Epidemiology of a Tuberculosis Outbreak in a South Carolina Junior High School

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Abstract: A 13-year-old, female, seventh-grade student (the index patient) was found to have smear-positive, cavitary, pulmonary tuberculosis. Epidemiologic and contact investigation, involving skin testing over 900 people, revealed a 40 per cent tuberculin reactor rate for persons in the junior high school she attended compared to a 2 per cent rate for control schools. Repeat skin testing of initial non-reactors identified an additional 3 per cent of infected school children. School teachers showed a seven-fold increase in the prevalence of positive skin-test reactions following the outbreak. Tuberculin-reactor rates for seventh graders were substantially higher than for eighth graders. The more classes shared with the index patient, the higher the probability of being a reactor. Among students who shared no classes with the index patient, the highest rates of tuberculin reactions were found for those who had entered a classroom immediately after the index patient had left it. Evidence of transmission on the school bus and in the church choir was also suggested. Six secondary cases (three pulmonary) resulted from the outbreak. Identical phage types from the index and secondary patients suggest that this was a common-source outbreak. Follow-up of students who had left school during the term proved useful in determining when transmission began. The index case was found to be a missed contact of a previously identified case of tuberculosis. Since household contacts are at high risk for developing active disease, there is a need for meticulous and complete investigation and preventive therapy for all such persons, especially children. (*Am J Public Health* 1985; 75:361–365.)

Introduction

Reports of tuberculosis outbreaks in public schools or other institutions for the young (e.g., summer camps, private schools, etc.) have become increasingly uncommon in the past two decades.[1-14] Fewer than 5 per cent of cases now reported in the United States occur in school-age children.[15] An outbreak of tuberculosis in a school provides an unusual opportunity to study factors associated with exposure and transmission, since the whereabouts of students during school hours can be readily ascertained and, in most communities, young people are susceptible to infection. This report summarizes an unusual outbreak in which a rural South Carolina seventh-grade student with infectious cavitary, pulmonary tuberculosis was implicated as the source of infections in 40 per cent of the junior-high-school student body. Epidemiologic and contact investigation suggested that classrooms were the primary site of transmission.

Background

The index case, a 13-year-old, Black, female, seventh-grade student, had been well until late November of 1980 at which time she developed a progressive, chronic cough and increasing fatigue. By January of 1981, weight loss, malaise, dyspnea, and chest pain were also noted and she left school on January 30. On February 6, 1981, she was hospitalized. An intradermal, five-tuberculin unit, purified protein derivative (5TU-PPD) skin test gave a 15 mm reaction. A chest x-ray film revealed mutliple cavities in the right upper-lobe of the lung, and sputum smears showed numerous (4+) acid-fast bacilli. Chemotherapy with isoniazid, rifampin, and ethambutol was begun, and the patient rapidly improved. Cultures of the sputum subsequently grew *Mycobacterium tuberculosis,* and drug susceptibility tests revealed that the organism was sensitive to all the commonly used antituberculous drugs.

The index patient had had a negative tuberculin skin test at the age of six. Two years later, in 1975, her paternal grandmother developed cavitary pulmonary tuberculosis. The index patient and her family had frequent exposure to the grandmother, but were not investigated as contacts because they did not live in the same household as the grandmother. In May 1980, the index patient came to the health department, was skin tested, and developed a 15 mm reaction. Although the mother was advised to bring in her daughter for a follow-up chest x-ray film and to be evaluated as a candidate for preventive therapy, they never returned.

During the 1981 contact investigation, the eight members of the immediate family were examined, and all eight were tuberculin reactors. Since two of the index patient's siblings were born after the grandmother was considered cured in 1977, their infection could not be attributed to the grandmother. Of ten other close family contacts examined, nine (90 per cent) were tuberculin reactors, and none had had contact with the grandmother.

The index patient attended a school for seventh- and eight-grade students. Built in 1960, it has 24 classrooms, a gymnasium, and a cafeteria. Several trailers are used as additional classrooms. Each school class period lasted 50 minutes except for a 20-minute homeroom period. The school does not have a central ventilation system. Seventh and eight graders do not share classes, have separate lunch hours, and are together only at monthly school meetings. In late March, 491 students attended the school. The index patient rode a school bus and also sang in a church choir.

In the five years prior to the outbreak, 56 cases of tuberculosis had been reported among county residents, 54

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per cent of which were from this city. Only one of these cases was in a child under the age of 16. In the county's population of 38,161, there were approximately 2,107 individuals between the ages of 12 and 14 (junior-high-school age).

Methods

Students, school staff, school bus riders, and church choir members potentially exposed to the index patient were examined according to standard guidelines for the investigation of tuberculosis contacts[16] and skin tested in March and April 1981. Skin testing was done with Aplisol® by Parke-Davis* by the Mantoux method using 5TU-PPD applied to the volar surface of the forearm. Tests were read once 48–72 hours after administration. Those with reactions measuring <5 mm of induration were retested two to three months later. Persons with ≥5 mm of induration were considered reactors.[17] All reactors had a chest x-ray film taken. School staff pre-employment skin tests records were reviewed.

Direct exposure to the index patient was defined as sharing an airspace such as a classroom or bus; indirect exposure was defined as entering an airspace shortly after the index patient had left. Two students who were known to have been tuberculin reactors prior to the outbreak were excluded from the subsequent analysis, as were a sibling of the index patient who attended the same school and two students who were not skin tested. Follow-up was sought on 32 students (dropouts, transfers, expellees) who had left school prior to the investigation.

Sixth-graders who were to enroll in the junior high the following year and ninth-graders who had attended the junior high the previous year were also skin tested in late 1981. County health department records concerning all tuberculin screening during the period 1979–80 were reviewed.

Medical records of all identified subsequent (i.e., secondary) patients with clinical ilness were reviewed. Available isolates of *M. tuberculosis* from the index and two secondary patients were submitted to the mycobacteriology laboratory of the Centers for Disease Control for phage typing.[18]

Results

School Children

Of the 486 junior high students tested, 195 (40 per cent) were tuberculin reactors; 190 (97 per cent) were identified on the initial testing, five (3 per cent) on the repeat skin testing of 296 students. The mean reaction size for students was 16.4 mm.* There was only one reaction in the 5–9 mm range (9mm).

The reactor rate for junior high students (195/486 positive) was substantially higher than that observed for the sixth-grade children (4/224, positive) and ninth-graders who had attended the junior high the previous year (3/119 positive) or those 5–14 years of age who had been routinely tuberculin tested at the county health department in 1979 and 1980 (17/978 positive).

Seventh graders had a much higher reactor rate (59 per cent) than eighth graders (20 per cent). There were no important differences in reactor rates by sex or race (Table 1). The reactor rate for students who shared a classroom with the index patient (Table 2) was appreciably greater than the rate for students who had no exposure to her (81 per cent versus 20 per cent). Among seventh graders, 25 per cent of students with no exposure to the index patient were reactors, but all of those who shared three or more classes with her were infected. Sharing only one of two classes constituted an intermediate risk. The reactor rate for students with indirect exposure to the index patient was 34 per cent (30/88). The reactor rate for students with no direct or indirect contact was much lower (20 per cent, 52/259).

Of the 195 reactors, 102 (52 per cent) shared at least one class with the index patient. Of the other 93 reactors, 30 entered a classroom which the index patient had just vacated (indirect exposure). Among the remaining 63 reactors, 10 (16 per cent) either rode a bus with the index patient or sang in a church choir with her. A site of exposure for the remaining 53 reactors (19 seventh graders, 34 eighth graders) could not be determined.

Students who shared the rooms used in period 1, 2, and 5 had 100 per cent reactor rates. The rooms used by the index patient in periods 2 and 5 (associated with the greatest risk to concurrent classmates) were also associated with the highest risk to students who would enter those rooms during the succeeding class hour (41 per cent and 55 per cent reactors).

Of the 32 students who had left the junior high school prior to the contact investigation, 21 were skin tested. The reactor rate for the group leaving school after the index patient's onset was 47 per cent (7/15). The reactor rate for those leaving school before onset in the index patient was 0 per cent (0/6).

School Bus and Choir Contacts

The index patient rode a school bus with 29 others (excluding her brother and the driver who was known previously to be a tuberculin reactor). Seventeen (59 per cent) of these students were tuberculin reactors. Of the 17 students who had no other direct or indirect exposure to the index patient other than on the school bus, eight (47 per cent) were reactors. This reactor rate was significantly higher than the rate (20 per cent) for those students who had no known exposure to the index patient (Table 2).

The index patient sang in a church choir which met once a week for one hour. Eleven of the 17 members in the choir were skin tested and seven (64 per cent) of them were tuberculin reactors. Of these eleven tested, only three had had no contact with the index patient other than in the choir and two (67 per cent) were reactors (Table 2).

TABLE 1—Tuberculin Skin Test Positivity by Grade, Race, and Sex, Outbreak Junior High School, South Carolina, 1981

	Grade					
	7th		8th		Total	
Race/Sex	No. Tested	% Positive	No. Tested	% Positive	No. Tested	% Positive
Female	124	58	109	26	233	43
Male	124	61	129	16	253	38
Black	120	66	109	20	229	44
White	128	53	129	20	257	37
TOTAL	248	59	238	20	486	40

*Use of a trade name does not constitute endorsement by the US Department of Health and Human Services, the US Public Health Service, or the South Carolina Department of Health and Environmental Control.

**The distribution of reaction sizes were 10–14 mm = 63 (32%), 15–19 mm = 85 (44%), 20–24 mm = 38 (19%), 25–29 mm = 5 (3%), and ≥30 mm = 4 (2%). The largest reaction size was 60 mm.

TABLE 2—Tuberculin Skin-Test Positivity Rates, by Group and Site of Exposure, Outbreak Junior High School, South Carolina, 1981

Site(s) of Exposure	Group	Type of Exposure	Skin Test No.	Skin Test % positive
School	Grade 7	None	73	25
		Indirect*	46	48
		Direct†	118	81
		1 class shared	74	74
		2 classes shared	35	91
		3 classes shared	9	100
	Grades 7 & 8	None	259	20
		Indirect	88	34
		Direct	118	81
School Bus	Grade 7	Direct	5	100
	Grades 7–9	Direct	17	47
Church Choir	Members	Direct	3	67
Multiple‡	Grade 7	Direct	6	100
	Grades 8–9	Direct	7	57

*Did not share a classroom with the index case but followed her into a room she had just left.
†Shared a classroom or airspace with the index case.
‡School and bus = 5, School and choir = 1, bus and choir = 7.

School Staff

Prior to the outbreak, two of 48 (4 per cent) of the staff were known tuberculin reactors (Table 3). After the outbreak, 12 of 40 (30 per cent) were reactors, a seven-fold increase in the reactor rate. Among those staff members known to have worked in classrooms with the index patient between November 1980 and January 1981, the reactor rate rose from zero to 60 per cent. One staff member was identified as a convertor during the repeat skin testing.

Secondary Cases

Six cases of tuberculosis were found by contact investigation and chest x-ray films of reactors. Two family members of the index patient (a one-year-old brother, and a 19-year-old cousin) developed pulmonary tuberculosis. Four other cases were identified among seventh graders at the junior high school: two presented with lymphatic disease (hilar adenopathy) (both had 18 mm skin test reactions), one with pulmonary disease (13 mm reaction), and one with a pleural effusion (22 mm reaction). Both of the school children with hilar adnopathy showed chest x-ray improvement after chemotherapy and one of them had a normal chest x-ray a few months prior to the outbreak. The risk of a secondary case of tuberculosis in a schoolmate as a function of skin test reaction size was 10–14 mm = 1.6 per cent, 15–19 mm = 2.4 per cent, 20–24 mm = 2.6 per cent, and ≥25 mm = 0 per cent.

TABLE 3—Tuberculin Skin-Test Positivity among School Staff, Outbreak Junior High School, South Carolina, 1981

Position	No. In Group	No. Skin Tested*	No. Positive	% Positive
Teacher	25	22	9	41
7th only	6	5	3	60
7th & 8th	11	9	5	56
8th only	8	8	1	13
Classroom Aides, Office Staff, Cafeteria and Janitorial	23	18	3	17
TOTAL	48	40	12	30

*Refusals (1), lost to follow-up (1), opted for chest X-ray instead of skin test (4), and previous positives (2) account for 8 staff not tested.

Culture specimens from two of the six persons with cases were positive for *M. tuberculosis*. Bacilli from these two patients (the cousin and the schoolmate with pleural effusion) and the index patient were found to be phage type 2 (lysis pattern 7, 12, 13).[18] All these cases occurred before institution of a preventive drug program.

Discussion

This outbreak demonstrates the infectivity of a cavitary, symptomatic, smear-positive case of tuberculosis. Counting household members, family friends, members of the church choir, and the junior high school student body, over 200 new infections can be attributed to exposure to the index patient. United States Public Health Service (USPHS) contact investigation data suggest that, in 1979, the average number of new infections per case was 1.53.[15] Styblo concluded that about 10 persons are infected during one year by each smear-positive person with pulmonary tuberculosis.[19] The USPHS figure would approach Stylbo's more closely if it were recalculated just for the subset of smear-positive pulmonary cases (i.e., 1.53 infections per case includes cases with little or no infectiousness—such as smear-negative pulmonary cases and extrapulmonary cases). The average number of new infections per case masks the fact that a limited number of transmitters in closed environments account, by themselves, for a disproportionate share of new infections. If one assumes even a 2.5 per cent background reactor rate for this age group (the rate found by testing the ninth graders who had attended the junior high school in the year prior to the outbreak), there would have been approximately 53 reactors expected in this age group in the whole county. In fact, almost 200 reactors were found in the index patient's school alone.

Data from the USPHS shows that, on the average, fewer than one in three close household contacts are found to be infected.[15] In this outbreak, 94 per cent of close contacts, 40 per cent of the school children, 60 per cent of the seventh graders, and 100 per cent of school children in some of the index patient's classes were found to be tuberculin reactors, which emphasizes the unusually infectious nature of the index patient described. Such overall high rates of positive skin test reactions have not been described in previously reported school-based epidemics in the United States.[1–14]

The infectiousness of the index patient is the more remarkable when one considers her age. The Division of Tuberculosis Control of the Centers for Disease Control has maintained an individual case-report system from selected sites, in which detailed information is reported for each individual case (rather than aggregate year-end data). Cases in the 10- to 14-year-old age group are substantially less likely to have smear-positive pulmonary tuberculosis than adults, whereas cases in post-pubertal adolescents (15 to 19 years) resemble more closely those in adults (Table 4). The index patient was in puberty at the time of the outbreak.

The airborne transmission of tuberculosis has been well studied.[20–22] Closed, poorly ventilated spaces favor transmission of tubercle bacilli. In this outbreak, some of the classrooms used by the index patient seemed more conducive to facilitating transmission as evidenced by the differences in the risk of infection between rooms. Airborne

TABLE 4—Smear Status of Pulmonary Tuberculosis Cases, by Age, United States, 1979–82*

Age in Years	No. of Cases	Smear Positive	
		No.	(%)
0–4	202	30	(15)
5–9	88	6	(7)
10–14	128	35	(27)
15–19	478	263	(55)
20–24	1,352	819	(61)
≥25	19,786	11,321	(57)
All Ages	22,034	12,474	(57)

*Data from Kenneth E. Powell, MD, MPH, Division of Tuberculosis Control, Centers for Disease Control, Individual Case Report System, selected areas. Data includes only cases with positive or negative smear and known age. Per cents are rounded off to nearest unit.

transmission was demonstrated by the relatively higher infection rates for students who shared no class with the index patient, but who entered the airspace just vacated by her. In a study of 70 students infected with tuberculosis transmitted by a teacher, 46 of the reactors shared a class with the source case. The other 24 reactors had no contact with the teacher, but used the classroom directly after the teacher had been there.[23] The lack of difference in skin-test reactor rate by sex and race suggests that personal contact is not as relevant a risk factor as exposure to airspaces.

The "child-centered tuberculosis program" in the United States was phased out once it was known that fewer than 1 per cent of previously untested school children were tuberculin reactors.[24] This outbreak might be used as an argument for the need to skin test all school children periodically. However, if the index patient had been identified as a contact of her grandmother in 1975, the index patient's infection might have been discovered earlier. Persons conducting contact investigations must recognize that "households" include related families who socialize extensively and may include several homes, as is often the case in communities with closely knit families who live near each other. In addition, "households" may include individuals not related by blood or marriage but who, nevertheless, should be considered "close contacts" from an epidemiologic point of view. This is one reason that thorough contact investigations cannot be done from the confines of a clinic, but will often require field work on the part of a specially trained investigator. The fact that the index patient failed to return for a chest x-ray film after being identified as a skin-test converter indicates that even a screening program alone might well have done little to prevent this episode. The quality of surveillance, follow-up, and containment activities is of greater importance than the quantity of screening activity in low-prevalence sub-populations.

The retesting of contacts with initial negative tuberculin tests is recommended by the American Thoracic Society[17] as some infected individuals may have a false-negative test because enough time has not elapsed for a delayed hypersensitivity response to tuberculin. Although considerable data exist on the effectiveness of contact examination (in terms of new infections found), there are little data regarding the productivity of a second skin testing of initially tuberculin negative contacts. With older contacts, a second test may be positive following an initial negative test, not because of recent infection, but because the initial test boosted a waned delayed hypersensitivity response.[25] Another factor to consider in assessing whether a repeat skin testing is of value in a contact investigation is the length of time between the initial skin test and the break in potential exposure. If this interval has been more than 10 weeks, a repeat skin test might not be productive, since most conversions that would occur have already occurred. In this outbreak, the initial skin testing took place eight weeks after exposure ended. It might be argued that all testing should have been deliberately delayed until 10 weeks after the index patient had left school, especially since only 2.6 per cent of the infected were found on the second test. However, as the household contact investigation had already established that the index patient was very infectious, deliberately delaying investigation of the school for a few more weeks would not have been warranted because some newly infected persons will develop progressive disease soon after infection. Indeed, clinical disease was noted in 2 per cent of the 195 infected classmates within four months following the index patient's diagnosis.

The excess risk of active disease in family contacts was alluded to by Downes in the prechemotherapy era.[16] He also noted, in 1936, that for every active case resulting from a familial exposure, there were two in the community. Although this is precisely the ratio which was observed in this outbreak, the ratio of familial to community cases has undoubtedly changed since the advent of chemotherapy.

The high risk of skin test positivity in the choir attests to the possibility of increased transmission from aerosols created during singing.[27] The significant skin tests for 53 students who had no contact with the index patient may be explained by: air shared with the index patient at school meetings; contact in hallways, bathrooms, or outside of school; previous infection: contact with other infectious persons in the community; infection with nontuberculous mycobacteria; and technical factors in the test (false positives).

Shortly after this outbreak, certain lots of Aplisol® were found to be hyperpotent.[28] We think it unlikely that hyperpotency accounted for many false-positive reactions in this outbreak for three reasons:

- the school and family group had a high probability of contact with a known infectious person and therefore, a positive reaction is not unexpected;
- the epidemiologic evidence suggested an association of skin-test reactivity and degree of exposure to the index case; and
- use of the same lot of Aplisol® in other settings in this community did not show an unusual prevalence of skin-test reactors.

Comstock suggested that teenagers with larger areas of induration on the skin test were more likely to develop secondary disease.[29] The point of his observation lies in the fact that individuals with large reactions are more likely to be infected with *M. tuberculosis* rather than atypical mycobacteria. In this outbreak, it is probable that essentially all of the children who reacted to tuberculin were infected with the tubercle bacilli, so that the subsquent risk of disease would not necessarily be expected to correlate with the reaction size. However, the number of cases of infection and secondary disease in this outbreak was too small to permit a refined analysis of Comstock's observation.

Extensive contact investigations such as the one described here challenge the capacity of local public health systems. Nevertheless, when indicated by epidemiologic evidence, they must be done. If one assumes that approximately 10 per cent of the persons infected with tubercle bacilli will, if left untreated, become cases during their lifetime,[16] one could expect that approximately 20 new cases of tuberculosis would develop in the persons infected by the index patient described here. Furthermore, since approximately half of the risk of developing disease is concentrated into the first two years after infection,[30] 10 cases of tuberculosis in this community's high school could have been anticipated within two years. We expect that the efforts made to provide preventive therapy to the individuals infected in this outbreak will prevent most of the cases which would otherwise have developed.

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Summer Institute in Administrative Medicine

The Administrative Medicine Program at the University of Wisconsin-Madison will sponsor a Summer Institute for physicians and other clinicians with management responsibilities June 16–July 6, 1985. Graduate courses from the ongoing master's degree program will be condensed into the three-week format. Participants may select two from the following offerings: Health Accounting and Finance; Quality of Health Care—Evaluation and Assurance; Microcomputing for Clinical Administration; Politics of Health Policy; Ethical Issues in Administrative Medicine; Personnel Management; and Legal Issues in Health Care. Courses may be taken for graduate or CME credit.

In addition, several senior clinician-executives will serve as visiting faculty to integrate the academic course work with the practical realities of medical administration.

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