# Laboratory Medicine Education at U.S. Medical Schools: A 2014 Status Report

Brian R. Smith, MD, Malek Kamoun, MD, PhD, and John Hickner, MD, MSc


## Abstract

### Purpose
To assess the current state of laboratory medicine education at U.S. medical schools.

### Method
From 2013 to 2014, the authors surveyed the appropriate dean, department chair, or undergraduate education director at each U.S. medical school accredited by the Liaison Committee on Medical Education about the state of laboratory medicine education, curriculum and competency assessment, and barriers to education at his or her institution. The authors used descriptive statistics to analyze the results.

### Results
The authors received 98 (75%) responses. Eighty-two schools (84%) offered course work in laboratory medicine; 76 (78%) required it. The median number of hours of required course work was 12.5, with 8.0 devoted to lectures and 4.5 to small-group, problem-based learning and/or laboratory sessions. Only 8 schools required training in a clinical setting. Fewer than half reported regular, formal review of the laboratory medicine curriculum. The assessment of students' competency in laboratory medicine was rare (8 schools), and only half of respondents were aware of published curriculum guidelines. Barriers to teaching laboratory medicine included lack of sufficient time in the preclinical curriculum (86; 88%) or clinical curriculum (84; 86%), lack of knowledge of best laboratory practices by residents (70; 72%), lack of student interest (62; 63%), and lack of knowledge by attending physicians (58; 59%). Half of respondents were likely to use a national standardized examination to assess competency in laboratory medicine, if one was available.

### Conclusions
Significant opportunities exist to improve laboratory medicine education, including in the proper use and interpretation of clinical laboratory testing.


The importance of cost-effective laboratory test use in both optimizing patient outcomes and controlling overall medical expenditures is well recognized in the medical and policy-making communities.[1–6] In 2008, the Centers for Disease Control and Prevention (CDC) commissioned a study entitled "Laboratory Medicine: A National Status Report" which noted:

> An integral component of care is laboratory medicine, which extends across research, clinical (i.e., screening, diagnosis, and treatment), and public health settings. Laboratory services account for only 2.3% of total health care expenditures; however, they have a significant role in informing health care decisions and spending. Appropriate use of laboratory testing is essential for achieving safe, effective, and efficient care to patients.[7]

Subsequently, a May 2009 update[8] to the study commented on the state of undergraduate medical education in this area:

> Medical education on laboratory testing is inadequate. Despite the integral role of laboratory testing in the practice of medicine, formal teaching of laboratory medicine is a relatively neglected component of the medical school curriculum.[9] … Without sufficient knowledge of laboratory tests, health care providers are more prone to inappropriate ordering and mistakes in interpreting test results, which can lead to poor case management, increased costs per patient, and adverse outcomes.[10*]

The challenges that medical students and practitioners at all levels face in ordering and interpreting laboratory tests have been well documented.[1–3,11,12]

*Original citation numbers updated by the authors to correspond to the numbering of this article's reference list.

A survey of laboratory medicine education at U.S. medical schools was carried out in 1992 by the Academy of Clinical Laboratory Physicians and Scientists.[13] At that time, 69% of schools had a course in laboratory medicine, and 57% had at least one required course. Since then, surveys of general pathology education[14,15] have been conducted, but no formal surveys have focused on the principles of test ordering and test interpretation. Yet, over the past 20 years, increasingly those in health care have come to recognize the importance of proper test ordering and interpretation to optimizing the use of health care resources.[1–6] Moreover, curricula in laboratory medicine and its subspecialties have been published to aid in this educational endeavor,[16–21] and laboratory medicine teaching innovations involving problem-based learning, electronic resources, and integrated preclinical/clinical approaches have been promoted.[22–24] In addition, the role of formal laboratory medicine consultation services in the management of patients has grown significantly at many medical centers in response to the need for the accurate and timely diagnosis of hospitalized patients.[25–31] Because of these changes, we performed a comprehensive survey to determine the current state of

**B.R. Smith** is professor and chair, Department of Laboratory Medicine, Yale School of Medicine, New Haven, Connecticut.

**M. Kamoun** is professor, Department of Pathology and Laboratory Medicine, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, Pennsylvania.

**J. Hickner** is head, Department of Family Clinical Medicine, University of Illinois College of Medicine, Chicago, Illinois.

Correspondence should be addressed to Brian R. Smith, Department of Laboratory Medicine, Yale School of Medicine, 333 Cedar St., PO Box 208035, New Haven, CT 06520-8035; telephone: (203) 688-2286; e-mail: brian.smith@yale.edu.

Acad Med. XXXX;XX:00–00.
First published online
*doi: 10.1097/ACM.0000000000000817*

Supplemental digital content for this article is available at http://links.lww.com/ACADMED/A294.



Copyright © by the Association of American Medical Colleges. Unauthorized reproduction of this article is prohibited.

laboratory medicine education at U.S. medical schools, especially as it pertains to test ordering and interpretation, to act as a baseline for future improvements.

## Method

In 2013–2014, we conducted a survey of all U.S. medical schools accredited by the Liaison Committee on Medical Education (LCME) as of 2010. We used the LCME Web site to identify these schools.[32] We eliminated the 17 Canadian and 4 Puerto Rican schools from our analysis (for a total of 131 of 152 LCME-accredited schools) to have a sample that was comparable to those in the studies by Gottfried et al[13] and Kumar et al.[15]

We attempted to contact three individuals from each medical school by mail and e-mail: (1) the individual identified as the associate dean/deputy dean/dean for education, (2) the chair of the Department of Pathology and Laboratory Medicine or the chair of the Department of Laboratory Medicine (if the departments were independent), and (3) the director of undergraduate medical education for laboratory medicine or, if not separately identified, the director of undergraduate medical education for pathology. The deans for education were identified either from data provided by the Association of American Medical Colleges or from the medical schools' Web sites. The chairs of pathology and laboratory medicine and the directors of undergraduate education in laboratory medicine were identified from data provided by the Association of Pathology Chairs. The communication requested that the most appropriate of the three individuals complete the survey. After an initial solicitation by regular mail and by e-mail, up to two reminder notices were sent to nonrespondents.

We and a group of academic pathologists, primary care physicians, and laboratorians from the CDC's Clinical Laboratory Integration into Health Care work group iteratively developed the survey.[33] It consisted of 15 questions with explanatory material (see Supplemental Digital Appendix 1 at http://links.lww.com/ACADMED/A294). We patterned several questions after the survey by Gottfried et al[13] to provide a basis for comparison. Questions explored time devoted to laboratory medicine instruction, timing of instruction within the curriculum, and the format used; required versus elective course work; whether schools had a formal review of the curriculum and/or competency assessment specifically devoted to clinical laboratory topics; disciplines of the instructors; the presence or absence of a laboratory medicine clinical consultation service at the institution; knowledge and use of published curricula; perceived barriers to education in the discipline; and whether a national assessment tool would be desirable. Because laboratory medicine clinical consultation services are an evolving area of medical practice, we also asked about opportunities for students to participate on these services, if offered.

Regarding time in the curriculum devoted to laboratory medicine education, we provided this definition: "Schools teach principles of clinical laboratory medicine in different parts of the curriculum. For this survey, we define formal Laboratory Medicine teaching as activities whose primary goal is to instruct in or to evaluate knowledge of the correct way to order and interpret laboratory tests."

We used descriptive statistics to analyze the results, reporting frequencies of responses here (GraphPad Prism 6 for Windows, version 6.03; GraphPad Software, Inc., La Jolla, California).

The Yale institutional review board reviewed the survey protocol and found it to be exempt from committee review.

## Results

Of the 131 schools included in our study, we received a response from a representative from 98 schools, for a response rate of 75%. Twenty-three responses (23%) were from deans of education, and 75 (77%) were from course directors.

### Required courses in laboratory medicine

Eighty-two schools (84%) offered some course work in laboratory medicine; 76 (78%) required it during the first two years. Nineteen schools (19%) also required course work in the clinical years. Forty-five (46%) required it in year one, and 74 (76%), 16 (16%), and 10 (10%) in years two, three, and four, respectively. Five schools with required course work (7% of those with required course work) had a separate, distinct course in laboratory medicine, whereas 71 (93%) included laboratory medicine as part of an integrated curriculum.

For the 76 schools that required laboratory medicine course work, the mean total number and range of hours of instruction by format and year are shown in Table 1. The median number of hours of instruction was 12.5, with 8.0 hours devoted to lectures and 4.5 hours devoted to small-group problem-based learning and/or laboratory sessions. All required course work included a lecture component. At approximately half of the schools, the course work included either laboratory sessions or small-group learning. At 17 schools (22%), it included both laboratory and small-group components; at 35 schools (46%), it included one or the other.

Whereas 14 schools (18%) of the 76 that required laboratory medicine course work mandated some form of training during the clinical years, only 8 (11%) did so in a clinical setting (versus in lectures), usually a brief "apprentice" experience with a clinical pathologist. The median time devoted to such activities was 8.0 hours.

Of the 76 schools that required laboratory medicine course work, less than a quarter (16; 21%) required digital or electronic learning exercises to supplement small-group or laboratory activities. The median time devoted to such exercises was 3.0 hours.

At 81 schools (99%), of the 82 with any laboratory medicine course work, pathologists were involved in the teaching, and at 81 schools (99%) they played a leadership role. At 61 schools (74%), internists taught laboratory medicine, and at 31 schools (38%) they played a leadership role. Similarly, at 61 schools (74%), family medicine physicians taught the laboratory medicine curriculum and, at 6 schools (7%) they played a leadership role. PhD laboratorians, medical technologists, and pathology residents participated in the teaching at 61 (74%), 44 (54%), and 61 (74%) schools, respectively, holding leadership roles at 30 (37%), 7 (9%), and 6 (7%) schools.

### Elective courses in laboratory medicine

Of all 98 schools, 6 (6%) offered an elective course in laboratory medicine during the preclinical component of the



Copyright © by the Association of American Medical Colleges. Unauthorized reproduction of this article is prohibited.

Table 1

**Format and Length (in Hours) of Required Course Work in Laboratory Medicine, by Year of Medical School, 2013–2014**

| Format[a] | Year 1 | Year 2 | Year 3 | Year 4 | Total |
|---|---|---|---|---|---|
| **Lectures** | | | | | |
| No. (%) utilization | 35 (46) | 65 (86) | 11 (14) | 5 (7) | 76 (100) |
| Mean length (range) in hours | 2.6 (0–24) | 11.0 (0–105) | 0.6 (0–20) | 0.2 (0–8) | 14.5 (1–105) |
| **Laboratory sessions** | | | | | |
| No. (%) utilization | 12 (16) | 32 (42) | 3 (4) | 4 (5) | 40 (53) |
| Mean length (range) in hours | 0.7 (0–10) | 5.6 (0–110) | 0.1 (0–3) | 0.3 (0–12) | 6.5 (0–110) |
| **Small-group learning** | | | | | |
| No. (%) utilization | 21 (28) | 36 (47) | 8 (10) | 4 (5) | 43 (57) |
| Mean length (range) in hours | 1.6 (0–34) | 6.1 (0–100) | 0.8 (0–20) | 0.3 (0–10) | 8.5 (0–120) |
| **Clinical consultations** | | | | | |
| No. (%) utilization | 1 (1) | 3 (4) | 5 (6) | 4 (5) | 8 (11) |
| Mean length (range) in hours | 0.0 (0–2) | 0.1 (0–2) | 0.3 (0–8) | 0.5 (0–20) | 0.9 (0–20) |
| **Electronic/digital exercises** | | | | | |
| No. (%) utilization | 1 (1) | 13 (17) | 4 (5) | 1 (1) | 16 (21) |
| Mean length (range) in hours | 0.0 (0–2) | 0.8 (0–18) | 1.2 (0–96) | 0.0 (0–2) | 2.1 (0–96) |

[a]Utilization reflects the no. (%) of responding medical schools that required instruction in each format (lectures, laboratory sessions, small-group learning, clinical consultations, electronic/digital exercises) in the designated year of medical school.

curriculum in lieu of a required course. Seventy-two schools (73%) offered an elective course at some point in the curriculum, either in addition to or in lieu of a required course. Of those offering elective opportunities, 2 (2%) had an optional course in the first year, and 9 (9%), 33 (34%), and 73 (74%) had one in the second, third, and fourth years, respectively.

Examples of elective opportunities include a pathology elective that had laboratory medicine components (53; 74%); a dedicated laboratory medicine elective separate from a surgical pathology/autopsy elective (42; 58%); a general internship "survival course" that included formal instruction in laboratory medicine, among many components (12; 17%); a specialized internship "survival course" dedicated almost exclusively to laboratory medicine, or to laboratory medicine, diagnostic imaging, and other diagnostic modalities (6; 8%); and "other" (9; 13%). Among the "other" types of activities, subspecialty electives were most common (e.g., blood bank, hematopathology, clinical chemistry, microbiology).

Table 2

**Overview of U.S. Medical School's Laboratory Medicine Curricula and Competency Assessments, 2013–2014**

| Survey item | No. (% of 98) respondents: Yes | No |
|---|---|---|
| Does your school periodically have a formal review of the overall laboratory medicine curriculum by laboratory medicine/pathology physicians? | 41 (42) | 57 (58) |
| Does your school periodically have a formal review of the overall laboratory medicine curriculum by a committee whose task is to evaluate the adequacy of the curriculum in this area? | 26 (27) | 72 (73) |
| Is competency in clinical laboratory medicine formally evaluated as a distinct curriculum component? | 8 (8) | 90 (92) |
| Are you aware of nationally published curricula in laboratory medicine, such as that proposed by the Academy of Clinical Laboratory Physicians and Scientists (ACLPS)? | 50 (51) | 48 (49) |
| Do you utilize nationally published curricular guidelines in the formulation of your school's medical student curriculum? | 46 (47) | 52 (53) |

### Laboratory medicine curricula and competency assessments

As shown in Table 2, a minority of schools had a formal review process for their laboratory medicine curriculum, and few schools separately assessed students' competency in the discipline. Slightly more than half (50; 51%) were aware of the nationally published curriculum guidelines, and slightly less than half (46; 47%) used those guidelines in curriculum development.

As shown in Table 3, about half of respondents (49; 50%) were either very or somewhat likely to use a national standardized exam to assess competency in laboratory medicine, if one was available.

### Influence of a formal laboratory medicine clinical consultation service on medical student education

Fifty-one schools (52%) had a laboratory medicine consultation service at one or more of their affiliated teaching hospitals. The specific disciplines covered by these services included coagulation (50; 98%) and hematology (47; 92%), microbiology/virology (40; 78%), toxicology and therapeutic drug monitoring (37; 73%), genetic testing (32; 63%), and endocrinology (29; 57%). Thirty-seven schools (73%) included medical students on their services. The median number of students participating on these services per year was 3.0, with a mean of 6.9 students.

### Barriers to optimizing laboratory medicine education

Table 4 summarizes the barriers to optimizing laboratory medicine education. Lack of time in the preclinical and clinical curricula was the most frequently cited barrier, followed by lack of knowledge of best laboratory practices by interns and residents, lack of medical student interest, and lack of knowledge of best practices by attendings.

## Discussion

The dramatic growth in available laboratory testing has reinforced the need for optimal medical student education in laboratory medicine. It is, therefore, encouraging that the percentage of schools that offer laboratory medicine course work has increased since the study by Gottfried et al.[13] In 1992, 69%



Copyright © by the Association of American Medical Colleges. Unauthorized reproduction of this article is prohibited.

Table 3

**Perceived Utility of a National Laboratory Medicine Assessment Tool to Evaluate Medical Students' Competency, 2013–2014**

| Survey item | No. (% of 98) respondents | | | |
|---|---|---|---|---|
| | Very likely | Somewhat likely | Somewhat unlikely | Very unlikely |
| If a national standardized examination in clinical laboratory medicine designed for medical students were easily available, how likely is it that your school would use it? | 14 (14) | 35 (36) | 31 (32) | 18 (18) |
| How likely would you be to use such a national standardized exam to: | | | | |
| Benchmark your institution by offering it to your students on a voluntary, anonymous basis? | 10 (10) | 35 (36) | 24 (24) | 29 (30) |
| Benchmark your institution by offering it to your students on a required, but anonymous, basis? | 8 (8) | 21 (21) | 28 (29) | 41 (42) |
| Help evaluate your students and institution by offering it to students on a voluntary, nonanonymous basis? | 4 (4) | 35 (36) | 32 (33) | 27 (27) |
| Help evaluate your students and institution by offering it to students on a required, nonanonymous basis? | 10 (10) | 30 (31) | 24 (24) | 34 (35) |

of schools taught laboratory medicine compared with 84% today. Laboratory medicine course work is now required at 78% of schools compared with 57% in 1992. Gottfried et al reported a longer duration for laboratory medicine courses, noting an average of 28.8 hours of lectures, 26.4 hours of laboratory sessions, and 19.3 hours of workshops compared with the 14.5, 6.5, and 8.5 hours, respectively, that we found. However, these numbers are not directly comparable because the 1992 study did not distinguish between required and elective hours of instruction. Moreover, we recognize that, despite careful instructions to respondents to include all laboratory medicine instruction regardless of where it is in the curriculum, some inaccuracy in the estimation of hours devoted to this teaching is likely because portions of lectures and workshops devoted primarily to physiology and therapy may incorporate aspects of diagnostic testing that were not captured in the total hours reported by respondents.

The distribution of required hours between the different instructional formats has not changed significantly over the years, with the exception of the addition of more small-group, problem-based learning. In a 1999 survey,[15] laboratory medicine instruction was not specifically addressed, but general pathology instruction was: Lectures accounted for 53% of the course work, laboratory sessions for 24%, and small-group learning for 18%. We found that lectures accounted for 49% of laboratory medicine instruction, laboratory sessions for 22%, and small-group learning for 29%.

Table 4

**Perceived Barriers to Optimizing Laboratory Medicine Education at Medical Schools, 2013–2014**

| Barrier | No. (% of 98) respondents | | | |
|---|---|---|---|---|
| | Major barrier | Problematic | Nuisance | Not an issue |
| Lack of time in preclinical curriculum | 56 (57) | 30 (31) | 8 (8) | 4 (4) |
| Lack of time in clinical curriculum | 48 (49) | 36 (37) | 10 (10) | 3 (3) |
| Lack of laboratory medicine knowledge by residents | 32 (33) | 38 (39) | 14 (14) | 14 (14) |
| Lack of medical student interest | 23 (23) | 39 (40) | 27 (28) | 9 (9) |
| Lack of laboratory medicine knowledge by attendings | 24 (25) | 34 (35) | 18 (18) | 22 (22) |
| Lack of sufficiently qualified faculty | 6 (6) | 24 (25) | 12 (12) | 56 (57) |
| Lack of published guidelines | 2 (2) | 24 (24) | 27 (28) | 45 (46) |
| Lack of adequate instructional material | 3 (3) | 16 (16) | 23 (24) | 56 (57) |
| Lack of standardized nomenclature | 0 (0) | 7 (7) | 25 (26) | 66 (67) |

Nearly all schools (93%) incorporated laboratory medicine instruction into an integrated curriculum, compared with 65% in 1992. This shift represents a continuing trend in medical education. Prior studies have suggested that incorporating pathology-related disciplines into an integrated curriculum neither diminishes nor enhances students' performance as measured by standardized examinations, such as the United States Medical Licensing Examination.[34] By contrast, several groups have noted the advantages of incorporating laboratory and pathology education into the clinical phase of the undergraduate medical curriculum and especially into direct patient care settings.[21–24] Although elective opportunities in laboratory medicine in the clinical years are available at many schools, relatively few (11%) require training in real clinical settings.

Formal laboratory medicine consultation services have been created at many institutions over the last 15 to 20 years.[25–30] We found that only 52% of schools had such a service at one or more of their affiliated teaching hospitals. Because nonpathologist physicians cannot be expected to have expertise in all areas of laboratory medicine, we believe it is of paramount importance to expand this type of team-based practice of clinical diagnosis, in which pathologists serve as consultants to advise primary care physicians and specialists on individual cases and advise health care systems in establishing efficient diagnostic protocols. Such services provide an ideal venue for medical student training in a clinical setting.

Regarding course and student assessment, respondents reported that formal review of the laboratory medicine curriculum occurred at less than half of the medical schools. Moreover, only about half were aware of published guidelines



Copyright © by the Association of American Medical Colleges. Unauthorized reproduction of this article is prohibited.

for education in this area, and fewer than 10% reported assessing students' competency in laboratory medicine. Likely, some schools review selected areas of laboratory medicine—for example, microbiology test interpretation and use by infectious disease groups. Similarly, competency in laboratory medicine likely is tested at least in part during specific clerkships, such as internal medicine, family medicine, and pediatrics, and during some specialty rotations. However, given the widespread concern over the misuse of laboratory tests and wasteful spending, as evidenced by the rapid endorsement of the Choosing Wisely campaign[6] by medical specialty organizations, a targeted assessment of medical student knowledge in test ordering and interpretation is an important and necessary step toward improving the efficiency of laboratory test use in our health care delivery system. Indeed, half of respondents expressed an interest in a voluntary national standardized testing mechanism.

We identified a number of barriers to optimizing laboratory medicine education. A major concern was the limited time devoted to the discipline. As medical knowledge continues to increase exponentially, time constraints during undergraduate medical education are a significant challenge. Novel approaches for better integrating laboratory medicine are needed. Another barrier is that we do not know the level of competency in laboratory medicine that is needed for good clinical practice. If a national assessment of knowledge (competency) could be implemented, educators could determine whether the current level of instruction is in fact accomplishing its goal. Moreover, such a tool would allow individual medical schools to adjust their curricula in a targeted fashion to ensure that students receive appropriate instruction.

Also concerning is our finding that 63% of respondents reported lack of student interest as a major barrier to optimizing laboratory medicine education. This finding needs further exploration with qualitative methods. Faculty may not be communicating to medical students the importance and relevance of laboratory medicine to the daily practice of modern medicine. The critical role of the laboratory in therapeutic decision making has been documented for several decades,[35] and thus it is disappointing that respondents described students as showing tepid interest in the topic.

Another important, and possibly related, concern is that residents and fellows, as well as some attending physicians, lack sufficient knowledge and skills in laboratory medicine to be good role models for students. This finding suggests a catch-22, in that each generation fails to adequately learn the topic and hence fails to adequately instruct the next generation, making it difficult to break this cycle. The best solution may be improved physician education at all levels of training as well as implementation of a faculty development plan for teaching laboratory medicine. Furthermore, ongoing efforts in the development of laboratory medicine clinical consultation services may help to ameliorate this problem. Finally, medical students' disinterest in the topic may be addressed in part by the same solutions. Often, students' attitudes reflect those of their immediate "elder peers" (i.e., residents and fellows). If the latter become convinced of the need for better laboratory testing ordering and interpretation, then students may follow suit. Improvements in physicians' education in laboratory medicine, in concert with the implementation of a team-based practice in which the pathologist serves as a consultant, should help effect a change in the attitudes and practice of physicians at all levels. We believe that such changes are necessary to meet the needs of today's health care delivery system.

A limitation of this and previous surveys is that they do not specifically evaluate learning objectives and milestones. Defining objectives that are attainable, relevant, and measurable is an important step in curriculum development. The objectives and the relevance of the material then need to be clearly communicated to the students for successful implementation of the curriculum. Importantly, national standards, developed by more than 50 pathologists, for teaching pathology and laboratory medicine were recently proposed.[36] Applying these standards locally at medical schools would be an important step in the right direction. The authors also suggest incorporating recorded media, online simulations, and interactions with databases into the curriculum to ensure that students gain the basic competencies in laboratory medicine necessary for clinical practice. However, doing so might not be sufficient to engage students to become active learners; improving interactions with faculty and role modeling are critical. Furthermore, medical schools should develop a rigorous course evaluation to ensure that effective teaching in the discipline is occurring and that continuous improvements are being made in response to outcomes assessments.

In summary, more medical schools today require laboratory medicine course work than did 20 years ago, but the effectiveness of these courses to train physicians to practice efficient and safe diagnostic testing and ultimately serve the public remains uncertain.

*Acknowledgments:* The Clinical Laboratory Integration into Healthcare Collaborative (CLIHC), established by the Centers for Disease Control and Prevention Division of Laboratory Programs, Standards, and Services in 2008, focuses on optimizing clinicians' use of laboratory services to improve patient care. The members of CLIHC were instrumental in initiating and providing advice for this study, especially Dr. Julie Taylor, Ms. Pamela J. Thompson, Ms. Anne M. Pollock, Ms. Elissa Passiment, Dr. Jim Meisel, Mr. Paul Epner, Dr. Michael Laposata, and Dr. Marisa Marques. The authors also acknowledge Dr. Carolyn Cambor, who reviewed the survey materials and provided helpful written comments. They are grateful for the cooperation of the Association of American Medical Colleges (especially M. Brownell Anderson, MEd), the American Medical Association Medical Student Section (especially Matthew Stull, MD), and the Association of Pathology Chairs (APC) for providing information on the institutional officials involved in laboratory medicine education, and to the APC for providing financial support for this effort.

*Funding/Support:* This work was supported in part by a grant from the Association of Pathology Chairs.

*Other disclosures:* None reported.

*Ethical approval:* The Yale institutional review board reviewed the survey protocol and found it to be exempt from committee review.

## References

1 Kim JY, Dzik WH, Dighe AS, Lewandrowski KB. Utilization management in a large urban academic medical center: A 10-year experience. Am J Clin Pathol. 2011;135:108–118.
2 Warren JS. Laboratory test utilization program: Structure and impact in a large academic medical center. Am J Clin Pathol. 2013;139:289–297.



Copyright © by the Association of American Medical Colleges. Unauthorized reproduction of this article is prohibited.

3 Hickner J, Thompson PJ, Wilkinson T, et al. Primary care physicians' challenges in ordering clinical laboratory tests and interpreting results. J Am Board Fam Med. 2014;27:268–274.
4 Cooke M. Cost consciousness in patient care—what is medical education's responsibility? N Engl J Med. 2010;362:1253–1255.
5 Procop GW, Yerian LM, Wyllie R, Harrison AM, Kottke-Marchant K. Duplicate laboratory test reduction using a clinical decision support tool. Am J Clin Pathol. 2014;141:718–723.
6 ABIM Foundation. Choosing Wisely: An Initiative of the ABIM Foundation. http://www.choosingwisely.org/. Accessed May 19, 2015.
7 Lewin Group. Laboratory medicine: A national status report. Prepared for: Division of Laboratory Systems, National Center for Preparedness, Detection, and Control of Infectious Diseases, Centers for Disease Control and Prevention. May 2008. http://wwwn.cdc.gov/futurelabmedicine/pdfs/2007%20status%20report%20laboratory_medicine_-_a_national_status_report_from_the_lewin_group_updated_2008-9.pdf. Accessed May 19, 2015.
8 The Lewin Group. Laboratory medicine: A national status report. Prepared for: Division of Laboratory Systems, National Center for Preparedness, Detection, and Control of Infectious Diseases, Centers for Disease Control and Prevention. Updated May 2009 [no longer available].
9 Burke MD. Clinical laboratory consultation. Clin Chem. 1995;41:1237–1240.
10 van Walraven C, Naylor CD. Do we know what inappropriate laboratory utilization is? A systematic review of laboratory clinical audits. JAMA. 1998;280:550–558.
11 Bergus G, Vogelgesang S, Tansey J, Franklin E, Feld R. Appraising and applying evidence about a diagnostic test during a performance-based assessment. BMC Med Educ. 2004;4:20.
12 Iwashyna TJ, Fuld A, Asch DA, Bellini LM. The impact of residents, interns, and attendings on inpatient laboratory ordering patterns: a report from one university's hospitalist service. Acad Med. 2011;86:139–145.
13 Gottfried EL, Kamoun M, Burke MD. Laboratory medicine education in United States medical schools. Am J Clin Pathol. 1993;100:594–598.
14 Taylor CR, DeYoung BR, Cohen MB. Pathology education: Quo vadis? Hum Pathol. 2008;39:1555–1561.
15 Kumar K, Indurkhya A, Nguyen H. Curricular trends in instruction of pathology: A nationwide longitudinal study from 1993 to present. Hum Pathol. 2001;32:1147–1153.
16 Wartman S, Davis A, Wilson M, Kahn N, Sherwood R, Nowalk A. Curricular change: Recommendations from a national perspective. Acad Med. 2001;76(4 suppl):S140–S145.
17 Magid MS, Cambor CL. The integration of pathology into the clinical years of undergraduate medical education: A survey and review of the literature. Hum Pathol. 2012;43:567–576.
18 Smith BR, Aguero-Rosenfeld M, Anastasi J, et al. Educating medical students in laboratory medicine: A proposed curriculum. Am J Clin Pathol. 2010;133:533–542.
19 Wieringa G, Zerah S, Jansen R, et al. The EC4 European syllabus for post-graduate training in clinical chemistry and laboratory medicine: Version 4–2012. Clin Chem Lab Med. 2012;50:1317–1328.
20 Wilson ML. Educating medical students in laboratory medicine. Am J Clin Pathol. 2010;133:525–528.
21 Haspel RL, Bhargava P, Gilmore H, et al. Successful implementation of a longitudinal, integrated pathology curriculum during the third year of medical school. Arch Pathol Lab Med. 2012;136:1430–1436.
22 Molinaro RJ, Winkler AM, Kraft CS, et al. Teaching laboratory medicine to medical students: Implementation and evaluation. Arch Pathol Lab Med. 2012;136:1423–1429.
23 Guidi GC, Lippi G, Plebani M. The holistic approach to teach laboratory medicine. Clin Chim Acta. 2008;393:51–53.
24 Elnicki DM, Taylor HL. An interdisciplinary approach to teaching clinical laboratory skills to medical students. Acad Med. 1997;72(10 suppl 1):S60–S62.
25 Klein RD, Kant JA. Opportunity knocks: The pathologist as laboratory genetics consultant. Arch Pathol Lab Med. 2006;130:1603–1604.
26 Burke MD. Clinical laboratory consultation: Appropriateness to laboratory medicine. Clin Chim Acta. 2003;333:125–129.
27 Kratz A, Laposata M. Enhanced clinical consulting—moving toward the core competencies of laboratory professionals. Clin Chim Acta. 2002;319:117–125.
28 Marques MB, Fritsma GA, Long JA, Adler BK. Clinical pathology consultation improves coagulation factor utilization in hospitalized adults. Am J Clin Pathol. 2003;120:938–943.
29 Marques MB, Anastasi J, Ashwood E, et al. The clinical pathologist as consultant. Am J Clin Pathol. 2011;135:11–12.
30 Karaarslan I. Joint Commission on International Accreditation workshop: Planning, development and provision of laboratory services. Clin Biochem. 2009;42:284–287.
31 Rollins G. The path to better test utilization: Why labs should step-up physician education, consultation. Clin Lab News. September 1, 2012. https://www.aacc.org/publications/cln/articles/2012/september/test-utilization. Accessed May 19, 2015.
32 Liaison Committee on Medical Education Web site. http://www.lcme.org/. Accessed May 19, 2015.
33 Clinical Laboratory Integration Into Healthcare Collaborative, Centers for Disease Control and Prevention. Division of laboratory programs, standards, and services. http://www.cdc.gov/ophss/csels/dlpss/eblm/index.html. Accessed May 19, 2015.
34 Kumar K, Indurkhya A. Changes in pathology instruction and student performance on the United States Medical Licensing Examination Step 1, 1995–2000: A nationwide 6-year longitudinal study. Hum Pathol. 2004;35:1435–1439.
35 Forsman RW. Why is the laboratory an afterthought for managed care organizations? Clin Chem. 1996;42:813–816.
36 Sadofsky M, Knollmann-Ritschel B, Conran RM, Prystowsky MB. National standards in pathology education: Developing competencies for integrated medical school curricula. Arch Pathol Lab Med. 2014;138:328–332.




Copyright © by the Association of American Medical Colleges. Unauthorized reproduction of this article is prohibited.