Evaluation of Effectiveness of a Continuing Education Program on Antimicrobial Susceptibility Testing

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OBJECTIVE: To evaluate the effectiveness of a course designed to increase use of the most recently published Clinical and Laboratory Standards Institute (CLSI) standards for antimicrobial susceptibility testing (AST) and reporting.

DESIGN: A one-day continuing education course in AST was designed and delivered at multiple sites. Data collected from course evaluations, pre- and post-tests, and pre- and post-practices assessments were used to evaluate the effectiveness of the training.

SETTING: The same course was held in 31 cities across the United States (US).

PARTICIPANTS: Clinical laboratory scientists who attended the courses.

MAIN OUTCOME MEASURES: Participant satisfaction; AST knowledge; number of labs using most recent CLSI standards; compliance with 28 specific CLSI AST recommendations.

RESULTS: Data indicate a high level of participant satisfaction, a gain in AST knowledge, an increase in the number of laboratories acquiring the most recently published CLSI guidelines, and improvement in 4 of 28 specific AST practices.

ABBREVIATIONS: ABC = active bacterial core; APHL = Association of Public Health Laboratories; AST = antimicrobial susceptibility testing; CDC = Centers for Disease Control and Prevention; CE = continuing education; CLSI = Clinical and Laboratory Standards Institute; CME = continuing medical education; NLTN = National Laboratory Training Network; VISA = vancomycin-intermediate *Staphylococcus aureus;* VRSA = vancomycin-resistant *Staphylococcus aureus.*

INDEX TERMS: clinical laboratory techniques; education, continuing; microbial sensitivity tests; program evaluation.

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Emerging bacterial resistance and the introduction of new antimicrobial agents have increased the complexity of antimicrobial susceptibility testing (AST) and reporting. To ensure that all clinical laboratories not only perform the tests but also interpret and report results accurately and consistently,

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the Clinical Laboratory and Standards Institute (CLSI), formerly NCCLS, publishes annual consensus standards developed by AST professionals. A 1998 study by the Active Bacterial Core Surveillance (ABC) program[1] of the Centers for Disease Control and Prevention (CDC) revealed that a number of clinical laboratories were not following the most recent CLSI AST guidelines, creating the potential for antimicrobial therapy to be administered inappropriately.

On the basis of the ABC study conclusions, the National Laboratory Training Network (NLTN), a nationwide laboratory-professional training network, sponsored by the Association of Public Health Laboratories (APHL) and CDC, designed a course to encourage greater use of the most recently published CLSI AST standards. The same course was delivered in multiple locations across the nation. The national scope of the project offered NLTN an opportunity both to evaluate the effectiveness of the training and to examine how a continuing education (CE) program might influence laboratory practices that could directly affect patient care.

Researchers have attempted to determine the effects of CE programs on practices of health-care personnel with varying results. A 1998 literature review of articles studying the results of continuing medical education (CME) for physicians determined that 70% of the studies documented a change in physician performance,[3] whereas a 2004 review conducted in Michigan reported no change in behaviors resulting from CME.[4] A 2003 study conducted in the Netherlands reported that both problem- and lecture-based CE were equally effective in improving knowledge levels of occupational health physicians.[5] These and additional articles note that empirically-based documentation is limited regarding outcomes of professional CE in terms of improved knowledge and skills or their transfer to the workplace, and that additional studies are needed related to training effectiveness.[6]

MATERIALS AND METHODS

A CE program, presented by a nationally recognized subject matter expert, was designed to review AST theory and methods, provide information on practical use of CLSI AST standards in a clinical setting, discuss recommendations for interpreting and reporting AST results, and reinforce public health responsibilities regarding AST reporting.

NLTN staff and personnel in CDC's Office of Workforce and Career Development developed a comprehensive plan to measure the effectiveness of the program. The plan incorporated the first three levels of Kirkpatrick's four-level model[2] for evaluating training – Level 1: participant satisfaction with the course; Level 2: increased knowledge of the course content; and Level 3: use of the content to change practices in the workplace. Kirkpatrick's fourth evaluation level measures the success of a training program in terms of the student's employer's business or organizational performance indicators. Determining results of a training course in financial and business terms is time consuming and expensive and was beyond the scope of this effectiveness study.

Table 1. Participants' satisfaction with specific course elements

Item from course evaluation	Agree	Disagree	N*
The level of the content presented was appropriate for my background.	96%	4%	1138
The course covered the objectives stated in the announcements and handouts	100%	0%	1147
The material presented in the course was relevant to my work.	97%	3%	1135
Much of the content covered was new or updated information for me.	84%	16%	1126
I was able to interact with faculty and other participants.	96%	4%	1124
The teaching methods used were appropriate to learning.	99%	1%	1140
I learned information or acquired skills I can use in my job immediately.	96%	4%	1132
Information presented can be applied when equipment/supplies are funded.	83%	17%	1064
Attending this course was worth the time and money invested.	100%	0%	1141
The training facilities were appropriate for learning.	97%	3%	1137

*N varies because all participants did not respond to each item

Figure 1. Pre- and post-course test

Please respond to the following questions to the best of your ability. The course is designed to help you with these questions, so do not expect to be able to answer all of them correctly before you take the course.

1. How often does the NCCLS update M100 tables?
   a. Annually*
   b. Every three years
   c. Every five years
   d. Whenever NCCLS deems it necessary

2. What type of lighting is used to measure the zones of inhibition for disk diffusion testing of an *E. coli*?
   a. Transmitted light
   b. Reflected light*
   c. Either transmitted or reflected light

3. Which of the following antimicrobial agents should not be reported on *Shigella* spp.?
   a. Ampicillin
   b. Ciprofloxacin
   c. Cephalothin*
   d. Trimethoprim-sulfamethoxazole

4. Which of the following methods cannot be used to confirm ESBL production in *E. coli*?
   a. Disk diffusion test
   b. MIC test
   c. Beta-lactamase test*
   d. Etest

5. Which of the following results are very uncommon in Enterobacteriaceae
   a. Cefepime resistance
   b. Ciprofloxacin resistance
   c. Imipenem resistance*
   d. Penicillin resistance

6. An acceptable susceptibility test method for *Burkholderia cepacia* is:
   a. routine disk diffusion.
   b. disk diffusion with 24 h incubation.
   c. standard broth microdilution MIC.*
   d. broth microdilution MIC with 24 h incubation.

7. Which of the following agents can be considered susceptible for staphylococci if they are penicillin resistant and oxacillin susceptible?
   a. Amoxicillin
   b. Ampicillin
   c. Cephalothin*
   d. Piperacillin

8. How long should disk diffusion tests on enterococci be incubated before reporting a vancomycin susceptible result?
   a. 16-18 h
   b. 16-20 h
   c. 16-24 h
   d. 24 h*

9. Enterococci with high-level gentamicin resistance have high-level resistance to which of the following?
   a. Amikacin*
   b. Erythromycin
   c. Streptomycin
   d. Vancomycin

10. What type of media should you use to perform disk diffusion tests on *Streptococcus* species other than *Streptococcus pneumoniae*?
    a. Mueller-Hinton agar
    b. Sheep blood agar
    c. Mueller-Hinton agar with 5% sheep blood*
    d. Mueller-Hinton agar with 10% sheep blood

11. Which of the following statements is true about *Neisseria meningitides*?
    a. It often produces beta-lactamase.
    b. It sometimes shows decreased susceptibility to penicillin.*
    c. It is always penicillin susceptible.
    d. It is always ampicillin resistant.

12. Your infectious disease clinician informs you that he has a dialysis patient with nosocomial bacteremia due to MRSA and that the patient is not responding to vancomycin. Based on results of your disk diffusion test, the isolate is susceptible to vancomycin. What would you do?
    a. Repeat the disk diffusion test
    b. Perform a vancomycin MIC on the isolate*
    c. Amend the result to vancomycin resistant
    d. Nothing/no formal instructions for this case

13. You discover that a CSF culture is growing *Streptococcus pneumoniae*. What should you do today in terms of susceptibility testing?
    a. Disk diffusion test with cefotaxime and oxacillin
    b. Disk diffusion test with cefotaxime and penicillin
    c. MIC tests for cefotaxime and penicillin*
    d. MIC tests for cefotaxime and oxacillin
    e. Don't know

14. A physician asks you to test cefoxitin against an isolate of *Pseudomonas aeruginosa*. This agent is not on your laboratory's routine test panel and there are no interpretive criteria for cefoxitin in the non-*Enterobacteriaceae* table. What would you do?
    a. Inform the physician that there are no NCCLS standards for testing cefoxitin against *P. aeruginosa**
    b. Test cefoxitin and use NCCLS interpretive criteria for *Enterobacteriaceae*
    c. Test cefoxitin and use NCCLS interpretive criteria for *Staphylococcus* spp.
    d. Extrapolate results obtained from testing ceftazidime (e.g., if ceftazidime susceptible, report as cefoxitin susceptible)
    e. Don't know

15. You perform a vancomycin Etest on a blood isolate of *Streptococcus* viridans and obtain an MIC of 32 mcg/ml. You repeat both the identification tests and Etest and obtain the same results. What would you do next?
    a. Report vancomycin as resistant
    b. Confirm Etest results with a vancomycin disk diffusion test
    c. Send the isolate to a reference lab that will perform a vancomycin MIC test using an NCCLS reference dilution method*
    d. Send the isolate to a reference lab that will perform a vancomycin MIC test using any approved method
    e. Don't know/don't have laboratory protocol for this situation

* indicates correct answer

To assess satisfaction an evaluation form, completed by participants at the end of each course, asked them to agree or disagree with statements about the course and to assess their confidence in meeting each of the course objectives. A 15-item multiple-choice test given immediately prior to and immediately following each course measured participants' changes in knowledge and understanding of appropriate AST methods, recognition of susceptibility patterns for common pathogens, and CLSI-recommended reporting practices (Figure 1). Written pre- and post-course practices assessments were designed to document use of CLSI standards in the participants' laboratories. To prevent duplicative data from the same facility, only one registered course participant from each facility was asked to complete both the pre-course and

Table 2. Item analysis of pre-tests and post-tests. N = 1012

Topic (abbreviated format)	%Pre-test correct*	%Post-test correct	McNemar's *p* value#
1. Frequency NCCLS updates M100 AST tables	68	89	<0.0001
2. Lighting method used to read *E.coli* disk diffusion tests	40	77	<0.0001
3. Select antimicrobial agents not to report for *Shigella* spp.	57	87	<0.0001
4. Select methods not useful to confirm ESBLs in *E.coli*	71	93	<0.0001
5. Some uncommon resistance in *Enterobacteriaceae*	61	90	<0.0001
6. Acceptable susceptibility test method for *Burkholderia cepacia*	22	45	<0.0001
7. Agents that can be considered susceptible for staphylococci if they are penicillin resistant and oxacillin susceptible	52	55	<0.0001
8. Time required to incubate enterococci disk diffusion test prior to reporting as sensitive to vancomycin	80	84	0.0018
9. Other high-level resistance in Enterococci with high-level gentamicin resistance	37	71	<0.0001
10. Recommended media used to perform disk diffusion on non-*S. pneumoniae* streptococcal species	74	89	<0.0001
11. Characteristic susceptibility pattern for *Neisseria meningitides*	44	73	<0.0001
12. Method to test *S. pneumoniae* isolated from CSF	78	92	<0.0001
13. Testing and reporting acceptable for patient with MRSA not responding to vancomycin (although routine tests indicate susceptibility)	62	83	<0.0001
14. Action if physician asks for test results on organism not on panel or in NCCLS interpretive criteria	71	85	<0.0001
15. Reporting vancomycin Etest for *Streptococcus viridans* (MIC 32mgc/ml)	44	77	<0.0001
Mean test score	**58**	**81**	

*Percentages rounded for readability

p values calculated using matched pre- and post-test data including cases in which post-course results declined. For simplicity, the table shows average scores

Refer to Figure 1 for design and exact wording of each question

post-course practice assessments. The post-course practice assessment was mailed to each participating laboratory three to six months after the course.

All evaluation instruments were developed concurrently with the course to ensure that their content reflected the course objectives. Each participant was asked to enter a unique identifier on all forms to link pre- and postcourse documents. The identifier, along with the date and location of the course, allowed evaluators to match responses, while maintaining participant anonymity. Matching was necessary because comparison of scores on pre- and post-tests would not be meaningful unless the same students complete both tests. Likewise, reports of changes in pre- and post-practices are not valid if the data came from different laboratories. Limited demographic information was obtained from course registration forms. Data were analyzed by using SAS® software (SAS Institute, Inc., Cary NC).

Thirty-one courses had been conducted at the time of this study. From a total of 1,321 registered participants, 1,158 completed part or all of the evaluation forms; data were analyzed on the basis of participant compliance.

Table 3. Pre-course practices survey (completed prior to course)

Laboratory practice item	Now in place#	N*
Use 2003 NCCLS AST standards	63%	540
Test VISA and VRSA by MIC methods	77%	533
Report suspected VISA/VRSA to recommended agency	81%	544
Inoculate purity plates from MIC inocula	84%	554
Report synergy screen results on enterococci isolated from non-sterile body sites	52%	511
Screen *E. coli* and *Klebsiella* for ESBLs	72%	534
Perform penicillin or ampicillin MICs on viridans streptococci isolated from sterile sites	71%	533
Verify imipenem resistance for *Enterobacteriaceae* before reporting	48%	500
Perform supplemental testing of gram-negative bacteria that are resistant to all drugs on test panel	66%	495
Report only ampicillin, a fluoroquinolone, and TMP-SMZ routinely on fecal isolates of *Salmonella* and *Shigella* spp.	59%	519
For *Stenotrophomonas maltophilia*, perform MIC tests only	63%	517
Report only ampicillin, a third generation cephalosporin, chloramphenicol, and meropenem on CSF isolates of *H. influenzae*	41%	496
Keep records indefinitely that are used to justify weekly QC	62%	499
Use *E. coli* ATCC 25922 and *Klebsiella pneumoniae* ATCC 700603 for QC of the ESBL screen tests	46%	513
Verify unusual drug/organism results such as those listed in NCCLS standards	78%	539
Prepare a cumulative antibiogram report according to NCCLS M39 recommendations at least annually	76%	533

*N varies because all participants did not respond to each item

#Forms asked participants to check if item was now in place in their laboratories, if they planned to implement the practice, or if item was not applicable

RESULTS

Information from registration forms provided a general description of the course participants. The majority (67%) were employed by private or community-based hospital laboratories, 8% by private clinical laboratories, and 5% by public health laboratories; 4% were employed in physicians' office laboratories, and 15% in other types of laboratories.

Data from the course evaluation forms found that participants were satisfied with overall and specific course content (Table 1). Content relevance and the ability to immediately use the information were rated ≥96%, all respondents agreed that attendance was worth the time and the money invested, and all said the content covered the objectives stated in the course announcements. Eighty-five percent of respondents indicated on the evaluation form that they were confident they could explain how to implement CLSI AST standards, including reporting results for those antimicrobial agents that are appropriate for specific bacteria isolated from specific body sites.

Table 4. Kirkpatrick's three levels of evaluation measured in this study

Kirkpatrick evaluation level[2]	Data-gathering instrument	Example of results
1. Participant satisfaction	Course evaluation form n = 1,158	83% agreed that course content as new or updated their knowledge; 96% agreed they had acquired information or skills they could use immediately
2. Increase in knowledge of course content	Written pre- and post-tests n = 1,012	Significant improvement between pre- and post-test scores ($p < .0001$)
3. Application of knowledge gained to improve workplace practices	Written pre- and post-practice assessments n = 129	Respondents' use of the most recently published CLSI AST guidelines increased significantly ($p < .001$), and some increased adherence to specific AST practices was shown. Post-course response rate precludes additional definitive conclusions

Differences between pre- and post-test scores of 1,012 participants who completed both tests indicated that their knowledge of recommended AST practices increased significantly (Table 2). The pre-test mean score of 8.6 (58%) increased to a mean post-test score of 12.2 (81%; $p < .001$). For example, participants' ability to select appropriate antimicrobial agents to report for *Shigella* species improved from 57% to 87%, and their ability to appropriately test for and report high-level gentamicin resistance in enterococci increased from 37% to 71%.

Results of the pre-course practice assessment showed the number of laboratories that adhered to specific practices prior to the course (Table 3). An identical post-course practices assessment was mailed to the laboratories of all course participants, but only 158 assessments were returned, even though postcard reminders were sent. Of those, only 129 could be matched to a pre-course assessment, probably because a different person completed the form. Pre- and post-course practice assessment analysis of the 129 matched sets demonstrated that the percentage of respondents using the most recently published CLSI AST standards improved significantly, from 69% before the course to 93% after the course ($p < .0001$). Additional analysis revealed increased adherence to many of the specific CLSI recommendations, but the increase was statistically significant in only four instances. For example, using Fisher's exact test, a significant difference between pre- and post-

course practices was shown for verifying imipenem resistance of *Enterobacteriaceae* before reporting results, and for performing supplemental testing for gram negative bacteria that are resistant to all drugs on the test panel. Some of the practice questions were about methods performed mostly in small laboratories, so if a large number of participants indicated that a particular question was "not applicable" the results are not reported here.

DISCUSSION

Our study evaluated the effectiveness of an NLTN-sponsored educational activity in promoting use of the most recently published CLSI standards, and attempted to determine whether that learning activity could contribute to changes in laboratory AST practices. The study was designed according to the following three levels of Kirkpatrick's four-level model for evaluating training (Table 4).

Level 1: Course satisfaction reflects participants' comfort with the course content, instructor, and overall course administration. Course evaluations revealed that a high percentage of participants were satisfied with the course content and instructor and were confident that they could perform the tasks listed in the course objectives. When participants are satisfied with the learning experience, they are more likely to learn and retain information.[2.]

Level 2: Because change in behavior can be expected only when learning has occurred,[2] the course first attempted to improve participants' knowledge of recommended AST practices. Scores on pre- and post-tests demonstrated a statistically significant increase in knowledge of recommended AST practices.

Level 3: Application of knowledge gained is reflected when changes in behavior can be related to information provided in the course.[2] Using pre- and postcourse practices assessments enabled us to demonstrate that recommended laboratory AST practices were adopted in laboratories whose staff participated in the NLTN learning activity and who responded to the assessments. Most important, the number of laboratories that had acquired the most recent CLSI AST standards increased significantly. (Certain laboratories were unaware of CLSI's schedule for updating documents and were using outdated documents.)

Improvement relative to specific AST practices was also noted; however, pre- and post-course gains in adherence to specific practice recommendations were not as substantial as had been expected. Data from the pre-course assessment indicated that the laboratories which participated in the study were at an unexpectedly high level of adherence before the course (Table 3), leaving limited room for statistically significant improvement after completing the training.

The findings are subject to certain limitations. Practices were self-reported; therefore, the degree of correlation between the reports and actual practice is unknown. Course participants are either sent to the course by their facility or choose to attend; therefore, our results cannot be extrapolated to all laboratories performing AST. However, they likely represent laboratories at the top of the spectrum of practice because of the locations of the courses and the types of laboratories represented.

Preserving respondent anonymity made follow-up difficult, contributing to the low number of matched pre- and post-practices assessments and limiting conclusions that might be made about practice changes. Smaller than expected practice differences might have been observed because certain facilities participating in the study were already meeting CLSI AST standards. Also, the low number of participants choosing to return the post-course practices instrument might have disproportionately represented facilities with initially high adherence to CLSI AST standards.

CONCLUSION

An NLTN course designed to promote changes in knowledge and use of appropriate AST practices and presented at strategic locations across the country was considered successful, given the data provided. The three levels of Kirkpatrick's four-level model for evaluating training measured during this study all demonstrated the success of this AST training activity (Table 4).

Despite the study limitations and the difficulties encountered, the authors encourage others to document laboratory training effectiveness. In future studies, a closer match between training activity content and needs of the target audience might result in more substantial changes in laboratory practices. However, this is difficult with self-selected audiences. To do this effectively, the attendees should be surveyed at the time of the course or before the course, and the instructor should adjust the course content to meet the specific needs of the audience. This might prohibit the course from being standardized across the country but is recommended for courses presented to a single audience. Inclusion of more demographic items might help differentiate practices on

the basis of type and size of laboratory. A shorter practices assessment, use of electronic survey tools, and incentives for completing forms might all encourage greater response to postpractices assessments. We strongly recommend using a method of matching forms so that evaluators can be assured that the pre- and postcourse data came from the same individuals. Further refinement of methods for matching forms while maintaining anonymity should be explored when collecting data to assess training effectiveness.

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