 37 potential outbreak-related cases were confirmed to be outbreak related. An outbreak-related case was associated with the outbreak by a known epidemiologic link,
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Figure 2. Epidemiologic links for 31 patients according to age and sex. *, Possible source case; circles, females; squares, males; unshaded symbols, fingerprint matches outbreak strain; shaded symbols, epidemiologic link only; solid line, link determined by means of traditional contact tracing methods; dashed line, link established through social network investigation. Numbers within geometric shapes indicate age in years.

a DNA fingerprint matching the outbreak strain, or both. No epidemiologic link or DNA fingerprint could be established for 6 of the 37 potential outbreak-related cases. Of the 31 confirmed outbreak-related cases, 16 (43%) had an epidemiologic link and matching DNA fingerprint, 13 (35%) had epidemiologic link only and the isolates had been discarded, and 2 (6%) had a matching DNA fingerprint and no epidemiologic link. Six patients had unknown epidemiologic links and no isolate was available for DNA fingerprinting. Twenty-nine of the 31 cases were culture confirmed. All isolates of M. tuberculosis were susceptible to first-line antituberculous agents. Twenty-nine cases completed treatment, 1 person died of TB, 1 person died of a separate illness during TB treatment, and 6 cases were still receiving therapy at the time of the investigation.

At least 6 cases that were not diagnosed and treated in a timely manner. All 6 cases had abnormal findings on chest radiographs documented prior to their diagnosis of TB, but TB was not suspected until late in their illness. Two of these 6 patients were evaluated by physicians for cough and fever but were treated for community-acquired pneumonia. Both patients presented 6 months later with advanced TB and were sputum smear-positive at diagnosis. A review of patient hospital records revealed that 5 patients with suspected TB initially received inadequate antituberculous therapy. Two of these 5 patients were initially treated for latent infection with isoniazid alone, pending the outcome of laboratory results, and 3 patients were initially treated with isoniazid and rifampin only, rather than the recommended 3- or 4-drug therapy [12].

No source patient was identified who accounted for all potential outbreak-related cases. However, a 1991 case was named as a contact by several cases and potentially accounted for 22 (71%) of the known outbreak-related cases (figure 2). This case initiated treatment for active TB in 1978, but there was no isolate available for DNA fingerprint analysis and no contact investigation was conducted for this case.

Transmission and social networks. From information discovered through interviews with patients and contacts, we deduced that transmission among patients occurred in congregate social settings, including an apartment complex, a junkyard, a local bar, and a liquor store, because these were named by patients as areas of frequent social gathering. Common activities at these places included use of drugs and alcohol. One patient’s apartment was a well-known place for social gatherings. The junkyard contains a ∼10 × ∼10 m building that at different times has been used as a primary dwelling and for various social purposes, including prostitution. At least 1 patient with TB listed the junkyard as a primary place of residence.

The discovery of epidemiologic links among patients was not straightforward. Only 8 adult cases initially provided names of contacts with TB to the health department. Three patients were children who had source-case investigations performed. Through retrospective questioning of cases and their contacts, we determined that 29 (94%) of the patients with known outbreak-related cases knew, either directly or indirectly, another outbreak case. Epidemiologic links for 18 cases (58%) were only discovered through complex social networks (figure 2). Although all of the 1999 cases had DNA fingerprints that matched the outbreak strain, no epidemiologic links were discovered among these cases;
all but 2 of the cases that presented in 1999 had an epidemiologic link to ≥1 cases from previous years.

The illicit activity and clandestine social network of some patients presented a barrier to obtaining pertinent contact information. For example, a 16-year-old male patient who presented in 1998 (figure 2) had a DNA fingerprint that matched the outbreak strain, but he did not provide adequate contact information to determine an epidemiologic link to other outbreak cases. He denied a known exposure to TB. In 1999, a 15-year-old female patient had active TB diagnosed. Her contact investigation revealed that the aforementioned 16-year-old male patient was her boyfriend and that they frequently purchased drugs from a 44-year-old patient who had TB diagnosed in 1998 and who lived at the apartment complex, which was one of the suspected areas of transmission.

In addition, the 59- and 77-year-old male 1998 cases lived in the same assisted-living complex and had known matching DNA fingerprint results but no epidemiologic links to other cases. A relative of the 77-year-old patient named a female commercial sex worker who made frequent home visits to both patients from 1996 to 1998. The commercial sex worker had TB diagnosed in 1996 and had no contact investigation performed initially. In 1998, a contact investigation was performed for the commercial sex worker, but the men were not named as contacts.

Twenty-four (77%) of the 31 known outbreak-related cases may have been prevented. For 12 patients (50%), no contact investigation was conducted for their source case, so there was no opportunity for these patients to be identified as a contact. Nine patients (38%) were not named as contacts during their putative source’s contact investigation. Two patients (8%) had source cases that were not identified earlier during contact investigations, and 1 person who had renal disease and who was undergoing dialysis was immunocompromised and had a negative skin test result at the time of screening after exposure to a person with active TB. This person should have received treatment for latent TB infection (LTBI). In addition, one of the patients who had no opportunity to be identified as a contact had a prior positive TST result and did not receive preventive therapy, presumably because he was >35 years of age.

*TB control and contact tracing.* At the time of the outbreak, the local health department was staffed by 4 full-time and 2 part-time nurses and a nursing supervisor, all of whom were white and native to the community. Daily public health activities included a variety of public health interventions: childhood immunizations; environmental health issues, such as lead poisoning; HIV testing; and, occasionally, STD assessments. Prior to 1997, there was minimal TB control activity in the community. Contact investigations were not performed regularly, and there was no consistent administration of treatment for latent infection. Organized TB control with performance of contact investigations and DOT for patients with TB did not begin until May 1997.

Progress during contact investigations was hampered by the failure of patients to provide the names of social contacts. Patients freely revealed the names of household contacts as well as the locations of their workplaces; however, they were not forthcoming about social contacts because of the types of illicit activity occurring within their social network and their concerns regarding anonyminity. In addition, the community involved in the outbreak did not realize that the public health department was a separate and distinct entity from law enforcement agencies, and they did not understand the health department’s role in controlling the outbreak. As a result, many epidemiological links among patients and infected contacts were not identified because of the reluctance of patients to cooperate in naming contacts.

Records for contact investigations conducted from May 1997 to November 1999 for 18 (49%) of the 37 potential outbreak cases were available for review. There were 445 contacts identified around the 18 cases, including 247 named contacts, which consisted of family members and household contacts, and 198 persons from 2 workplace screenings. Because the patients with TB at both workplaces worked in large, open areas with little direct or close contact with other persons, the risk of transmission was low. Chest radiographs were performed on all contacts who had a positive skin test result (≥5 mm). No additional cases of TB were found during contact screenings.

A targeted skin test screening was later performed at the junkyard. The junkyard was considered to be a place with a high-risk of exposure, because many patients reported associating with persons who visited the facility frequently. A comparison of the skin test screening results for named contacts, persons at the workplaces, and persons at the junkyard is shown in table 1. The positivity rate of 55% among named contacts was higher than the rate of 3% at the workplaces (OR, 33.7; P < 0.0001). The results of the junkyard screening revealed a skin test positivity rate of 42%, which was also considerably

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Named contacts</th>
<th>Persons in the workplace</th>
<th>Persons in the junkyard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identified</td>
<td>247</td>
<td>198</td>
<td>25</td>
</tr>
<tr>
<td>Screened</td>
<td>142 (57)</td>
<td>173 (67)</td>
<td>19 (76)</td>
</tr>
<tr>
<td>TST positive</td>
<td>78 (55)</td>
<td>6 (3)</td>
<td>8 (42)</td>
</tr>
<tr>
<td>Isoniazid therapy</td>
<td>Initiated 50 (64)</td>
<td>2 (33)</td>
<td>5 (63)</td>
</tr>
<tr>
<td>Completed</td>
<td>44 (88)</td>
<td>Unknown</td>
<td>5 (100)</td>
</tr>
</tbody>
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NOTE. TST, tuberculin skin test.
higher than that in the workplace (OR, 20.2; P < 0.0001). The positivity rate at the junkyard was similar when compared with that of the named contacts (OR, 1.32; P = 0.562). Health department personnel were able to achieve an 88% completion rate for treatment of latent infection in the named-contacts group.

DISCUSSION

This was a preventable outbreak that was responsible for at least 76% of the TB cases that were reported in a low-incidence area, and it illustrates the necessity of establishing and maintaining effective TB control programs in local health departments [13]. Many communities in the United States have a TB incidence that is equal to or lower than the national rate of 6.8 cases per 100,000 population [14], so expertise and experience in TB control and case management may be limited in these areas. In addition, local health departments are responsible for a variety of public health issues, and budget constraints often mandate that diseases with higher incidence receive higher priority. The repercussions of this oversight become apparent when TB is quiescent for several years and health care personnel become complacent about TB. As a consequence, the infrastructure for TB disease control deteriorates, and a slow but steady increase in local TB case rates may proceed undetected for several years and culminate in a preventable outbreak, as was seen here.

Inattention to 3 crucial areas of TB control fueled this outbreak. First, persons suspected of having TB were not identified and treated in a timely manner. Although the health department bears little responsibility for identification of persons suspected of having TB, the decreased awareness of TB in the medical community contributed to years of ongoing transmission within the community. As a result, the infected pool of individuals within the community gradually increased until new cases began to emerge.

Second, because health department personnel were not trained in TB control, contact investigations were not targeted to identify those persons at highest risk of infection with M. tuberculosis; therefore, those individuals who were screened initially (named contacts and persons at the workplaces) were not at the highest risk of infection. The results of the screening at the workplaces illustrate the need for targeted skin test screening, given the striking differences in skin test positivity rates when compared with those of named contacts and contacts at the junkyard. Traditionally, household contacts, followed by individuals within the workplace, hold the highest priority when identifying persons at risk for TB infection. However, in this outbreak, social contacts had exposure risks that were equal to or greater than those of household contacts, because many social contacts had extensive and often close contact with persons who had TB.

The last major area of deficiency in TB control that contributed to this outbreak was the delinquency in initiating treatment for latent TB infection and follow-up of infected contacts. Soon after the outbreak was identified, some infected contacts were not consistently followed-up and offered treatment for LTBI. In contrast, several months into the outbreak and after reorganization of the health department, personnel efficiently identified new cases of TB, administered treatment for LTBI, and were instrumental in halting the outbreak.

When the initial increase in the TB case rate was identified, a social network approach to contact investigations would have been helpful in identifying contacts and halting the outbreak. The role that social networks play in disease transmission has been studied extensively in STD control, and this approach has been used with some success [15, 16, 17]. It has been shown that failure to consider unnamed contacts leads to missed cases of disease. Disease control in the context of social networks requires identification of groups of persons who share similar social settings and mores with infected persons. Once these groups are identified, testing and treatment is offered not only to the infected person and the few named contacts, but to the entire network. This approach improves rapport with clientele, helps eliminate stigma, and identifies persons who may have otherwise been missed. Adoption of this approach requires the willingness of health department personnel to become highly visible within the outbreak community. In this outbreak, this type of relationship was necessary to establish the rapport needed to secure valuable contact information and ultimately was very successful in decreasing TB case rates within the community.

Initially, the racial and cultural dissimilarities between health department personnel and the outbreak community created a barrier to TB control efforts. Despite this obstacle, health department personnel were persistent in their attempts to communicate with the outbreak population and increased their visibility within the community. Their efforts aided tremendously in penetrating the social network of persons with TB, and, as a result, members of the outbreak community began to understand the goals and functions of the health department. Increased cooperation from patients and contacts, as well as improvements in TB control activities, led to halting the outbreak. TB case rates within the community appear to be on the decline.

Our initial recommendations to the local and state health departments were focused on measures that would halt the outbreak. Because there were likely to be more active cases in the community, we recommended continued active case finding and targeted skin testing in high-risk areas like the junkyard, including, but not limited to, local bars, corner stores, and the “popular” apartment complex. Although targeted testing is in-
tended primarily for the identification of infected persons, this method can expose additional active cases of TB within the community and might prove useful in an acute outbreak setting [12, 18]. In addition, we recommended expanded contact investigations for persons with TB who have high percentages of infected contacts, and we recommend treatment for latent TB infection for any persons who had previously been screened and found to have infection with M. tuberculosis, but who were not started on therapy.

This outbreak demonstrates the need for adopting novel methods of TB control, such as a social network approach, particularly in hard-to-reach populations. TB case rates in the United States are the lowest ever. As TB case rates continue to decrease in this country, and as the burden of disease is concentrated in disenfranchised communities, like the one described in this article, specific efforts and strategies that target these populations are imperative to achieve the national goal of TB elimination. The use of social networks will assist health departments in early case identification and expedient control of future outbreaks, as well as significantly bolster our efforts toward eliminating TB. The lessons we learned from this outbreak can set a precedent for the future of TB control in the United States.

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References