INT J TUBERC LUNG DIS 7(12):S384–S390


# Tuberculosis contact investigations: outcomes in selected areas of the United States, 1999

**J. Jereb,* S. C. Etkind,† O. T. Joglar,‡ M. Moore,* Z. Taylor***

*** Division of TB Elimination, Centers for Disease Control and Prevention, Atlanta, Georgia, † Massachusetts Department of Public Health, TB Prevention and Control, Jamaica Plain, Boston, Massachusetts, USA; ‡ Puerto Rico Department of Health, TB Control Program, San Juan, Puerto Rico**

SUMMARY

**SETTING: Twenty-nine United States jurisdictions.**

**OBJECTIVE: To determine yields of tuberculosis (TB) contact investigations.**

**METHODS: Health departments within the jurisdictions reported counts and outcomes from routine contact investigations for cases reported in 1999.**

**RESULTS: The 29 jurisdictions reported 9199 TB cases, 51.9% of the US and Puerto Rico 1999 total, and listed 67 585 contacts. While 571 (10.6%) of 5405 pulmonary cases confirmed by sputum bacteriology had no contacts listed, 13 904 contacts were listed for other cases that were unlikely to be contagious. Diagnostic evaluation was completed for 56 100 contacts (83.0%), with 561 TB cases found. Of 13 083 contacts found to have latent TB infection, 5746 (44.5%) completed treatment to prevent TB. Loss to follow-up and self-discontinuation of treatment accounted for 70% of reasons why treatment was not completed.**

**CONCLUSION: Contact investigations capture substantial numbers of TB cases and latent TB infections, but the impact on prevention is limited by the poor treatment rates for infected contacts. Contacts should be sought for each potentially contagious TB case; why so many contacts are sought for cases who are unlikely to be contagious needs to be determined.**

**KEY WORDS:** tuberculosis; transmission; contact investigation; program evaluation

CONTACTS of contagious tuberculosis (TB) patients are at risk for active TB or latent TB infection (LTBI). Contacts who have LTBI present an opportunity for preventing future TB cases if these individuals complete an LTBI treatment regimen.[1] In the United States, contact investigations are central to the national strategy for eliminating TB.[2–4]

The US Advisory Council for the Elimination of Tuberculosis, the Institute of Medicine Committee on the Elimination of Tuberculosis in the US, and the Centers for Disease Control and Prevention (CDC) have recommended that programs should assess contact investigations in order to gauge their scope and efficiency.[2–4] In January 2000, TB control officials nationwide adopted a new system for reporting aggregated TB contact data to the CDC. Reports from the system focus on findings from contact investigations around those TB patients who are likely to be contagious[5,6] and rates of starting and completing treatment for contacts found to have LTBI. The reports also include contacts who were evaluated for other reasons, for example, investigations of extra-pulmonary or pediatric cases.

TB program officials of 24 states, four large cities reporting independently of their states, and the Commonwealth of Puerto Rico started using the new report prior to nationwide implementation. This paper summarizes their results for 1999.

## METHODS

### *Structure of reports and definitions for reporting*

The contact data are divided into three categories by the types of TB cases being investigated. The first two data categories are paired with the potential contagiousness of the index TB cases; these are 1) contacts of pulmonary cases with a positive sputum smear result for acid-fast bacilli ('contacts of AFB+'); and 2) contacts of pulmonary cases with a negative sputum smear result but a sputum culture yielding *Mycobacterium tuberculosis* complex ('contacts of Cult+'). A third, heterogeneous category ('other contacts') includes contacts related to any the following events: extra-pulmonary TB, pulmonary TB not confirmed by sputum bacteriologic results, pediatric source case or associate contact investigations,[7] and suspect TB that was later discounted because of either diagnostic results or surveillance policies. Numbers and types of

Correspondence to: John Jereb, Division of TB Elimination, Centers for Disease Control and Prevention, Mail Stop E-10, 1600 Clifton Road, Atlanta, GA 30333, USA. Tel: (+1) 404-639-8125. Fax: (+1) 404-639-8961. e-mail: jxj4@cdc.gov

investigations are not reported for the 'other contacts' category. Definitions for TB cases under investigation in the first two categories match US national surveillance recommendations,[8,9] except that laryngeal and endobronchial forms of TB are included in this report with pulmonary rather than with extra-pulmonary cases because of potential contagiousness.

A contact is defined here as a person having sufficient exposure to TB to warrant diagnostic evaluation. The definition of 'sufficient exposure' has not been determined nationally, and currently depends on local practices.[10] A contact is counted as 'evaluated' when results from a TB symptoms review and from diagnostic tests establish or exclude active TB and LTBI. Contacts are not counted as evaluated until results are obtained from a second tuberculin test if one is indicated. Only those TB cases and latent infections that are found during and because of contact investigations are counted among the results.

Each contact who has LTBI is considered a candidate for treatment.[1] 'Started treatment' is defined as taking at least the first dose of a regimen for LTBI. 'Completed treatment' means taking at least 80% of the doses in a prescribed regimen within 150% of the intended treatment duration, as observed by local methods for monitoring adherence.

### *Data collection*

A health department counts only the contacts of TB cases that it registers.[8,9] It accounts for all contacts of its cases, and their diagnostic evaluation and treatment whenever possible, even those contacts who are seen by private providers or those who are in or move to other jurisdictions. Data are gathered at local health departments and referred to state TB programs for collation and then transmission to CDC.

In 1999 and 2000, US TB program officials attended 2-day CDC training seminars about the data definitions and reporting instructions for the new system. The attendees were asked to provide similar seminars to the localities within their jurisdictions. CDC provided further technical assistance by telephone consultation during implementation of the system.

### *Analysis*

The aggregate counts and the calculated indices were paired by site and then compared across all sites. The slope ($\beta$) and the correlation coefficient ($r^2$) for each comparison were estimated by least-squares fit to a linear relationship as a first-order approximation.[11]

## RESULTS

The CDC received the contact reports for 1999 in the last quarter of 2001 and the first quarter of 2002. The 29 participating jurisdictions reported 9199 TB cases during their reporting periods (25 reported for the entire year and four reported for 1 July–31 December). This represents 51.9% of 17 731 cases reported from the US and the Commonwealth of Puerto Rico in 1999.[8] Of 5405 pulmonary TB cases confirmed by sputum bacteriology, contacts were not listed for 571 (10.6%): 285 (8.1%) of 3527 AFB+ cases, and 286 (15.2%) of 1878 Cult+ cases. These statistics from the 29 jurisdictions are different from those in Table 1, which shows the results from 28 of the 29 jurisdictions.

### *Contact counts*

The 29 jurisdictions reported 67 585 total contacts: 41 478 (61.4%) contacts of AFB+, 12 203 (18.1%) contacts of Cult+, and 13 904 (20.6%) other contacts. The mean ratio of contacts to TB cases (i.e., the ratio of contacts to cases who had any contacts listed) was 12.8:1 for AFB+ cases and 7.7:1 for Cult+ cases. A ratio of contacts to cases cannot be determined for other contacts because the numbers and types of cases investigated are not reported.

### *Diagnostic evaluation of contacts and treatment of LTBI*

Diagnostic evaluation of 56 100 (83.0%) of the 67 585 contacts found TB in 561 (1.0%) evaluated contacts

**Table 1** Outcomes of TB contact investigations* with treatment data for LTBI, 28 US health jurisdictions,† 1999

| TB case types‡ | Cases | Cases without known contacts *n* (%)§ | Contacts | Contacts evaluated *n* (%)§ | Contacts with active TB *n* (%)¶ | Contacts with LTBI *n* (%)¶ | Contacts who started treatment *n* (%)§ | Contacts who completed treatment *n* (%)§ |
|---|---|---|---|---|---|---|---|---|
| AFB+# | 3474 | 284 (8) | 40 515 | 33 521 (83) | 375 (1.12) | 8 890 (27) | 6394 (72) | 4038 (63) |
| Cult+** | 1821 | 274 (15) | 12 004 | 9 987 (83) | 72 (0.72) | 2 100 (21) | 1383 (66) | 857 (62) |
| Others†† | ‡‡ | ‡‡ | 13 899 | 11 909 (86) | 104 (0.87) | 1 911 (16) | 1241 (65) | 851 (69) |
| Summary | | | 66 418 | 55 417 (83) | 561 (1.01) | 12 901 (23) | 9018 (70) | 5746 (64) |

* Reporting definitions in Methods.
† Twenty-nine jurisdictions reported contact data; one that did not have treatment completion data is omitted from the Table.
‡ Types of TB index cases being investigated—these determine categories of cases and their contacts for the report.
§ Percentages calculated from denominator in preceding column.
¶ Percentages calculated from denominator of evaluated contacts.
# AFB smear result positive from sputum.
** AFB smear result negative but culture result positive from sputum.
†† Other types of index cases and contact investigations; two jurisdictions did not report data for this category.
‡‡ Case denominator not included in reports.
TB = tuberculosis; LTBI = latent tuberculosis infection; AFB = acid-fast bacilli.

and LTBI in 13 083 (23.3%). The 28 jurisdictions with treatment completion data for infected contacts (Table 1) reported 66 418 (98.3%) contacts overall; among these contacts, 12 901 (19%) had LTBI. Of those with LTBI, 9018 (69.9%) started treatment and 5746 (63.7% of contacts who started, or 44.5% of those with LTBI) completed it. The treatment start rate was greatest for contacts of AFB+ (71.9%), while the completion rate was greatest for the other contacts (68.6%).

### *Reporting areas compared to non-reporting areas*

All regions of the US were represented by states that reported their contact data. Relatively more of the 24 states that reported data had low 1999 TB incidence rates than the 26 states that did not: nine (38%) vs. eight (31%) had very low incidence (≤3.5/100 000), seven (29%) vs. nine (35%) had intermediate incidence (3.6/100 000–5.8/100 000), and eight (33%) vs. nine (35%) had high incidence (>5.8/100 000, i.e., greater than the national average rate in 2000).[8,12]

Compared with states not reporting contact data, fewer of the states reporting contact data had at least half of their TB patients reported as foreign-born: six (25%) of 24 reporting vs. nine (35%) of 26 not reporting.[8] However, a greater number of TB patients in the states reporting contact data were foreign-born: 4440 (46.9%) of 9466 patients having country-of-origin data for those reporting vs. 3091 (40.4%) of 7660 for those not reporting.

The reasons why some TB program officials implemented the contact reports in 1999 while others waited were not determined systematically.

### *Ranges and correlations of contact investigation results*

The number of cases for investigation, the number of contacts, and the calculated indices varied widely by

**Table 2** Contact investigation indicators reported by 29 jurisdictions for 1999, with statistics by jurisdiction

**A** Indicators from contact investigations around sputum AFB smear-positive patients (AFB+)*†

| Statistic | AFB+ TB cases *n* | Rate, cases without contacts, % | Contacts *n* | Contacts per case,‡ % | Contact evaluation rate, % | Active TB rate, % | LTBI rate, % | Treatment of LTBI rate, % | Treatment completion rate, % |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 122 | 5.2 | 1481 | 17.4 | 83.1 | 1.17 | 24.5 | 74.7 | 66.1 |
| Median | 64 | 5.9 | 942 | 13.5 | 87.4 | 1.08 | 24.7 | 75.1 | 70.0 |
| Minimum | 0§ | 0.0 | 67 | 6.0 | 51.3 | 0.00 | 6.3 | 50.0 | 20.6 |
| 1st quartile | 33 | 0.0 | 328 | 9.8 | 76.4 | 0.50 | 18.0 | 65.6 | 60.7 |
| 3rd quartile | 114 | 8.1 | 1790 | 21.4 | 93.4 | 1.56 | 30.3 | 81.8 | 75.1 |
| Maximum | 755 | 16.7 | 7035 | 50.0 | 97.9 | 4.76 | 53.8 | 97.6 | 100 |

**B** Indicators from contact investigations around sputum AFB smear-negative, culture-positive patients (Cult+)*†

| Statistic | Cult+ TB cases *n* | Rate, cases without contacts, % | Contacts *n* | Contacts per case,‡ % | Contact evaluation rate, % | Active TB rate, % | LTBI rate, % | Treatment of LTBI rate, % | Treatment completion rate, % |
|---|---|---|---|---|---|---|---|---|---|
| Mean | 65 | 15.9 | 421 | 11.9 | 84.4 | 0.67 | 20.7 | 71.1 | 60.1 |
| Median | 30 | 11.4 | 199 | 8.0 | 86.6 | 0.00 | 19.2 | 69.0 | 66.7 |
| Minimum | 1 | 0.0 | 7 | 4.4 | 46.7 | 0.00 | 0.0¶ | 50.0 | 0.0 |
| 1st quartile | 13 | 2.3 | 60 | 5.9 | 79.3 | 0.00 | 11.1 | 63.1 | 50.0 |
| 3rd quartile | 52 | 20.0 | 469 | 10.2 | 91.9 | 0.93 | 27.8 | 80.0 | 72.7 |
| Maximum | 449 | 90.0 | 2154 | 60.0 | 100 | 4.35 | 100 | 100 | 93.5 |

**C** Indicators from other types of contact investigations (other contacts)*†#

| Statistic | Contacts *n* | Contact evaluation rate, % | Active TB rate, % | LTBI rate,% | Treatment of LTBI rate, % | Treatment completion rate, % |
|---|---|---|---|---|---|---|
| Mean | 515 | 86.4 | 1.01 | 15.0 | 64.2 | 69.7 |
| Median | 391 | 84.6 | 0.83 | 13.9 | 66.7 | 70.6 |
| Minimum | 3 | 50.0 | 0.00 | 0.0** | 0.0 | 0.0 |
| 1st quartile | 52 | 80.8 | 0.00 | 5.5 | 50.4 | 63.7 |
| 3rd quartile | 781 | 96.7 | 1.73 | 21.7 | 79.8 | 81.8 |
| Maximum | 2233 | 100 | 4.55 | 44.4 | 100 | 100 |

* For calculating each indicator, reports that were non-contributory were omitted (e.g., a jurisdiction reporting zero infected contacts in a category could not contribute to results for treatment of LTBI and completion of treatment for that category).
† The means are calculated per jurisdiction (no weighting), which causes differences from the aggregate means.
‡ Cases with no contacts identified removed from the denominator.
§ Data from one jurisdiction that had no AFB+ cases and thus no contacts of AFB+ are omitted from subsequent columns.
¶ Three jurisdictions (with 1–3 cases for investigation and 7–60 contacts per jurisdiction) found no LTBI in contacts of Cult+. These jurisdictions are not included in the summary statistics under treatment of LTBI rate and treatment completion rate.
# For other contacts, only 27 jurisdictions reported their data.
** Four jurisdictions reporting other contacts (with 5–46 contacts per jurisdiction) found no LTBI. These jurisdictions are not included in the summary statistics under treatment of LTBI rate and treatment completion rate.
AFB = acid-fast bacilli; TB = tuberculosis; LTBI = latent tuberculosis infection.

jurisdiction and were generally not evenly distributed (Table 2A–C). The greatest numbers of contacts per TB case were reported by jurisdictions with the fewest cases, but the dispersal between jurisdictions was substantial (e.g., for the contact-to-case ratio for AFB+ cases, the slope $\beta = -0.02$, and the correlation coefficient $r^2 = 0.07$). The fraction of TB cases who did not have contacts also correlated poorly with the number of cases for investigation. For all three groups of contacts, the following indices did not correlate with the total number of contacts within that category: contact evaluation rates, active TB and LTBI rates for evaluated contacts, treatment rates for contacts with LTBI, and treatment completion rates.

For contacts of AFB+, the LTBI rates showed a negative correlation with the contact-to-case ratio ($\beta = -0.006$, $r^2 = 0.40$, Figure). For each increase of one contact per case that was investigated, the LTBI rate lessened by on average 0.006, but only 40% of the observed variability in the LTBI rate was predictable from this correlation (Figure). As shown, the dispersal of datum pairs is prominent. For contacts of Cult+, a similar correlation was present but with greater dispersal ($\beta = -0.006$, $r^2 = 0.12$). No other calculated index showed a potential correlation with the contact-to-case ratio.

A typical jurisdiction reported a contact-to-case ratio for Cult+ cases that was half that of its AFB+ cases, but the dispersal was large ($\beta = 0.48$, $r^2 = 0.17$). There was no discernable correlation between the proportion of cases with no contacts and the contact-to-case ratio for either the AFB+ or Cult+ case categories. Treatment start and completion rates for infected contacts of Cult+ patients correlated positively with the analogous rates for infected contacts of AFB+ patients ($\beta = 0.67$ and $r^2 = 0.28$ for treatment start, $\beta = 0.80$ and $r^2 = 0.34$ for treatment completion).

### *Cities reporting independently*

For contacts of AFB+, the four cities each had a contact-to-case ratio that was less than the overall median (6.1, 11.3, 6.0, and 6.3 vs. 13.5), and their rates of cases without contacts were ⩾ the median (8%, 6%, 11%, and 7% vs. 6%). Their evaluation rates for contacts were < the median for three of four (88%, 84%, 76%, and 80% vs. 87%). The rates of active TB and LTBI in evaluated contacts for each city were similar to the medians. Their LTBI treatment rates were < the median for three of the four cities (65%, 85%, 64%, and 72% vs. 75%), and their treatment completion rates were < the median also for three of the four cities (21%, 71%, 64%, and 53% vs. 70%). The city-specific data for the other categories of contacts showed wide ranges of the calculated indices that were both greater and less than the medians, and no patterns emerged.

### *Reasons why treatment for LTBI was not completed*

The 28 jurisdictions that reported treatment completion data also reported mutually exclusive reasons why treatment for LTBI was not completed for 2899 (88.6%) of the 3272 contacts who started but did not complete treatment. The reasons were reported most often for non-completers who were contacts of AFB+ (90.3%), and least often for those who were contacts of Cult+ (81.6%). The distribution of reasons was similar among the three categories of contacts, and the combined results are shown (Table 3). The most common reasons for not completing treatment for

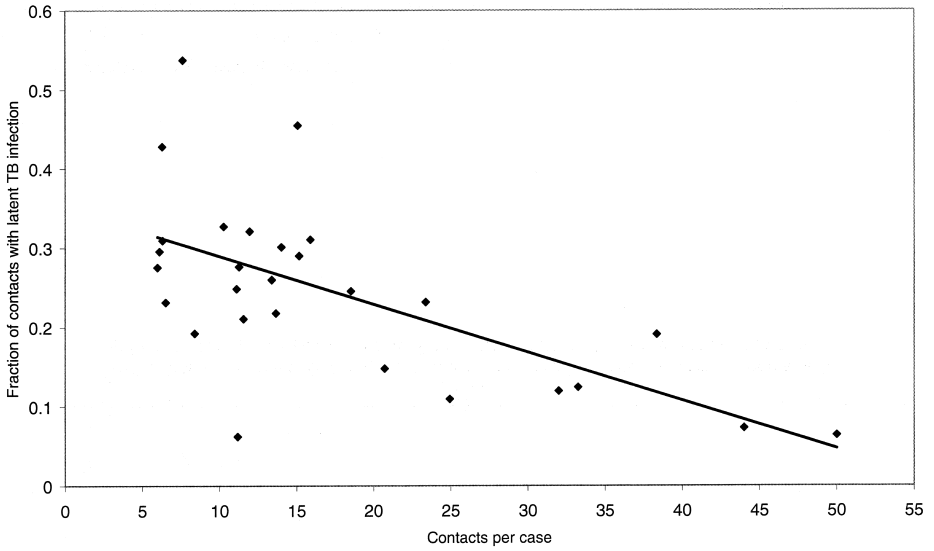


**Figure** Relationship between latent TB infection rates among evaluated contacts and the contact-to-case ratios for sputum AFB smear-positive pulmonary cases in 28 jurisdictions. Least-squares best-fit line.

**Table 3** Reasons why treatment for latent TB infection was not completed for 2899 (88.6%) of contacts who started but did not complete therapy in 28 US health jurisdictions, 1999*

| Reasons for not completing treatment | *n* (% of column total) |
|---|---|
| Contact died during treatment regimen | 27 (0.9) |
| Contact moved before completing† | 376 (13.0) |
| Active TB developed in contact‡ | 40 (1.4) |
| Contact had adverse effect from treatment§ | 247 (8.5) |
| Contact elected to stop treatment¶ | 1259 (43.4) |
| Contact was lost to follow-up# | 784 (27.0) |
| Provider elected to stop treatment** | 166 (5.7) |
| Total non-completers with reported reasons | 2899 |

* The reasons are mutually exclusive.
† Treatment was assumed incomplete for contacts who moved unless a receiving provider confirmed completion.
‡ Contact was believed to be adherent to treatment at the time that TB developed.
§ Adverse effect as confirmed/documented by a provider.
¶ Contact might have elected to stop treatment after self-diagnosing adverse effects without consulting a provider.
# No more specific reason for not completing could be determined.
** For reasons besides adverse effects of treatment.

LTBI were that the contact elected to stop treatment and that the contact was lost to follow-up (and no more specific reason could be determined)—which totaled 70% of failure to complete treatment.

## DISCUSSION

As TB cases decline in the US, the national TB elimination strategy increasingly focuses on efforts to find, evaluate, and treat contacts infected with *M. tuberculosis*. These persons can have active TB soon after infection, or they join the reservoir of LTBI and represent opportunities for preventing future cases, when effectively treated. The findings reported here indicate that contact investigations entail substantial work because of the large number of contacts. During their reporting periods, the 29 jurisdictions accounted for 51.9% of the TB cases reported from the US and the Commonwealth of Puerto Rico in 1999. When extrapolated by simple proportion, the estimated total number of contacts of TB patients in the US in 1999 would exceed 130 000, with approximately 1300 having active TB and 26 000 having LTBI.

The substantial fraction of potentially contagious TB patients who had no contacts listed is of concern. Although some of these patients actually might not have had contacts, in other situations this probably represents missed opportunities for detecting transmission and preventing future cases. Two patient-related factors that have been associated with listing few or no contacts are unstable housing status and early death of index patients, presumably before interviews for eliciting contacts.[6,13] Either situation hampers contact investigations and requires alternative, more intensive approaches to determine who the contacts are.

Each contact investigation is a lengthy, multiphase process. At the start, public health personnel obtain names of contacts by interviewing the patient who has potentially contagious TB and by surveying other sources. After contacts are traced, the evaluation of each contact requires two or more visits with health care providers for a TB symptoms interview and tuberculin skin testing. Contacts with evidence of TB infection or disease require radiographic and sometimes bacteriologic examinations. To prevent TB, contacts who have LTBI need treatment (most often isoniazid for 9 months), and this requires monitoring for adherence and adverse effects.[1] The CDC is collaborating with state and local health departments to estimate the health care burden of TB contact investigations.[10]

TB contact tracing is a productive method of active case finding. The 561 cases found through contact investigations represent 6.1% of the 9199 cases found through all methods by the participating jurisdictions during their reporting periods. Approximately 1% of contacts evaluated had TB disease; in comparison, 0.006% of the overall US population had active TB reported in 1999.[8] For contacts, this >150-fold higher TB rate could be attributed either to recent infection with *M. tuberculosis*, which increases the risk for incipient disease, or to greater disease prevalence in specific settings or population groups where index cases originate and contact investigations are done.[14,15]

The 0.87% of 'other' category contacts with active TB, i.e., contacts who were sought for reasons other than known exposure to potentially contagious pulmonary TB, was unanticipated, as was the 16% with LTBI. A recent epidemiologic study of contact investigations in Spain encountered even larger rates among comparable 'other contacts'.[15] Further unanticipated results reported here for other contacts in the US were their large number and their rates for diagnostic evaluation and treatment completion, which were higher among contacts in the 'other' category than among contacts in the AFB+ and Cult+ categories.

Pulmonary TB cases confirmed by sputum smear or culture are more likely to transmit *M. tuberculosis*, and thus a higher priority is recommended for investigation of such cases.[3,5,6,16,17] Each of the unanticipated results for other contacts calls into question whether the priorities are being observed and whether these priorities are sufficient for guiding program strategy.

The TB and LTBI rates raise the possibility that the other contacts are members of populations with a greater than average incidence or prevalence, e.g., immigrants from countries with endemic TB transmission. The yields of TB and LTBI suggest that at least some of the contact investigations in this category are contributing to TB prevention; focused epidemiologic studies are needed to clarify the types and the relative value of these investigations in the US.

The system for reporting aggregated TB contact data and its initial implementation in 1999, described in this report, have limitations. The contact data do not

allow direct assessment of whether the results from the 29 reporting jurisdictions represent the experience in the rest of the US. States with low TB incidence were slightly over-represented, although the inclusion of high-morbidity jurisdictions allowed the contact reports to capture half of the 1999 TB incidence. The greater than average percentage of foreign-born TB patients who were possibly included in the contact data might have influenced results.

Unfamiliarity with the new reports could have affected data collection and classification; systems for data validation were likely to differ among sites. Although the CDC held training seminars for state and some big city public health officials, personnel in local health departments received variable training. The new reports were intended for measuring program process and are not comparable to epidemiological study methods, and some TB control officials relayed anecdotes that the data definitions were being reinterpreted in some localities. The wide jurisdiction-to-jurisdiction variability of the reported results could be caused by incorrect reporting practices in addition to differences in actual outcomes. However, the similarity between the summary results and the results that have been gathered through systematic on-site research[5,6,13,15,18] suggests that the reporting practices were usually consistent with the instructions, and conversely that the published studies are representative of routine outcomes of contact investigations.

The current contact reporting system does not include information about optimal selection of contacts: some of the reported contacts might have had little risk of *M. tuberculosis* infection, while others at great risk might have been missed. The data in the reports are aggregated, and a detailed nationwide analysis of TB cases, contacts, and contact investigations is impossible under the current system. To accomplish this, a national reporting system with more details, linking data for individual contacts with the TB morbidity surveillance data, is needed.

## CONCLUSION

Incomplete yields at each step in the process of contact investigations were reported: one tenth of potentially contagious TB cases had no contacts listed, one sixth of contacts did not have medical evaluations completed, one third of contacts who had LTBI did not start treatment, and one third of contacts who started treatment for LTBI did not complete it. Poor results at any of these steps diminish the potential impact of contact investigations and suggest missed opportunities for early case detection and prevention. The productivity of TB contact investigations should be monitored with data summaries such as those described here, and the procedures used in contact investigations should be assessed in more detail locally when low yields are noted.[2–4,6,10,16–18]

The unexpectedly large numbers of contacts who are being sought for reasons other than exposure to bacteriologically confirmed pulmonary TB, and the rates of TB and LTBI in these contacts,[15] should be examined more closely for adjusting priorities in contact tracing.

The yields from contact investigations for TB and LTBI were substantial, but their impact on TB prevention might not increase noticeably until improved methods for diagnosing and treating LTBI are discovered and applied. In the interim, the prominent reasons why treatment for LTBI is not being completed (self-discontinuation of treatment and loss to follow-up) suggest a key role for innovative patient-centered strategies, designed in collaboration with communities affected by TB.[3,16–19]

### *Acknowledgements*

Linda Leary, Division of Tuberculosis Elimination, CDC, assisted with report collection. The following TB control officials kindly shared their data: N Brook Keenon, Div of TB Control, Alabama Dept of Public Health; L Johnson, TB Control Bureau, California Dept of Health Services; J Bettridge, Colorado Dept of Public Health and Environment; J Eaton, Denver Public Health, Denver, Colorado; J Miller, J Cobb, Bureau of TB & Refugee Health, Florida Dept of Health; R M Sales, Tuberculosis Epidemiology Unit, Div of Public Health, Georgia Dept of Human Resources; V Biddle, Illinois Dept of Public Health; D Minnice, W Paul, TB Control Program, Chicago Health Dept; P T Britton, TB Control Program, Indiana Dept of Health; M Reece, G Pezzino, Kansas Dept of Health and Environment; A Misikir, Maryland Dept of Health; R Vogel, R McClain, Communicable Disease and Epidemiology, Baltimore City Health Dept, Baltimore, Maryland; GJ Palumbo, Div of Communicable Disease and Immunization, Michigan Dept of Community Health; M Bailey, TB Control Program, Detroit Dept of Health, Detroit, Michigan; W Mills, D Sodt, TB Prevention and Control, Minnesota Dept of Health; G V Tomlinson, L Phillips, Vaccine Preventable Diseases, Missouri Dept of Health; J M Holcombe, TB Program, Mississippi State Dept of Health; D Ingman, Montana Dept of Public Health and Human Services; J Proctor, J T Montero, Bureau of Disease Control, New Hampshire Dept of Health and Human Services; S Cook, M Dorsinville, Bureau of TB, New York City Dept of Health, New York, New York; K Mongeon, TB Control Program, North Dakota Dept of Health; J Tillinghast, T Crisp, H Gretz, Tuberculosis Div/Acute Disease Svc, Oklahoma State Dept of Health; M Gosciminski, Div of Disease Prevention and Control, Rhode Island Dept of Health; C Haley, Tennessee Dept of Health; W Heirendt, W White, T Epps, TB Control Program, Virginia Dept of Health; T V Oemig, Wisconsin Tuberculosis Program, Div of Public Health, Wisconsin Dept of Health and Family Services; B Simpkins, West Virginia TB Control Program, West Virginia Dept of Health and Human Resources; N A Bowler, TB Program, Preventive Health and Safety Div, Wyoming Dept of Health; A Rodriguez, J Rullán, Puerto Rico Dept of Health.

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