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Contrast of Survey Results between State and a Cohort of Nonstate Mycobacteriology Laboratories: Changes in Laboratory Practices

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Based on the recommendations of a 1992 conference on tuberculosis, the Centers for Disease Control and Prevention (CDC) established programs for upgrading mycobacteriology laboratories by providing them with monies and focused training. In 1991, state public health laboratories were surveyed to determine the methods they were using for primary *Mycobacterium tuberculosis* testing and their turnaround times for reporting testing results. A similar survey of nonstate laboratories participating in the National Laboratory Training Network-sponsored, *M. tuberculosis*-focused training programs was conducted from May 1992 to June 1993. In 1994, follow-up surveys of both the state- and nonstate-laboratory cohorts were conducted with the questionnaire from the initial survey plus additional questions that asked about interventions and changes occurring in the laboratory since the original survey. Although both cohorts showed increases in the percentages of laboratories meeting the recommended turnaround times for reporting *M. tuberculosis* testing results and using the recommended rapid methods for testing, generally, the increases made by the state laboratories were greater. By June 1994, all state laboratories were using a rapid method for *M. tuberculosis* isolate identification compared with 88% of the nonstate laboratories. The percentage of laboratories identifying isolates within the recommended 21 days also increased more in the group of state laboratories than in the group of nonstate laboratories (state laboratories, 22 to 73%; nonstate laboratories, 55 to 59%). Responses from the follow-up survey showed large differences in the percentages of laboratories that received CDC funding (state laboratories, 100%; nonstate laboratories, 6%) and participated in *M. tuberculosis* training (state laboratories, 98%; nonstate laboratories, 45%). These results indicate that adequate funding and focused training are critical in maintaining state-of-the-art mycobacteriology laboratories.

At the 1992 conference "Meeting the Challenge of Multidrug-Resistant Tuberculosis," the laboratory-issues work group identified an immediate need for improving the laboratory's ability to achieve more rapid turnaround times (TATs) for *M. tuberculosis* testing and reporting (5). The 1991 survey of state and territorial public health laboratories substantiated this need (6). To achieve this goal, it was determined that laboratories would need new equipment and training.

Based on the recommendations, the Centers for Disease Control and Prevention (CDC) established programs for upgrading mycobacteriology laboratories by providing them with monies and focused training. Particular emphasis was placed on upgrading the state public health laboratories, because they are an integral part of the national system for tuberculosis (TB) surveillance and control and serve as primary referral centers.

Following the conference, a training seminar, "Meeting the Challenge: Multidrug-Resistant Tuberculosis, the Laboratory DOES Make a Difference," was developed at the CDC and presented to representatives of state and territorial mycobacteriology public health laboratories. This seminar provided laboratories with strategies for achieving the recommended goals. The CDC prepared a training package of the seminar's contents for the National Laboratory Training Network (NLTN). The NLTN is a training system sponsored by the Association of State and Territorial Public Health Laboratory Directors (ASTPHLD) and the CDC as a guideline for their training (1). In May 1992, the NLTN began presenting TB-focused laboratory programs nationwide. Forty-six programs were given during the 2 1/2 years covered by this study. These programs were open to anyone involved in mycobacterial testing. Participants attending the programs in 1992 and 1993 were asked to complete a questionnaire identical to the one used for the 1991 survey of state laboratories. Those laboratories providing responses formed the initial nonstate-laboratory cohort for this study.

In the spring of 1992, as a competitive supplement to existing TB prevention and control cooperative agreements, additional federal funds were made available for upgrading the diagnostic capabilities of public health mycobacteriology laboratories. In 1992, approximately $4 million was distributed among state and territorial laboratories; in 1993 and 1994, $5 million and $8.6 million, respectively, were distributed (4).

In June 1994, follow-up surveys were performed to determine changes in laboratory practices in state and territorial public health laboratories and in the cohort of nonstate laboratories. In addition to the questions used in the initial surveys, the follow-up surveys asked about interventions and changes occurring in the laboratory within the study interval.

Results from state public health laboratory responses to the questionnaire portion of the follow-up survey have been reported elsewhere (2). Responses from the state laboratories about their interventions and changes, however, are presented here. Also presented are the results from both the initial and

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the follow-up surveys of the cohort of nonstate laboratories. This study contrasts the two groups of laboratories in their ability to reduce TATs and in their use of rapid testing methods. Examined also are group differences in participation in TB training, in receipt of increased funding, and in changes made that affect the operation of the laboratory.

MATERIALS AND METHODS

Both the initial and the follow-up surveys of the state and territorial public health laboratories and of the cohort of nonstate laboratories were conducted by the staff of the ASTPHLD. The principal survey instrument, a questionnaire, focused on primary testing for *M. tuberculosis*. It asked about laboratory testing methods and the lengths of TATs from receipt of clinical specimens to the reporting of results. The same questionnaire was used for all four surveys, i.e., the initial surveys of both the cohort of state laboratories and the cohort of nonstate laboratories and the follow-up surveys of both cohorts.

In addition, the follow-up surveys requested information about training and funding. These additional questions asked respondents if any of their laboratory's staff had participated in educational programs in addition to the CDC seminar or the specific NLTN program at which the initial questionnaire was received and, if so, the types and sponsors of the attended program(s). They were asked if their laboratory had received an increase in funding since the initial survey and, if so, the source of the funds but not the specific amount. Questions were asked about any changes made in the TB laboratory, such as purchases of new equipment and reagents, changes in personnel, and changes in the number of days that TB testing services were being provided. They were also asked if they had attempted to improve specimen collection and transport. Finally, they were asked if they believed that the quality and/or quantity of their laboratory's TB testing services had improved and to list any factors they thought contributed to the improvement.

Completed survey documents were forwarded to the CDC for analysis. The data were analyzed with SAS (7, 8). Chi-square tests were used to test the statistical significance of differences between cohorts and between cohort subgroups. Only the results obtained from laboratories that responded to both the initial and follow-up surveys are reported here.

RESULTS

Description of cohorts and survey response rates. (i) State public health laboratories. Completed survey documents were received from 51 (93%) of the 55 state and territorial laboratories included in the follow-up. Because 2 of these 51 laboratories were no longer performing *M. tuberculosis* testing, data from only 49 laboratories were analyzed. For all the state laboratories, the interval between the initial and the follow-up survey was 30 months.

(ii) Nonstate laboratories. Between May 1992 and June 1993, questionnaires representing 218 nonstate laboratories were collected from participants in 12 NLTN TB training programs. In the follow-up study, 123 (57%) of the 218 nonstate laboratories returned one survey document or both survey documents; this cohort was composed of 105 (85%) hospital laboratories, 8 (7%) public health laboratories other than state laboratories, and 8 (7%) independent laboratories. Two (1%) laboratories could not be classified.

Only questionnaire data from the 119 laboratories which were performing *M. tuberculosis* testing in June 1994 were analyzed. Because the survey respondents of 2 of these 119 laboratories did not answer the additional questions about training and funding, data from only 117 laboratories could be analyzed for those elements.

The interval between the initial and follow-up surveys varied from 11 to 25 months, depending on when respondents to the initial survey attended their first NLTN TB training program.

Extent of testing. Table 1 contrasts the extents of testing performed by both cohorts of laboratories in June 1994. More state than nonstate laboratories were performing *M. tuberculosis* identification ($P < 0.001$) and *M. tuberculosis* drug susceptibility testing ($P < 0.001$). Of the 49 nonstate laboratories forwarding samples to another laboratory for *M. tuberculosis* identification and of the 94 nonstate laboratories forwarding samples for drug susceptibility testing, 20 (41%) and 56 (60%), respectively, forwarded samples to either a state or a large-city public health laboratory.

TABLE 1. Extent of *M. tuberculosis* testing in state laboratories and a cohort of nonstate laboratories, June 1994

Type of testing	%[a] (no.) of laboratories performing the indicated testing	
	State laboratories ($n = 49$)	Nonstate laboratories ($n = 119$)
AFB microscopy	100.0 (49)	100.0 (119)
Primary culture	100.0 (49)	91.6 (109)
M. tuberculosis identification	98.0 (48)	61.3 (73)[b]
M. tuberculosis drug susceptibility	91.8 (45)	23.5 (28)[b]

[a] Percentage of laboratories performing the indicated type of testing among the laboratories in the group that were performing *M. tuberculosis* testing in-house at both the initial and follow-up survey.

[b] Differences are significant at the 0.001 level.

Questionnaire results. Changes occurring in *M. tuberculosis* testing and reporting practices in the state and territorial public health laboratories have been previously reported (2) but are summarized here for comparison.

The percentages of both cohorts using the recommended rapid methods for *M. tuberculosis* testing are shown in Fig. 1. Only data from those laboratories performing the indicated test were used in calculating the percentages. On follow-up, increases were seen in the use of all recommended testing methods.

The percentages of both state and nonstate laboratories generating test results within the recommended TATs are shown in Fig. 2. Both cohorts showed increases in the proportion of laboratories meeting each recommended TAT. By June 1994, the laboratories in both cohorts were similar in their abilities to report acid-fast bacillus (AFB) microscopy results within 24 h of specimen receipt and in their abilities to report *M. tuberculosis* isolation, identification, and drug susceptibility test results within 28 days of specimen receipt. Greater variability between the cohorts was seen in the proportions meeting the recommended TAT for isolate identification, although this difference is not statistically significant ($P = 0.118$).

The greatest variability between the two cohorts was in the receipt of specimens within 24 h of collection. Although both cohorts showed improvement in 1994, only 16% of the state laboratories received specimens within the recommended time. In contrast, 94% of the nonstate laboratories received specimens within 24 h ($P = 0.001$).

Of the laboratories performing isolation and identification, 80% of the state laboratories used the BACTEC system for primary culture and 100% used at least one rapid method for *M. tuberculosis* isolate identification; 51% of the nonstate laboratories used the BACTEC system for culture, and only 88% used a rapid identification method. These differences between cohorts are statistically significant ($P = 0.002$ and 0.049, respectively).

In the subgroup of 22 state laboratories generating drug susceptibility reports in 28 days or less, 96% used the BACTEC system for primary culture and 91% used it for drug testing. In the subgroup of 23 state laboratories taking longer than 28 days, 69% used the BACTEC system for primary culture and 57% used it for drug testing. The subgroup differences are statistically significant ($P = 0.047$ and 0.009, respectively). In the subgroup of 13 nonstate laboratories generating drug testing reports in 28 days or less, 92% used the BACTEC system

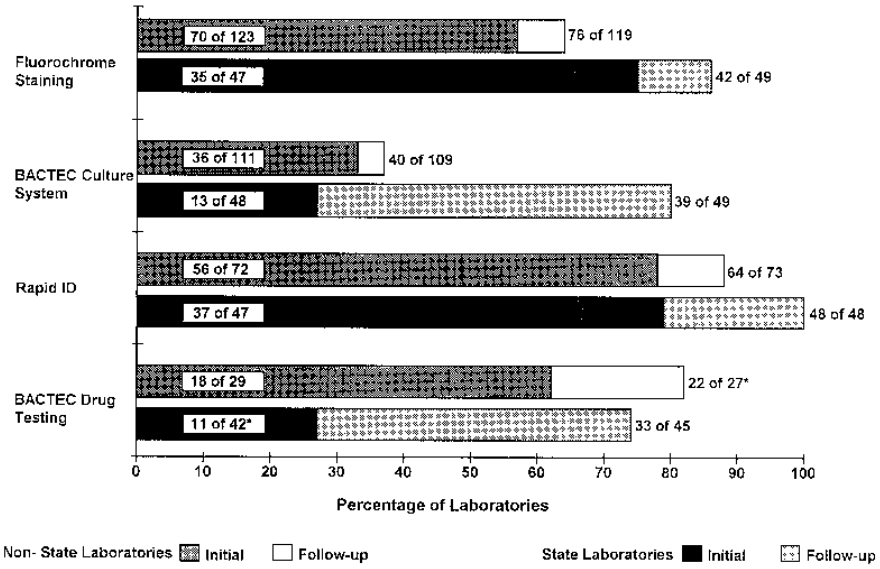

FIG. 1. Proportions of laboratories using recommended *M. tuberculosis* testing methods. An asterisk indicates that one laboratory did not provide information.

for primary isolation and 100% used the BACTEC system for drug testing. In the subgroup of 14 nonstate laboratories taking longer than 28 days, 64% used the BACTEC system for primary culture and also for drug testing. The subgroup difference for BACTEC system drug testing is statistically significant ($P = 0.040$); that for primary culture is not ($P = 0.165$).

Interventions and changes. (i) Training and funding interventions. The percentage of the state laboratories that had staff participating in TB training programs other than the original program was 98% compared with 45% for the nonstate laboratories ($P < 0.001$). On average, 79% of each state mycobacteriology laboratory's staff and 28% of each nonstate mycobacteriology laboratory's staff participated in additional training ($P < 0.001$). NLTN-sponsored teleconferences, many of which focused on the needs of BACTEC system users, were the type of training most frequently used by the state laboratories; programs sponsored by organizations other than the CDC or the NLTN were used most frequently by the nonstate laboratories.

All state and territorial laboratories reported receiving an increase in laboratory-directed funds during the study interval. The major source of the additional monies was federal funds or grants, with 100% of the state laboratories receiving such funds. In addition to federal monies, 23% of the state laboratories received funds from internal reapportionment and 2% received funds from other sources. Only seven (6%) of the nonstate laboratories reported an increase in funding. Three of these laboratories received only federal funds, two received federal funds and funds from internal reapportionment, and two received federal funds and funds from other sources.

(ii) Changes and improvements. Table 2 shows the percentage of laboratories reporting specific changes occurring in their facility. All the differences are statistically significant at the 0.05 level except for the percentage of laboratories that increased the number of days per week that testing services are provided. Most of the new reagents and equipment purchased by both cohorts' laboratories were to support rapid testing methods, such as the BACTEC system, nucleic acid probe

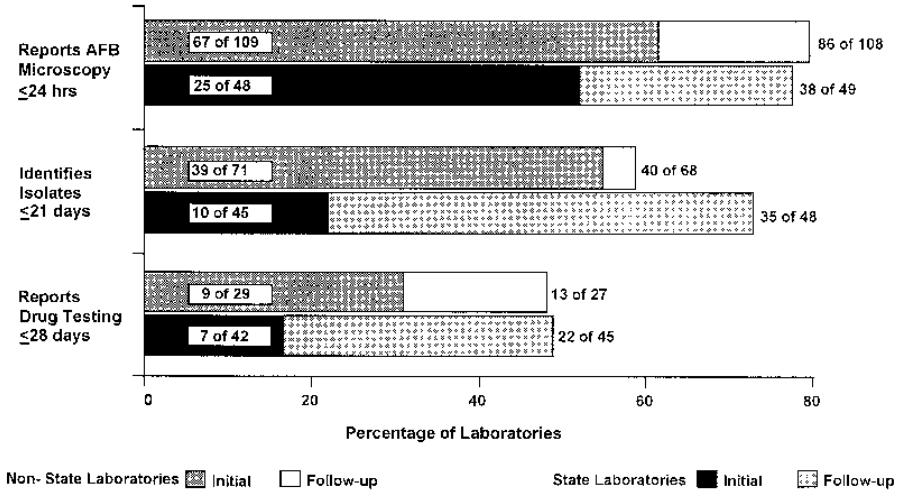

FIG. 2. Proportions of laboratories meeting recommended TATs for *M. tuberculosis* testing.

TABLE 2. Percentages of laboratories in which specific activities and changes have occurred[a]

Type of change	% of laboratories that made the indicated change	
	State laboratories (n = 49)	Nonstate laboratories (n = 117)
Acquired new equipment	100	27[b]
Purchased new reagents	100	37[b]
Purchased computer equipment	78	9[b]
Purchased safety-related materials	74	36[b]
Increased no. of personnel performing TB testing	63	17[b]
Instigated improvements for collecting and transporting specimens	57	10[b]
Increased laboratory space for TB testing	33	15[c]
Remodeled existing TB laboratory facility	27	12[c]
Increased no. of days per week TB testing services are provided	25	30

[a] During the interval between the two surveys.
[b] Differences are significant at the 0.05 level.
[c] Differences are significant at the 0.001 level.

identification, and for some state laboratories, high-performance liquid chromatography.

When asked if they thought that the quality and/or quantity of their laboratory's TB testing service had improved since the time of the initial survey, all respondents from state laboratories replied yes and 83 (71%) respondents from nonstate laboratories also replied yes ($P < 0.001$). These respondents listed a variety of factors they thought had contributed to the perceived improvement. Table 3 lists the seven factors mentioned most frequently by each cohort. Five of the nonstate-laboratory respondents believed that the services they were providing initially were already very good.

DISCUSSION

During the study interval, both cohorts improved their ability to achieve the recommended TATs and increased their use of the recommended testing methods. Generally, greater changes in TATs occurred in the state laboratories than in the nonstate laboratories. The smallest change occurred in the nonstate-laboratory cohort's ability to identify *M. tuberculosis* isolates within 21 days. In contrast, for the state-laboratory cohort, the greatest change occurred, interestingly, in the same category, namely, identifying isolates within 21 days.

The findings show substantial differences that are statistically significant between the two cohorts in their use of rapid methods for primary culture and isolate identification. The use of the BACTEC system appears to be a major factor in the ability of laboratories to reduce TATs. In both cohorts, a higher percentage of the laboratories that were able to generate drug-susceptibility reports within the recommended 28 days or less used the BACTEC system for primary culture and drug testing than did the laboratories that took more than 28 days to generate their reports.

The low percentage of state laboratories receiving clinical specimens within 24 h of collection was not unexpected. As discussed previously (2), differences in the proximities to the collection sites between state laboratories and nonstate laboratories (85% of which were hospitals) affect the ability to receive specimens quickly. The time from specimen collection to receipt by a hospital laboratory is usually measured in minutes or hours; in contrast, receipt by a state laboratory is measured in days. Because the time from specimen collection to specimen receipt by the laboratory is a component of the total time before test results are available to the patient's physician, all diagnostic laboratories should work diligently with their clients to make certain that specimens arrive in the testing laboratory as soon as possible after collection so that effective patient management is not unduly delayed.

Of the various types of laboratories in the study, state public health laboratories carry the heaviest burden for diagnostic *M. tuberculosis* testing. When the percentages of the laboratories of the two cohorts processing >500 specimens per month were compared, the percentage of the cohort of state laboratories was significantly higher (state laboratories, 38%; nonstate laboratories, 8%; $P < 0.001$). Ninety-two percent of the state laboratories offered complete testing services (AFB microscopy, isolation, identification, and drug susceptibility), whereas only 24% of the nonstate laboratories offered such services. Woods and Witebsky (9) found that 62% (441 of 663) of their respondents referred isolates for drug susceptibility testing. Of these 441 laboratories, 51% sent their isolates to their state public health laboratory.

Some limitations related to TAT estimates apply to the data. It is difficult to assess the accuracy of the estimated TATs. A few respondents provided estimates in terms of both calendar days and working days, but most respondents did not indicate whether their estimates were in calendar or working days; therefore, it could not be determined how often working days were reported instead of calendar days. For 23% of laborato-

TABLE 3. Top seven factors believed by respondents to have contributed to a perceived improvement in the quality and/or quantity of their laboratory's TB testing services

Factor cited by state laboratories (%)[a]	Rank	Factor cited by nonstate laboratories (%)[a]
Use of rapid technologies (65)	1	Use of probes and additional probes (20)
Receipt of additional funds (25)	2	AFB smears reported faster and read more often (15)
Training, education, or increased awareness of multidrug-resistant TB (22)	3	Reorganization of work flow and protocol reviews (13)
Increase in the no. of personnel performing TB testing (14)	4	Use of the BACTEC system (12)
Purchase of new equipment (14)	5	Increase in the no. of days per week TB testing service is provided (11)
Reporting results by fax, phone, or electronic transmission (10)	6	Education, training, or increased awareness of multidrug-resistant TB (8)
Increase in the no. of days per week that TB testing service is provided (8)	7	Better service from the reference laboratory (8)

[a] These percentages were calculated by using as a denominator the number of laboratories perceiving improvement in each cohort (49 for state laboratories and 83 for nonstate laboratories).

ries in the state-laboratory cohort and 19% in the nonstate-laboratory cohort, the person who completed the follow-up survey was not the same individual who completed the initial questionnaire; thus, inconsistencies in the way TATs were estimated within a laboratory could exist.

Although the interval between the initial and follow-up surveys was not the same for the two cohorts, no statistically significant associations were found between shorter intervals and longer TATs (correlation analyses).

A potential source of bias in only the initial survey is that respondents from some of the nonstate laboratories may have answered the questions off-site, without having access to actual laboratory records; this was not true for those responding from state laboratories.

Finally, the cohort of nonstate laboratories is not a probability sample of the more than 2,000 mycobacteriology laboratories; therefore, one should avoid generalizing exact percentages to the national population of nonstate laboratories. If, however, large-scale changes in testing and reporting practices had occurred in the national population of nonstate laboratories during the study period, one would expect to see those changes reflected in the data. Because all state mycobacteriology laboratories were surveyed and responses were received from 93% of the laboratories, the results from these laboratories can be accepted at face value.

The additional questions in the follow-up survey focus on some of the major factors generally recognized as being essential for improving mycobacteriology laboratories. Responses to these questions can be used to identify factors which contributed to the laboratory improvements documented in this study.

Some large differences between the two cohorts are seen when comparing data from these responses. One difference is the receipt of federal funding. All of the state laboratories received such funding, but only 6% of the nonstate laboratories received federal funds. The grants that became available to the states in 1992 marked the first time that federal monies had been designated specifically for upgrading public health mycobacteriology laboratories. Before this time, the public health laboratories were supported by money from their states' general funds. In some states, only a fraction of the state laboratory's operating expense was covered by the allotment from the general funds. During the era of declining TB incidence (1953 [when national reporting was initiated] to 1984), fiscal support of mycobacteriology laboratories also decreased. The laboratories, therefore, were unprepared to effectively handle the upsurge of TB and the onset of multidrug-resistant TB outbreaks.

Large differences between the two cohorts are also seen in Table 2. Except for one item, that of increasing the number of days per week that testing services are provided, the percentage of state laboratories making the indicated changes far exceeds that of the laboratories in the nonstate-laboratory cohort. Because many of these changes required an outlay of funds, the differences may reflect, at least in part, the additional monies received by state laboratories. The differences may also reflect, however, that a larger percentage of the nonstate-laboratory cohort was using the recommended methods at the onset of the study and may, therefore, have already made many purchases and improvements.

It is encouraging to note that laboratories in both cohorts have attempted to increase the number of days that testing services are offered. The greater the number of days that testing is done, the less the need to batch testing samples. Reducing the amount of batching can lead to reductions in TATs.

Another large difference between the two cohorts is in their amount of participation in TB training programs and in the types of programs utilized. Both the CDC and the NLTN training focused on strategies for achieving the goals set forth at the 1992 conference; we do not know the contents of other TB training programs.

Additional insight can be gained from the responses to the query as to what factors the respondents believed had contributed to the perceived improvement in the TB testing service provided by their laboratory. Among the top seven factors listed by both cohorts are factors related to training and to money (Table 3). For state laboratories, all of which received additional funding, receipt of the funds was the second most frequently mentioned factor. Not only did state laboratories utilize training more often than nonstate laboratories, but training was the third most frequently mentioned factor by respondents from the state laboratories. In contrast, training ranked sixth on the nonstate-laboratory cohort's list of contributing factors. The pattern of these responses seems to confirm our belief that the additional funding and focused TB training enabled the state laboratories to achieve the improvements documented by this study. Interestingly, seven laboratories in the nonstate-laboratory cohort indicated that their TB services had improved because they were getting better service from their reference laboratory. Because the reference laboratory is likely to be a state laboratory, improved quality in state laboratories influences the quality of service in the laboratories which they serve.

After annual increases in the number of reported cases of TB in the United States from 1985 to 1992, 1995 marked the third consecutive year in which incidence declined (3). Because of the major responsibility borne by state public health laboratories for *M. tuberculosis* testing, it is essential that the recent momentum shown by the state laboratories for reducing TATs and improving laboratory practices not be lost. Public health mycobacteriology laboratories must be maintained as state-of-the-art diagnostic facilities if the ultimate goals of controlling and eliminating TB are to be realized. Results of this study indicate that adequate funding of testing laboratories and continued availability of focused laboratory training will be critical factors in maintaining the quality of service required of public health mycobacteriology laboratories.

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REFERENCES

1. **Bird, B. R. (ed.).** 1992. Meeting the challenge: multidrug-resistant tuberculosis: the laboratory does make a difference. CDC, Atlanta, Ga.
2. **Bird, B. R., M. M. Denniston, R. E. Huebner, and R. C. Good.** 1996. Changing practices in mycobacteriology: a follow-up survey of state and territorial public health laboratories. J. Clin. Microbiol. **34:**554–559.
3. **CDC.** 1996. Tuberculosis morbidity—United States, 1995. Morbid. Mortal. Weekly Rep. **45:**365–370.
4. **CDC.** Unpublished communication.
5. **Hinman, A. R., J. M. Hughes, D. E. Snider, Jr., and M. L. Cohen.** 1992. Meeting the challenge of multidrug-resistant tuberculosis: summary of a conference. Morbid. Mortal. Weekly Rep. **41**(No. RR-11)**:**31–36.
6. **Huebner, R. E., R. C. Good, and J. I. Tokars.** 1993. Current practices in mycobacteriology: results of a survey of state public health laboratories. J. Clin. Microbiol. **31:**771–775.
7. **SAS Institute, Inc.** 1988. SAS language guide for personal computers, release 6.03 ed. SAS Institute, Inc., Cary, N.C.
8. **SAS Institute, Inc.** 1988. SAS procedures guide, release 6.03 ed. SAS Institute, Inc., Cary, N.C.
9. **Woods, G. L., and F. G. Witebsky.** 1995. Mycobacterial testing in clinical laboratories that participate in the College of American Pathologists' mycobacteriology E survey: results of a 1993 questionnaire. J. Clin. Microbiol. **33:**407–412.