Evaluation of the Status of Laboratory Practices and the Need for Continuing Education in Medical Mycology

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Key Words: Training; Medical mycology; Laboratory practice

Abstract

A survey to determine the need for training in medical mycology was sent to 605 US laboratories. Training needs were determined by comparing actual laboratory mycology practices with recommended practices, documenting the extent of mycology training reported by employees, and asking respondents to specify the fungi they considered most difficult to identify. The response rate was 56.7% (with only 316 laboratories providing sufficient information). Results showed a large degree of interlaboratory variation in practices and suggested that more judicious practices could lower costs and improve clinical relevance. Only 55.6% of laboratories reported that at least 1 employee attended a formal mycology continuing education program in the 4 years before the survey. Species of dermatophytes, dematiaceous fungi, and non-Candida yeasts were the most difficult to identify. Training may be needed in basic isolation procedures and in advanced topics such as identification of problematic molds and yeasts and antifungal susceptibility testing. Educators should consider clinical relevance and cost-containment without sacrificing quality when designing courses. Support for additional mycology training may improve if hospital and laboratory administrators are alerted to potential dangers and costs involved in treating patients with invasive fungal infections.

Although some laboratory tests are becoming less difficult as technology advances, identification of fungi in the medical laboratory requires more expertise now than in the past because laboratory technologists are asked to identify a larger group of fungi. The distinction between well-known fungal pathogens and “contaminants” is no longer clear since species once considered harmless may now produce life-threatening infections.1 The patient population susceptible to fungal infections has risen in proportion to the number of immunocompromised patients, especially those receiving hematopoietic stem cell or solid-organ transplants, as well as persons living with AIDS.2 Patients who undergo complex surgical procedures with or without immunosuppressive therapy also are at increased risk for invasive fungal infections. The net result is an increased incidence of fungal infections caused by a broader variety of fungi.6 In some cases, this combination has resulted in misidentifications.7 Accurate identification to the species level of isolates is important because more antifungal drugs now are available that differ in their spectrum of activity.

At the same time that the incidence of fungal diseases is increasing, efforts to control the costs of laboratory tests have gained momentum. This has led to the consolidation of laboratories and staff reductions.8 The need for expertise in mycology has increased, but the number of students enrolled in clinical laboratory science programs has decreased from approximately 6,500 in 1980 to 2,500 in 1997,9 and the time allotted for mycology training remains short or unspecified. In undergraduate training programs geared to generalists, mycology competes with other disciplines for limited time and resources. As a result, medical technology and microbiology students are exposed marginally to procedures for identifying
medically important fungi. Consequently, they require substantial on-the-job training to develop diagnostic competence. Appropriate training and continuing education are even more important to maintain and improve the skills of a smaller number of medical mycology laboratory staff.

To our knowledge, a nationwide survey in the United States of the status of medical mycology practices and training has never been conducted, although the need has been underlined.\textsuperscript{10} One study conducted by the New York State Department of Health was limited to assessment of mycology practices in the 180 laboratories it licensed.\textsuperscript{11} The goal of the present survey was to evaluate medical mycology practices across the United States to gain insight that would better guide the identification of continuing education needs of laboratory staff who work in mycology. Although recommended practices for mycology are available,\textsuperscript{6,12-14} we were interested in the extent to which interlaboratory variation exists, bearing in mind that variation may reflect adaptation to local needs (eg, occurrence of endemic mycoses, special patient populations, particular drug resistance patterns). Furthermore, we wanted to know whether continuing education programs were available to mycology staff, and, if so, whether barriers prevented staff from accessing these programs.

**Materials and Methods**

In 1998, the Association of Public Health Laboratories (APHL) developed and distributed a survey to determine laboratory practices and staff training in mycology for public health and private laboratories. The survey was funded through a cooperative agreement with the Public Health Practice Program Office (PHPPO) of the Centers for Disease Control and Prevention (CDC). Content was reviewed by the CDC’s PHPPO and the National Center for Infectious Diseases. Before the survey was mailed, a focus group of laboratory mycology supervisors from both public health and clinical laboratories was convened to review the content and clarity of the questions. After revisions, the survey was approved for distribution by the APHL Board of Directors.

The population of laboratories was obtained from a list of laboratories that were registered in the Center for Medicare and Medicaid Services database (formerly the Health Care Financing Administration) to perform mycology testing and also in a mycology proficiency testing program. Of the 30,000 laboratories registered to perform mycology testing, almost 24,000 performed only “waived” testing, ie, wet mounts and/or potassium hydroxide preparations, and approximately 6,000 performed testing of high complexity so were enrolled in a proficiency testing program. A random sample of all of the registered laboratories would have yielded a disproportionate number of those that perform only waived testing and would not have provided detailed information about culturing practices. Therefore, a stratified random sample of each laboratory type in the proficiency testing group was selected. APHL staff mailed the surveys to the sample of 605 laboratories, followed several months later by a postcard reminder. The data were analyzed using the Statistical Analysis System (SAS, Cary, NC) to calculate the Fisher exact test.

**Results**

The overall response rate for the survey was 56.7% (343/605). From our stratified sample, 227 of 421 hospital laboratories, 21 of 41 physician office laboratories (POLs), 35 of 60 independent laboratories, and 60 of 73 from an “other” category responded. Some of the 262 laboratories failing to respond may not have performed mycology testing when they received the survey, as stated in 27 surveys returned. This finding implies that our response rate from laboratories that perform mycology testing might be higher than calculated. After incomplete or otherwise invalid surveys were eliminated, the final number included in the analysis was 316.

**Respondent Laboratory Characteristics**

The survey asked participants to select the types of laboratories in which they worked. The question yielded 221 respondents from hospital laboratories, 18 from POLs, 24 from independent laboratories, 20 from state PHLs, and 25 from local PHLs. Five respondents selected an “other” category, and 3 did not respond to this question.

Of the major job responsibilities, 92 respondents indicated they were mycology laboratory supervisors, 93 were microbiology supervisors/managers, 64 were nonsupervisory testing personnel, 32 were laboratory managers/supervisors, 16 were medical directors, and 19 had other job titles. Analysis of the responses by job type showed little difference in either practices or training.

Most respondents (205) indicated that mycology was not a full-time job in their facilities. Forty-six stated that 1 to 5 employees performed mycology testing as a full-time job. The number of staff members rotating through the mycology section ranged from 1 to 16. State PHLs were more likely to have at least 1 full-time mycology employee than other types of laboratories (\(P < .001\); Fisher exact test\textsuperscript{15}). Most non-PHLs performed testing primarily for medical diagnosis, while only 35\% of state PHLs (\(P < .01\)) reported testing only for medical diagnosis. Most state PHLs (15/20 [75\%]) reported they also performed mycology testing for environmental monitoring. Respondents from other laboratory types did not examine environmental samples for fungi.
Laboratory Practices

All but 4 responding laboratories maintained written mycology procedure manuals. Of the 316 respondents, the number reporting that manuals contained the following information was as follows: inoculation procedures for each type of specimen, 289; stock cultures for quality control of media, reagents, and assays, 255; specimen rejection criteria, 252; incubation time and temperature requirements, 250; safety precautions for each procedure, 239; instructions in the proper use of a biological safety cabinet, 235; interpretation of test results, 220; flow charts for identification of yeasts, 194; flow charts for identification of molds, 141; and procedures for using commercially available rapid identification systems, 141. Only 69 laboratories had instructions for troubleshooting problem cultures.

Almost all responding laboratories (295/316 [93.4%]) indicated they examine direct preparations of assorted clinical specimens using the methods shown in Table 1. Asked to write in additional tests performed, respondents from all laboratory types inserted Gram stain for cerebrospinal fluid (CSF) specimens. About 24% of the hospital laboratories performed Gram stains and other stains on respiratory cultures, and a few laboratories performed periodic acid–Schiff stains for both CSF and respiratory specimens. Only 7 laboratories reported receiving previously isolated cultures for testing rather than original specimens.

All respondents who isolated yeasts or molds in their laboratories listed the microbiologic media they used for isolation procedures Table 2. Table 2 shows the level of identification performed on different types of cultures according to the laboratory type. Most respondents (237) also said they identify aerobic actinomycetes in their own laboratories or refer them to another laboratory for identification. Of the respondents, 86 indicated that they send selected fungi to a referral laboratory for identification. Only 9 responding laboratories performed antifungal susceptibility tests, and 153 reported testing serum specimens for cryptococcal antigen.

Table 1
Procedures Used for Direct Examination of Primary Clinical Specimens for the Presence of Fungal Elements by 295 Laboratories Responding to the Question*

<table>
<thead>
<tr>
<th>Specimen Type</th>
<th>10% KOH Mount</th>
<th>India Ink Mount</th>
<th>Calcofluor White Stain</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hair, skin, nails</td>
<td>252</td>
<td>4</td>
<td>50</td>
<td>23; eg, Gram stain, PAS stain, commercial system, KOH with DMSO, LPCB</td>
</tr>
<tr>
<td>Cerebrospinal fluid</td>
<td>21†</td>
<td>203</td>
<td>24</td>
<td>64; eg, Gram stain, Kinyoun stain, Wright stain†</td>
</tr>
<tr>
<td>Respiratory (all types)</td>
<td>136</td>
<td>10§</td>
<td>50</td>
<td>96; eg, Gram stain, methylene blue, PAS, Kinyoun stain, Wright stain§</td>
</tr>
</tbody>
</table>

DMSO, dimethyl sulfoxide; KOH, potassium hydroxide; LPCB, lactophenol cotton blue; PAS, periodic acid–Schiff.
† Data given are the number of respondents reporting use of the method. Some respondents indicated the use of more than 1 method.
§ Eleven respondents were supervisory personnel.

Table 2
Media Used to Inoculate Specimens for Isolation of Fungi*

<table>
<thead>
<tr>
<th>Specimen Type</th>
<th>With Antibiotics</th>
<th>Without Antibiotics</th>
<th>DTM</th>
<th>Mycosel, Mycobiotic, or NCA</th>
<th>Inhibitory Mold Agar†</th>
<th>Sabouraud Glucose Agar‡</th>
<th>Other Media or Incubation Temperature§</th>
</tr>
</thead>
<tbody>
<tr>
<td>Respiratory</td>
<td>109</td>
<td>49</td>
<td>3</td>
<td>177</td>
<td>93</td>
<td>224</td>
<td>65</td>
</tr>
<tr>
<td>Blood, bone marrow</td>
<td>82</td>
<td>79</td>
<td>1</td>
<td>117</td>
<td>63</td>
<td>182</td>
<td>115</td>
</tr>
<tr>
<td>CSF</td>
<td>208</td>
<td>82</td>
<td>2</td>
<td>134</td>
<td>75</td>
<td>212</td>
<td>58</td>
</tr>
<tr>
<td>Hair</td>
<td>58</td>
<td>29</td>
<td>46</td>
<td>205</td>
<td>77</td>
<td>202</td>
<td>47</td>
</tr>
<tr>
<td>Skin, nails</td>
<td>60</td>
<td>29</td>
<td>54</td>
<td>207</td>
<td>78</td>
<td>210</td>
<td>47</td>
</tr>
<tr>
<td>Abscess (closed)</td>
<td>102</td>
<td>63</td>
<td>3</td>
<td>170</td>
<td>90</td>
<td>221</td>
<td>56</td>
</tr>
<tr>
<td>Eye</td>
<td>92</td>
<td>58</td>
<td>4</td>
<td>145</td>
<td>74</td>
<td>217</td>
<td>49</td>
</tr>
<tr>
<td>Ear</td>
<td>95</td>
<td>49</td>
<td>5</td>
<td>162</td>
<td>85</td>
<td>210</td>
<td>47</td>
</tr>
<tr>
<td>Joint fluid</td>
<td>101</td>
<td>72</td>
<td>2</td>
<td>152</td>
<td>80</td>
<td>220</td>
<td>52</td>
</tr>
<tr>
<td>Urine</td>
<td>90</td>
<td>42</td>
<td>2</td>
<td>153</td>
<td>81</td>
<td>208</td>
<td>50</td>
</tr>
<tr>
<td>Tissue</td>
<td>104</td>
<td>74</td>
<td>3</td>
<td>165</td>
<td>84</td>
<td>222</td>
<td>57</td>
</tr>
<tr>
<td>Vaginal</td>
<td>75</td>
<td>33</td>
<td>5</td>
<td>156</td>
<td>75</td>
<td>210</td>
<td>51</td>
</tr>
</tbody>
</table>

BHI, brain heart infusion; CSF, cerebrospinal fluid; DTM, dermatophyte test medium; NCA, noncommercial agar.
† Data are the number of laboratories reporting use. Use of trade names does not imply endorsement by the Association of Public Health Laboratories or the Centers for Disease Control and Prevention.
‡ With chloramphenicol or gentamicin.
§ Of the laboratories responding, 100 use Emmons modification, 88 use the original formula, and 5 use both.
# Respondents wrote in additional media and incubation temperatures. The number is the sum of write-in responses. Some included names of commercial systems or specific media.
A significant difference was observed between different types of laboratories in methods used to identify yeasts. Although 89.0% of respondents used commercial identification systems to identify yeasts, only 60.5% said they included cornmeal agar for identification. State PHLs were more likely than other laboratories to use Wickerham assimilation and fermentation tests and lactophenol cotton blue mounts. A majority, 60% to 79%, used germ-tube tests to identify *Candida albicans*. Of the responding laboratories, 260 indicated their methods for identifying molds (Table 4). State PHLs were most likely to use nucleic acid probes and *Trichophyton* agars (*P* < .01).

### Proficiency Testing Enrollment

The majority (289) of laboratories were enrolled in the College of American Pathologists proficiency testing program, 10 in the New York State Department of Health clinical laboratory evaluation program, 6 in the Wisconsin State Laboratory of Hygiene proficiency testing program, and a few in more than one program. Three laboratories said they were not enrolled in any program, although they were selected from a list of enrolled laboratories.

### Limitations of Resources

Limitations of staff, cost of performance, and test volume were cited, in that order, as the greatest deterrents to offering additional mycology testing in the laboratories. Forty-five respondents stated they would add antifungal drug susceptibility testing if resources (training and funds) were available, 24 would adopt additional staining procedures, and 14 were interested in adding molecular testing. Some laboratories would add identification of dermatophytes and additional yeasts and molds and would perform rapid methods and exoantigen tests.

### Training

Of the 316 laboratories that identify fungi, only 96 (30.3%) indicated that staff members participated in a “wet” workshop in mycology between January 1994 and the date they completed the survey in 1998. One hundred four (32.9%) indicated participation in a symposium or seminar, 44 (13.9%) a teleconference, and 33 (10.4%) a self-study program. Self-study included audio or videotape, print-based material, or information on the World Wide Web. Overall, only 176 (55.7%) of 316 respondents indicated attendance at any mycology training. Table 5 lists topics included in the training programs. Topics infrequently covered in training were mycology-specific quality assurance and biosafety.

Slightly more than 58% of the respondents stated they could receive approval to attend an off-site training program, 35.1% were unsure, and only 6.8% stated they could not. Of the 290 respondents who identified barriers to attending a course, cost was the first choice for 44.0% of the respondents.
24.7% listed personnel shortages, and 17.4% cited distance from the workplace to the training location. A few respondents mentioned program date or time as factors that could influence their ability to attend an offsite program. More state PHLs than other laboratories attended training that included quality assurance in mycology (P < .01). No difference by laboratory type was observed in other questions related to course content.

**Fungi Most Difficult to Identify**

Genera of yeast that respondents said were the most difficult to identify were, in descending order, Hansenula, Trichosporon, and Cryptococcus species. Twenty-seven hospital laboratories listed Candida species other than C albicans as most difficult to identify. Molds most difficult to identify were, in descending order of frequency, species of Trichophyton, Wangiella, Exophiala, and other dematiaceous molds, including Phialophora species.

**Discussion**

This survey was undertaken to assess the mycology education and training needs of medical laboratory staff and to provide a rationale for maintaining or improving fungal diagnostic ability in laboratories in the United States. We reviewed laboratory practices, previous training in mycology, and fungi named as most difficult to identify to evaluate the mycology training needed. Although observing practices and performance of laboratories would yield more accurate information, we were not able to implement such a study on a national scale because of the cost of observing a sufficient number of laboratories. Surveying a random sample of laboratories permitted us to look at gaps between reported practices and recommended practices as a basis for training topics. Although recommended practices for mycology are available, they are quite flexible and can vary with factors such as type of laboratory, geographic area, and diagnostic needs. Therefore, the practices reported herein are evaluated in the light of general recommendations, with full awareness that valid exceptions may occur. Since this level of mycology is performed only in high complexity laboratories, some of the practices reported likely were influenced by inspection.
criteria such as those in College of American Pathologists checklists and those of other accrediting agencies.

Laboratory Practices

A wide variety of practices to identify fungi are used by laboratories. Table 1 shows that laboratories still rely on potassium hydroxide preparations for direct examinations of specimens of hair, skin, and nails and respiratory specimens. Some mycologists recommend Calcofluor white fluorescent brightener for direct examination of these specimens because it binds to cell wall components of fungi, making fungal elements more readily visible. Direct examination is useful as a presumptive screen for fungal infections of the hair, skin, and nails, but unless cultures are prepared, important information may be lost. Knowledge of the causative agent of nail infections can aid in establishing the identity as a dermatophyte or nondermatophyte mold, which may affect treatment options. The majority of the respondents performed both cultures and direct examinations.

Most respondents reported using the India ink preparation for direct examination of CSF specimens, although the latex agglutination test for cryptococcal antigen is considered a superior method to detect Cryptococcus neoformans in CSF. Since C neoformans is the most common fungal pathogen found in CSF, the latex agglutination test is recommended. We could not determine whether our results reflected true practices or whether the latex test was performed in another section of the laboratory.

In some cases, laboratories used more media and performed more extensive identification (Table 2) than is generally recommended for the type of specimen. Including the “other” write-in category, 91 different combinations of media were listed for blood cultures and 71 combinations for CSF cultures. Although some differences in processing these specimens could be due to isolation procedures that would cover both bacteria and fungi, the majority of media listed were fungal isolation media. Often 2 or more media containing antibiotics were used as primary isolation media for blood and CSF cultures. Neither Mycosel (Becton Dickinson Diagnostic Systems, Sparks, MD) nor mycobiotic agar is recommended for normally sterile sites because these media contain cycloheximide and chloramphenicol and, as such, will inhibit yeasts and some potentially pathogenic environmental molds. One such medium may be used to inhibit skin contaminants, but it seems difficult to justify the cost of more than one for a normally sterile site. For the recovery of fungi from blood, bone marrow, CSF, closed abscesses, joint fluid, biopsy samples of deep tissues, and other sterile site specimens, the Emmons modification of Sabouraud glucose agar with chloramphenicol (CAP) is preferred to the original formulation because it contains a lower concentration of glucose, favoring sporulation. Nevertheless, 45.5% of the laboratories reported use of the original formula. Additional use of enriched media such as brain-heart infusion agar or brain-heart infusion agar containing chloramphenicol can improve the recovery of C neoformans, Blastomyces dermatitidis, and Histoplasma capsulatum. A few laboratories have reported use of dermatophyte test medium (DTM) from sterile sites. DTM can be recommended only for hair, nails, or skin scrapings suspected of being infected with a dermatophyte.

DTM was used by approximately 12.5% of responding laboratories for hair, skin, and nail specimens. Another medium, dermatophyte identification medium, has been recommended to replace DTM because it produces fewer false-positive results. Inhibitory mold agar containing chloramphenicol and gentamicin but not cycloheximide can be used to isolate cycloheximide-sensitive fungi that cause clinical infections resembling dermatophytosis. Regarding yeast identification, 89.0% of the laboratories reported using a commercial identification system, while only 60.5% reported including cornmeal agar to aid in observing the morphologic features of yeast (Table 4). By laboratory type, 17 (89%) of 19 state PHLs but only 3 (23%) of 13 POLs and 124 (58.2%) of 213 hospital laboratories reported using cornmeal agar for identification of yeasts. Cornmeal (or similar) agar is essential to determine the isolate’s morphologic features for yeast identification, regardless of whether a commercial or an in-house system of biochemical tests is used. Many clinically important yeasts have identical or almost identical biochemical profiles, in which case, observation of microscopic morphologic features on cornmeal or a similar agar is necessary for identification.

Specific identification of non-C albicans yeast is justified when the yeast is isolated from a sterile site because certain species, notably Candida glabrata and Candida krusei, may be less susceptible to fluconazole, and some isolates of other species may be less susceptible to amphotericin B, eg, Trichosporon beigelii, Candida lusitaniae, and Candida guilliermondii.

Of 220 respondents who reported isolation of molds from sterile sites, 75 (34.1%) identify them only to the genus level, although the potential clinical importance of such molds warrants species identification. On the other hand, 46.5% (105/226) of laboratories identified isolates from nonsterile sites to the species level. Rees et al3 reported that only one quarter of “sterile-intermediate” site isolates reflected clinically significant illness. Responses to our survey suggest that some laboratories routinely identify fungi from nonsterile sites to the species level. It may be possible for laboratories to conserve resources by identifying only this group of fungi at the request of clinicians and/or infectious disease consultants. On the other hand, species identification of fungi even from nonsterile sites such as hair, skin, and nails can help in 2 ways: (1) recognition of new...
fungal pathogens and (2) recognition of new trends. Without species identification, a change in the pathogen causing scalp ringworm would not have been noted. In the 1950s, *Microsporum audouinii* was the leading cause of scalp ringworm in the United States, but it has been almost completely replaced by *Trichophyton tonsurans*. Species identification of dermatophytes also can be justified when there is an outbreak, such as might occur in an elementary school.

Clearly there are some taxa, eg, *Fusarium* species, that represent challenges to species identification. In cases that suggest a strong suspicion of an invasive fungal infection, laboratories that do not have the capacity for species identification may refer problematic molds to reference laboratories or, through the public health infrastructure, to the CDC. Proficiency test results show that many laboratories do not identify some of the more difficult yeast and dermatophyte challenges but refer them to a reference laboratory.

When a yeast is isolated, 70.9% of laboratories rely on germ-tube tests and 89.0% on commercial identification systems. For specimens suspected of containing molds, 10.8% of laboratories reported the use of histologic sections or smears stained for fungal elements. Hence, the inference is that most responding laboratories use culture methods to detect molds. Most POLs reported the use of DTM for isolation of fungi from hair, skin, and nails. These results suggest that most responding laboratories did primarily dermatology offices and clinics.

The continuing threat to public health posed by mycoses, combined with the severity of invasive fungal infections and the difficulty encountered in their treatment, requires a skilled workforce with the capacity to rapidly identify causative agents in time to institute effective antifungal therapy. At the same time, judicious use of appropriate media and test procedures can reduce personnel and supply costs. These findings show that training could provide information to improve laboratory practices in this field. Key findings of an earlier survey of laboratories enrolled in the New York State Department of Health’s proficiency testing program indicated that training was needed in direct examination methods for mycotic specimens, the appropriate use of available media, and improved approaches to the identification of unusual yeasts by decreasing reliance on rapid presumptive tests such as the germ-tube test. Findings were corroborated by the findings of the present survey of a cross-section of US laboratories.

Training

A large number of respondents indicated that none of the staff in the mycology laboratory had received mycology training of any kind between January 1994 and survey completion in the fall of 1998. Because of the rotational nature of assignments to mycology work in many laboratories and the scant attention given to medical mycology in medical laboratory curricula, workers with minimal instruction and experience in mycology may be asked to identify fungi. As a result, many of these employees receive only on-the-job training—a method that presumes that the coworker or supervisor is qualified to provide correct information and will not perpetuate poor practices. Since some practices cited were not consistent with current recommendations and additional training had not been used by laboratory staff, it is possible that less than optimal practices are being perpetuated in some laboratories. The Clinical Laboratory Improvement Amendments of 1988 require supervisors and laboratory directors to verify competency of their employees for all testing they perform. Evaluation of competency rests on the judgment of the employer. One-time competency testing may not be sufficient, especially if the laboratory does not encounter unusual fungi frequently. Laboratory inspections and proficiency testing specimens may help employers identify workers who need additional training in this field. However, a laboratory can only use proficiency testing challenges to educate its staff to the extent that the challenges contain the more difficult fungi that staff might encounter.

Although most colleges and universities with clinical laboratory science (medical technology) programs include mycology in the curriculum, neither the “Checklist” nor the “Standards” as specified by the National Accrediting Agency for Clinical Laboratory Sciences recommends specific content or method of mycology training, and few mycology questions are incorporated into national board examinations. Owing to the potential morbidity and mortality of fungal pathogens, we believe that universities and other educational institutions should place more emphasis on the identification of these pathogens. This is an area in which the skilled laboratory professional can excel.

**Recommendations**

From our survey of laboratory practices and access to training, we conclude that hands-on workshops may be needed now even more than previously. Since they involve time and effort by course participants and host laboratories, continuing education should address the most important needs. In this context, it should be kept in mind that errors leading to misdiagnosis and suffering can be quite costly if not detected. Our results indicate a need for more clinically appropriate and cost-effective practices. Clinically appropriate mycology is the rubric for determining how extensive identification procedures should be. To our knowledge, workshops in mycology that emphasize cost-effective practices have not been conducted. Our results show that most laboratories have written protocols that delineate how to perform direct examinations and the type of media and procedures to use based on the source of the specimen.
However, based on our results, if practices as described by respondents are followed, these protocols must vary greatly among laboratories. Training in medical mycology should be built on a rational approach to isolation techniques for the identification of yeasts and molds using specimen type and clinical relevance. Such basic training underlies the more specialized training needs. As mycology testing evolves, continuing education in intermediate to advanced topics for the already experienced mycologist will be needed in identifying problematic fungi, conducting antifungal susceptibility testing, and, looking to the future, molecular identification using an array of nucleic acid probes.

Fungi Difficult to Identify

Respondents identified certain yeasts and molds as most difficult to identify. Our results show that training is needed in topics that aid in identification, such as rapid methods, biochemical testing, and morphologic features of fungi. Most state PHLs (14/19 [74%]) also perform mycology testing for environmental monitoring. This activity requires an even broader knowledge of mycology since more types of fungi must be identified using specialized procedures for air, water, and surface sampling. Additional training in environmental mycology was requested by laboratories that examine environmental samples.

Since this survey was completed, additional mycology training has been provided by several organizations, with the emphasis on advanced courses focusing on identification procedures. The National Laboratory Training Network (managed by the APHL, Washington, DC, through a cooperative agreement with the CDC) offers training in topics of public health significance, including mycology. Because courses often are given in a series covering different aspects of mycology, the same laboratory personnel may attend, complicating efforts to determine the actual numbers of different participants who attended mycology training. At the time of the survey, 44.4% of responding mycology staff had not participated in any type of continuing education in mycology during the 4 years before the survey.

The emergence of opportunistic fungal infections has increased the complexity of medical mycology practices, underlining the need for laboratory staff to have access to high-quality and clinically relevant continuing education, especially in the absence of specific mycology training or competency requirements in undergraduate clinical laboratory science programs. Our results provide a baseline of practices and training in mycology as of 1998. An extension of the present study would be to conduct an inventory of various resources for continuing education in medical mycology, eg, wet workshops and print-based and electronic media. In addition, laboratory directors and clinicians should collaborate to establish guidelines for appropriate use of the mycology laboratory. Appropriate use of the laboratory in tandem with cost-effective and clinically relevant testing procedures should help clinicians provide timely therapeutic interventions to minimize the morbidity and mortality associated with invasive fungal infections.

Study Limitations

This study has limitations common to data obtained using self-reported surveys. We might have asked laboratories to report the number of specimens processed for mycology and analyzed the results using that information. We purposely did not ask for the numbers of specific fungi isolated because we thought that would decrease our response rate. Our recommendation that training is needed in the use of more cost-effective approaches was based on our assessment of the practices reported, rather than on actual cost-effectiveness studies. Nevertheless, we believe that the results provide a basis for further discussion of more standardization of medical mycology practices, minimal education requirements, and measures of competency of mycology staff.

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