Teaching Laboratory Medicine to Medical Students

Implementation and Evaluation

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• ***Context.*—Laboratory medicine is an integral component of patient care. Approximately 60% to 70% of medical decisions are based on laboratory results. Physicians in specialties that order the tests are teaching medical students laboratory medicine and test use with minimal input from laboratory scientists who implement and maintain the quality control for those tests.**

***Objective.*—To develop, implement, and evaluate a 1.5-day medical student clinical laboratory experience for fourth-year medical students in their last month of training.**

***Design.*—The experience was devised and directed by laboratory scientists and included a panel discussion, laboratory tours, case studies that focused on the goals and objectives recently published by the Academy of Clinical Laboratory Physicians and Scientists, and medical-student presentations highlighting salient points of the experience. The same knowledge quiz was administered at the beginning and end of the experience and 84 students took both quizzes.**

***Results.*—A score of 7 or more was obtained by 16 students (19%) on the initial quiz, whereas 34 (40%) obtained the same score on the final quiz; the improvement was found to be statistically significant ($P = .002$; $t = 3.215$), particularly in 3 out of the 10 questions administered.**

***Conclusions.*—Although the assessment can only measure a small amount of knowledge recently acquired, the improvement observed by fourth-year medical students devoting a short period to learning laboratory medicine principles was encouraging. This medical student clinical laboratory experience format allowed teaching of a select group of laboratory medicine principles in 1.5 days to an entire medical school class.**

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Laboratory results provide objective data about patient health across the continuum of patient care.[1] In addition, laboratory results enable health care providers to assess early disease risk, opt for preventive therapies or less-invasive treatment, select and monitor appropriate treatment, and follow the natural progression of diseases.[1] The pressure for physicians to see more patients in many settings limits the time for data collection from patient interviews and examinations. As a result, physicians increasingly rely on laboratory test results in addition to other clinical data commonly generated by health care professionals outside of direct patient contact (such as radiology).[2] The number, type, and complexity of laboratory testing have increased markedly during the past 50 years. In addition, when laboratory tests are used appropriately, health care providers contribute to optimizing the use of health care resources and decrease short-, medium-, and long-term costs of care.[3]

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Although the purpose of medical education is to transmit the knowledge, impart the skills, and instill the values of the profession in an appropriately balanced and integrated manner and the Flexner report of 1910 helped standardize curricula in the United States,[4–6] very little formal education in laboratory medicine currently exists in most traditional medical school curricula.[2] Pathology has traditionally been taught as an independent 6- to 12-month course with an emphasis in pathogenesis and how tissues are affected from the anatomic pathology perspective but with little emphasis on laboratory medicine. To compound the issue, many medical schools have modified their curricula, so the different topics are presented in a more-integrated context. As a result, physicians in different specialties teach medical students the tests they use. This instruction occurs without input from the clinical laboratory professionals who have implemented the tests in the clinical laboratory and have the training to understand their utility, their limitations, and the regulatory components necessary for providing the service.

In 2011, we implemented a CAPSTONE course in the final month of the students' fourth year, after the National Resident Matching Program. The primary goal of CAPSTONE was to ensure that students were ready for the next phase of their medical education by focusing on the Accreditation Council for Graduate Medical Education core competencies, including Systems-Based Practice.[7] All fourth-year medical students were required to attend the

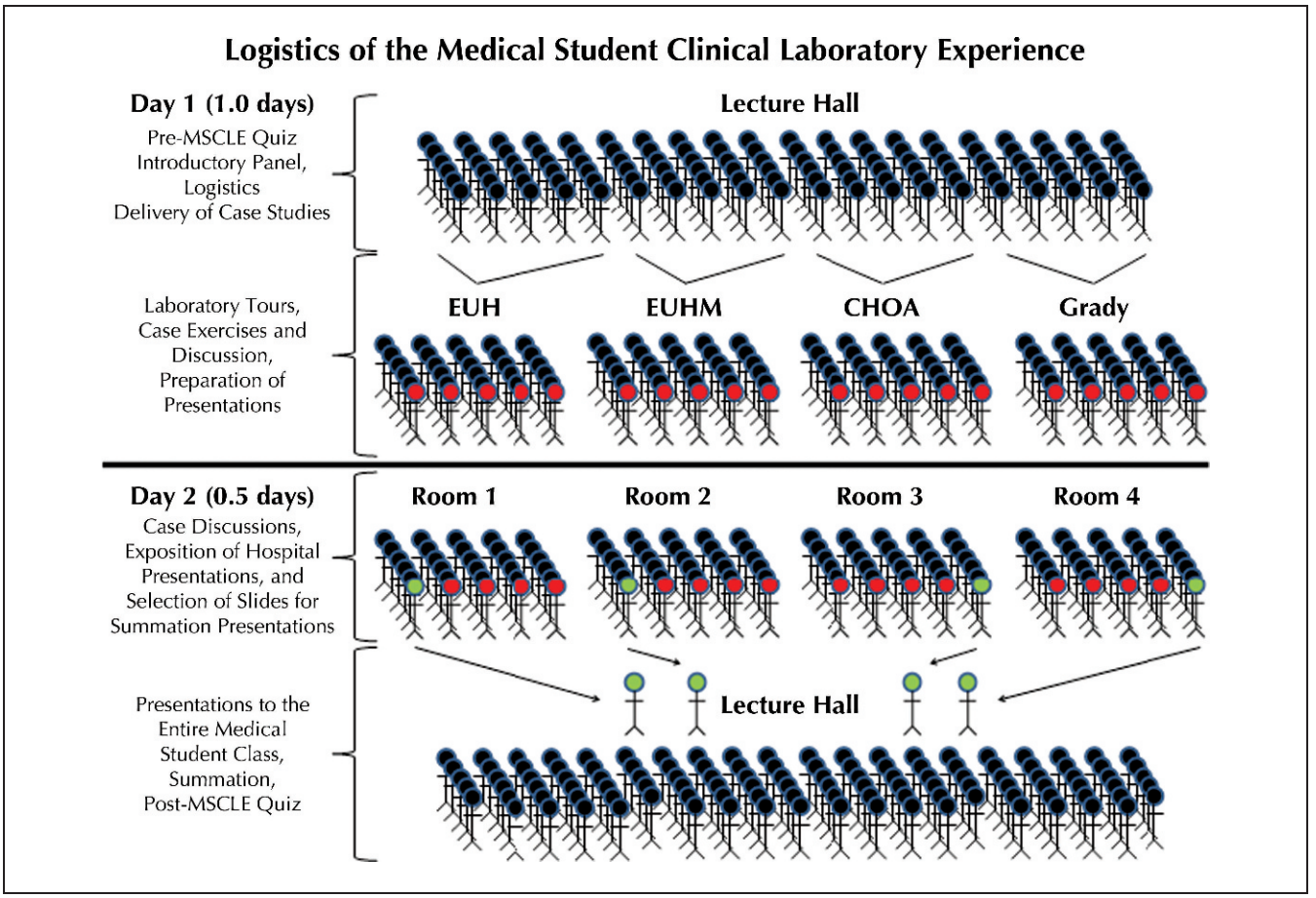

Figure 1. *Logistics of the medical student clinical laboratory experience (MSCLE). Day 1 included the pre-MSCLE quiz, introductory panel, logistics, and the delivery of the case studies. Students were assigned to 4 different hospitals in Atlanta, Georgia—(1) EUH, Emory University Hospital, (2) EUHM, Emory University Hospital Midtown, (3) CHOA, Childrens Healthcare of Atlanta at Egleston, and (4) Grady, Grady Health System—according to their matched specialty. Groups toured the clinical laboratories, worked on case studies, chose a representative (red) for their group, and prepared presentations to be given on day 2. Day 2 included case discussions and presentations by representatives. A final presentation was prepared by each hospital laboratory group, and delegates (green) were chosen for the medical class presentations. The final presentation from each hospital was given at the summation, which included a compilation of salient points by the director of the clinical laboratories, and the post-MSCLE quiz was administered.*

CAPSTONE modules and were graded on a pass/fail basis determined by attendance and participation. The Department of Pathology and Laboratory Medicine sought and was granted a 1.5-day module to provide a laboratory medicine curriculum as a component of the Systems-Based Practice during CAPSTONE. The goals of the Medical Student Clinical Laboratory Experience (MSCLE) were to showcase hospital laboratories through tours and to illustrate the fundamentals of laboratory medicine that have been described by the Academy of Clinical Laboratory Physicians and Scientists performing case-based discussions.[8] In the following article, we describe the MSCLE that was devised and directed by laboratory scientists.

MATERIALS AND METHODS

Curriculum Design and Implementation

The format of the MSCLE is presented in Figure 1. Ethical approval for this study was waived by the university's Institutional Review Board. Assessment drives learning[9]; therefore, we began the MSCLE with a 10-question multiple-choice knowledge quiz to assess the status of laboratory medicine awareness by fourth year medical students. The MSCLE quiz addressed knowledge of the foundations of laboratory medicine[8] presented by the Academy of Clinical Laboratory Physicians and Scientists and was vetted by a faculty member who specializes in education evaluation. Correct answers to the quiz were not presented to the medical students at this point.

The quiz was followed with a 1.5-hour panel discussion designed to introduce the laboratory as a multidisciplinary entity with which they would have to relate as part of the health care system team during residency and as practicing physicians. The panel was composed of an internal medicine resident, an infectious disease physician, the medical director of the clinical laboratory, 2 medical technologists, and a patient. The internal medicine resident and infectious disease physician discussed specific cases in which the laboratory affected patient care and research. The medical director of the clinical laboratory provided an overview of how technologists and clinical laboratory faculty serve as consultants to practicing physicians. The medical technologists described the qualifications required to perform patient testing as well as examples of both positive and negative interactions they have experienced with physicians during their career. The patient described how the clinical laboratory was important to the management of his disease. He realized that students were not engaged because they were not asking questions, so he successfully drew the students into the activity by asking questions himself. Overall, the panel's key messages

Table 1. Question-Specific Topics and Overall *P* Values and *t* Statistics Comparing Results From Students Who Took Both the Pre–Medical Student Clinical Laboratory Experience (MSCLE) and Post-MSCLE Quizzes

Question	Topic	*P* Value	*t* Statistic
1	Reference intervals	.54	0.623
2	Test panels	<.001	5.863
3	Diagnostic specificity	.16	1.408
4	Test interpretation	.01	2.645
5	Assay standardization	.62	0.498
6	Proper blood draw	<.001	3.879
7	Preanalytic variables	.13	1.524
8	Point-of-care testing	.82	0.228
9	Critical values	>.99	0.000
10	Test validation	.81	0.241
Overall (n = 84)		.002	3.215

were (1) residents need to know the clinical laboratory of the hospital at which they will be working, (2) there are medical professionals working within the clinical laboratory that are great resources, and (3) quality patient care is only achieved when there is constructive interactions between laboratory medicine professionals and practicing physicians.

For the second part of the first day, the medical students were assigned to 1 of 4 groups, each comprising approximately 30 students, corresponding to the particular specialty to which they had been matched. Medical students who were matched with internal medicine and neurology were assigned a visit to the laboratory of an adult tertiary-care hospital and were given a case study of a renal transplant patient with multiple infections who was taking medications that required monitoring (Appendix). Medical students who were matched to surgical specialties were assigned a visit to the laboratory at a level 1 trauma hospital and were given a case study of a trauma patient requiring a massive blood transfusion (case not shown). Medical students who were matched with emergency medicine and obstetrics were assigned a visit to a laboratory at a university-owned, community-based, acute care teaching hospital and were given a case study of a pregnant woman with ketoacidosis and a previous history of cervical dysplasia (case not shown). Medical students who were matched with pediatrics and other specialties in which they would see pediatric patients (ie, anesthesia, dermatology, radiology, and pathology) were assigned a visit to the laboratory in a tertiary care, pediatric hospital and were presented with a case study of a patient with Kawasaki disease (case not shown). The 4 cases covered patient scenarios with laboratory medicine aspects in clinical chemistry, cytology, hematology, clinical microbiology, and transfusion medicine. Every case was accompanied by a series of questions related to the fundamentals of laboratory medicine.[8] The case questions were designed so the students would engage in strategic thinking, and some questions were appropriate for discussion or debate. Three to 5 facilitators, composed of pathologists, doctoral-level clinical chemists and clinical microbiologists, pathology residents, fellows, and medical technologists, were assigned to each hospital to lead the laboratory tours and case discussions. Once each group of medical students arrived at their respective hospitals, they were asked to form smaller groups of 5 to 6 students to enable interactions between the facilitators and medical students during their tours through the clinical laboratories. In addition, these smaller groups worked with facilitators to complete their cases, prepare presentations, and choose a representative to give the presentations to the hospital group. The students were given a standardized template for their presentations, which was designed to cover the case scenarios and salient points of each hospital laboratory.

The medical student groups from each of the 4 hospital laboratories met separately at the start of the second day. Each hospital group went through the presentations given by the smaller group's representatives. With facilitators present, each hospital group then chose the salient points, the slides, and one delegate to present the group findings to the entire student body during the summation, allowing students an opportunity to learn about the hospital laboratories they had not visited. The summation's 10-minute presentations were a culmination of the case scenarios provided to the medical students at the 4 hospitals. They highlighted several of the foundations of laboratory medicine,[8] such as preanalytic, analytic, and postanalytic issues of concern for clinical laboratory testing as well as how those issues affected the interpretation of the laboratory results and patient diagnoses in their cases. After the student presentations, the medical director of the clinical laboratory provided a summary, highlighting the pertinent learning points in laboratory medicine presented during the student presentations. Finally, the same knowledge quiz that had been administered before the MSCLE was given out to the students again to evaluate whether the students had gained knowledge through the 1.5-day activities. The answers to the quiz were then discussed with the students after the answer sheets were collected.

Implementation Evaluation and Statistical Analysis

The quiz questions included a mix of mastery of concept (recall) and discrimination of various levels of knowledge (strategic thinking) on concepts covered during the case presentations and discussions. Table 1 shows the topics chosen from the previously published fundamentals of laboratory medicine by the Academy of Clinical Laboratory Physicians and Scientists,[8] which reflected the MSCLE learning objectives. The MSCLE was designed to cover the chosen topics; however, the facilitators did not focus discussions or tours to address quiz questions specifically. To determine whether there was an increase in knowledge, we compared the before and after quiz results using a matched-pairs *t* test. An open-ended anonymous survey was used to assess student satisfaction with the MSCLE. To obtain facilitator feedback, we used an anonymous survey that contained a combination of open-ended and specifically graded questions.

RESULTS

Assessment of Learning and Program Evaluation

The MSCLE program was evaluated on 2 levels: (1) student learning with a before and after MSCLE quiz, and (2) satisfaction. Out of 124 medical students who participated in the MSCLE, 84 (68%) completed both the before and after MSCLE knowledge quizzes and were included in the statistical analyses. The remaining 40 students (32%) were not included in the statistical analysis because they did not complete either one or the other of the MSCLE quizzes. Figure 2, A, presents the distribution curve for those students who completed the pre-MSCLE quiz, whereas Figure 2, B, presents the distribution curve for students completing the post-MSCLE quiz. A right-tailing of the post-MSCLE distribution indicated more medical students scored higher after the completion of the MSCLE. The average score for the pre-MSCLE, 10-question, multiple-choice quiz was 5.1, the average score for the post-MSCLE quiz increased to 5.9. Of the 84 medical students who took both the before and after MSCLE quizzes, 16 students (19%) scored a 7 or greater on the pre-MSCLE quiz, and 34 students (40%) scored a 7 or greater on the post-MSCLE quiz. This difference between the pre-MSCLE and post-MSCLE quiz results was statistically significant ($P = .002$; $t = 3.215$) (Table 1). Interestingly, 3 (30%) of the 10 questions that focused on test panels, test interpretation, and proper blood drawing showed the highest statistically significant gains ($P \leq .01$; $t \geq 2.645$) in knowledge.

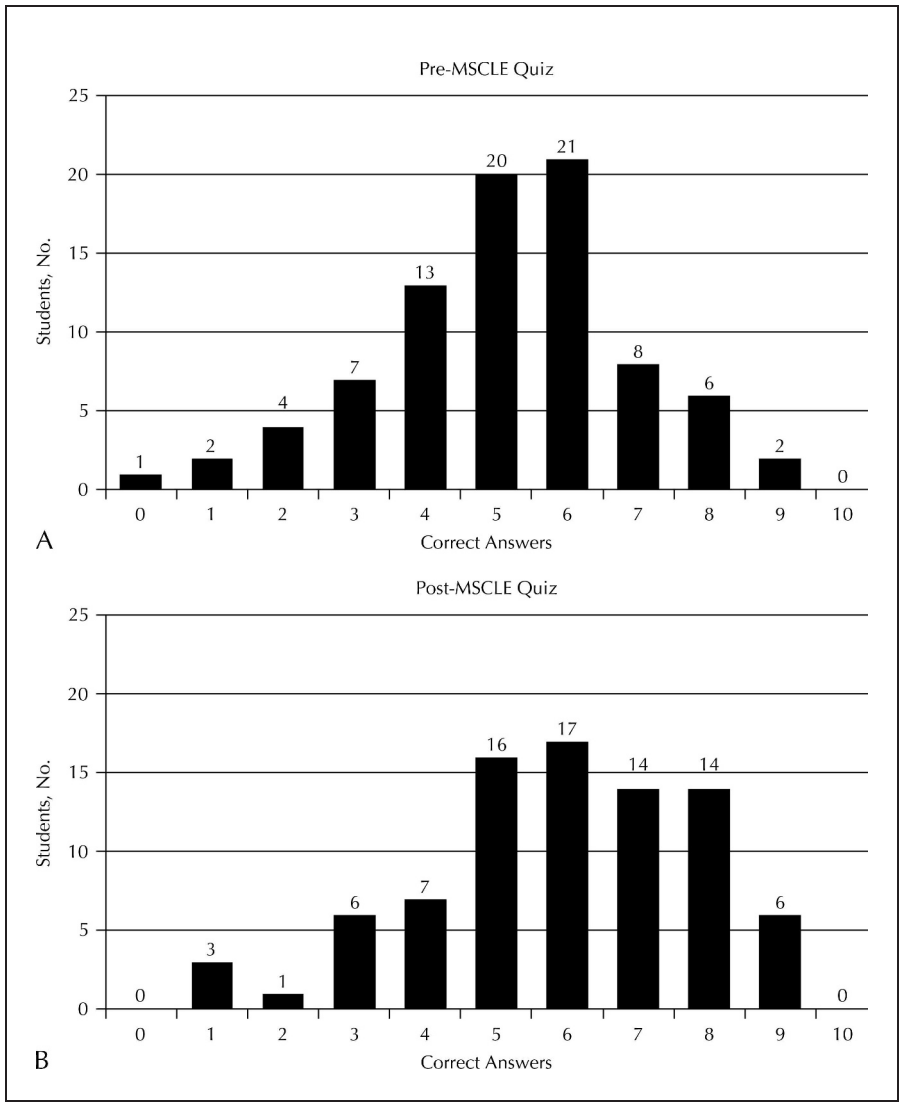

Figure 2. *Distribution of scores before and after students engaged in the medical student clinical laboratory experience (MSCLE). Eighty-four medical students took both the (a) pre-MSCLE and the (B) post-MSCLE quizzes, and their answers were included in the analysis. The MSCLE quiz distribution shifted toward the right after the students went through MSCLE (B). Although 16 medical students (19%) scored 7 or greater on the pre-MSCLE quiz, 34 (40%) scored a 7 or greater on the post-MSCLE quiz.*

An anonymous student survey was performed for the entire CAPSTONE course, and 3 questions pertained to the MSCLE. The first question asked whether the students felt that the MSCLE would be useful in their upcoming practice (41% agreed that it would be useful, 27% were neutral, and 32% disagreed), the second question asked whether the student presentations were redundant (94% agreed), and the last question was open-ended for the students to provide comments. Eighty-seven students provided comments, and a compilation of the common topics is presented in Table 2. Representative student comments included: ''I really appreciated the lab tour and learning the ins and outs of what happens to samples,'' ''I learned some really useful things,'' ''the tour was really the best part of this whole experience,'' ''learning about how the lab works and the different jobs that are done in the lab was valuable,'' ''getting to tour the lab was rushed,'' and making presentations was ''busy work.''

Fifteen of the 18 facilitators (83%) participated in an anonymous survey and provided feedback for improvement of the MSCLE. From their perspective, medical student engagement during the panel and case discussions was rated as neutral, whereas engagement was rated as excellent for the laboratory tours and the student presentations during the summation. Facilitators commented that in certain areas where the laboratory space was constrained, the interactions were more limited even with smaller groups of 5 or 6 medical students. Facilitators felt students were more intent on completing their required presentations than they were in delving into the questions in each case scenario and the presentation preparation was redundant. Facilitators pointed out that one of the highlights of the panel discussion was the patient who noticed the lack of engagement and drew the students into an active conversation by asking them questions. Some representative comments from the facilitators included: ''More time in labs. Shorter cases. Less emphasis on presentation preparation. Panel should ask students questions to facilitate more interaction,'' and ''I would suggest that the groups each have a separate case and present the pearls of each case that they learned. Also, would probably have the facilitators be more active in the discussion—especially with references that they need.''

Table 2. Compilation of Open-Ended Comments by 87 Students	
Comment	**Student Answers, No. (%)**
Tours of the laboratories useful, interesting, or helpful	44 (51)
MSCLE activity should take place before they started their clinical years	9 (10)
Interesting cases, with good content and questions	12 (14)
Panel discussion was not useful	11 (13)
Mentioned the interaction with the patient in the panel	8 (9)

Abbreviation: MSCLE, medical student clinical laboratory experience.

DISCUSSION

Medical student knowledge regarding the foundations of laboratory medicine[8] was improved through a 1.5-day curriculum delivered using the MSCLE format as shown by the pre- and post-MSCLE quiz results. The quiz could only measure a small amount of knowledge acquired recently, which may not estimate adequately what was learned; however, it was encouraging that improvement could be observed by fourth year medical students devoting a short period to learning laboratory medicine principles. The quiz did not count toward passing or failing a student and was not used as an incentive for completing the module, which may account for lack of motivation to complete it or to score well. Interestingly, however, the increase in knowledge regarding laboratory medicine occurred, even though approximately 99% of the medical students did not choose pathology as their specialty. In addition, the facilitators and the patient in the panel noticed a diminished level of attentiveness, commonly present in the last month of medical school training. The quiz evaluated only a finite number of concepts from the foundations of laboratory medicine,[8] and currently, there is no evidence that medical students once in practice will retain those concepts. Some important positive, unmeasured gains of MSCLE included the students learning there are medical professionals with extensive training in the clinical laboratory who can complement their knowledge of a patient's condition by providing a perspective on test use, preanalytic, analytic, and postanalytic issues that can confound test-result interpretation.

Finding the time to teach laboratory medicine principles in an already packed medical school curriculum has proven challenging. A 1.5-day MSCLE is too short a period for the material that the Academy of Clinical Laboratory Physicians and Scientists suggests covering; however, that time was more than what many physicians get during their entire career. The format we devised permitted close contact with laboratory professionals in a concentrated period, the cases were tailored to the specialty to which the students had been matched to keep their interest, and the laboratory medicine foundations were presented as they applied to the specialty cases. We think that this format can be used by other institutions and can be applied at different times during the medical school curriculum.

It was encouraging to see an increase in medical student knowledge in such a short period; however, some limitations and areas for improvement were identified, not only by the medical students but also by the MSCLE facilitators. For example, short lectures with exercises and an audience-response system could be substituted for some of the concepts presented by the panel. The tours were well accepted by most medical students, but some thought visiting additional clinical laboratory areas, such as molecular diagnostics, and performing the tours and hospital visits by shifts would allow more time for interaction with the facilitators and technologists. In addition, more cases of smaller size and less complexity would serve to decrease redundancy in the various presentations. The preparation for the summation could be shifted from presentations with a stipulated format to discussions of the answers in the cases and distilling ''laboratory medicine pearls'' that could then be presented by each hospital group in the summation. Further objective studies are required to assess the presented structure as well as other approaches to teaching laboratory medicine to medical students. It will also be important to determine, in future years, how this MSCLE may have affected the medical students' residency and which of these approaches proved most useful to their success as practicing physicians providing quality patient care.

In summary, we have developed, implemented, and evaluated a 1.5-day curriculum to teach clinical laboratory principles to medical students at the end of their medical school education. During the MSCLE, 124 medical students toured clinical laboratories, completed case studies that emphasized laboratory medicine, and gained a better understanding of clinical pathology through interaction with medical laboratory professionals. We demonstrated a statistically significant increase in knowledge regarding laboratory medicine using a 10-question quiz. Similar MSCLE formats could be implemented by other medical schools to successfully impart laboratory medicine concepts to medical students.

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APPENDIX

Medical Student Clinical Laboratory Experience Case Study (Example)

A 63-year-old man presented to his primary physician (private practice in Duluth, Georgia) with complaints of hematuria, back pain, and fever. The patient had received a deceased-donor renal transplant 3 years earlier for diabetes and hypertensive nephropathy. He described the back pain as dull and constant and without radiation to groin. He denied any colicky type pain, and there was no history of nephrolithiasis. He stated that the hematuria had been intermittent, but during the previous day, he noted blood every time he urinated, and he felt that he was not urinating as often, despite eating and drinking. He denied excessive exercise. He had been taking all his medications (immunosuppressants, antihypertensives, and diabetic medicines).

On physical exam, the patient had a temperature of 38.2°C, a heart rate of 111 beats/min, blood pressure of 156/95 mm Hg, and a respiratory rate of 14 breaths/min. The patient appeared in no acute distress; he was obese with moon facies and had muddy sclera. His skin had normal turgor, but he had xeroderma and a few keratotic lesions; he had dry mucous membranes. The patient had no elevated neck veins; he had a faint, right-carotid bruit, and a thrill over the left arm from a previous arteriovenous fistula. There was evidence of previous sternotomy. On heart exam, the patient had a grade 1/6 systolic murmur and S_4 gallop. His lungs were clear. His abdomen was obese, but there was no guarding or rebound, and bowel sounds were normal on auscultation. He did have pain in his right lower quadrant at the site of his transplanted kidney, and there was mild costovertebral angle tenderness.

A point-of-care urinalysis showed 500 red blood cells and 50 white blood cells with positive leukocyte esterase and positive nitrite. Specific-gravity test demonstrated concentrated urine. The primary physician ordered routine complete blood cell count, chemistry, and blood and urine cultures, which were obtained in the office. The patient was sent home with a prescription for levofloxacin, 500 mg by mouth, daily, for 5 days, for a presumed urinary tract infection. The physician told the patient that he would call with his results within the next 3 to 5 days.

Two days later, the patient began to vomit and sought care in the emergency department of the University Hospital (Atlanta, Georgia). The patient was admitted for intractable vomiting.

After obtaining the above history, the admitting hospitalist asks you (the medical student) to call the primary physician's practice to obtain the laboratory results. The urine culture returned with more than 100 000 colonies of *Escherichia coli*. The blood cultures show gram-positive cocci in clusters in 2 of 4 bottles. The patient was started on vancomycin and levofloxacin.

1. What else do you want to know about the blood cultures?
   a. What is important to know about how the cultures were obtained?
   b. Why is it important to know which set of bottles had the positive result?
   c. Why has the laboratory only indicated there are gram-positive cocci in clusters and not identified the bacteria (staphylococci or other) at this time?
   d. How long will it take to get an identification of the organism(s) grown in the blood?

During the admission, the hospitalist asks you to order the ''kidney transplant rejection panel.''

2. Regarding laboratory panels:
   a. Which panels are those that are recognized by the American Medical Association (AMA)? What do you think when one test is out of reference range in a laboratory panel, but all others are within reference limits?
   b. What do you do with this abnormal result?
   c. What do you think about different hospitals having different laboratory panels?
   d. How are non-AMA panels incorporated in computer order entries at the University Hospital?

3. Regarding the *E coli* culture that has grown from the urine:
   a. Why are susceptibilities to different antibiotics important?
   b. Would you modify your treatment accordingly?
   c. Is it important to know the amount of *E coli* present?
   d. How does the laboratory determine the quantity of bacteria in urine specimens?

4. Is the *E coli* bacteria considered a pathogen in this setting?

5. When you visited the microbiology laboratory during the tour:
   a. What measures did you see the technologists using to protect themselves from the different infectious agents?
   b. Are these the same measures you saw being used in the core laboratory?
   c. Are the microbiology technologists only protecting themselves from infectious agents?

Hematuria persists. The clinical team questions the possibility of obstruction or stricture of a ureter causing the patient's infection, and an intravenous pyelography was ordered. Radiology is ready to perform the test but cannot find the creatinine results in the chart, so a point-of-care creatinine level is performed in radiology, and the result is 2.1 mg/dL. As the point-of-care result is available, the resident finds that the creatinine level obtained that morning was 1.92 mg/dL (study performed at the central laboratory).

6. Is this a real change in creatinine level?
   a. Which 1 of the 2 values do you consider the true value in this patient?
   b. Why?
   c. What do you think about the point-of-care result having 1 place after the decimal point, whereas the central laboratory report has 2?

The hospitalist discusses the patient's condition with the nephrologist. The nephrologist suggests checking a tacrolimus level and asks the resident in the consult rotation to order the drug level, but he accidentally orders a phenytoin level.

7. The phenytoin level result returns as less than 10 mg/dL; why is it not zero, when the patient is not taking this medication?

The tacrolimus level is 316 ng/mL, and you are called by the laboratory technologist with this result. The technologist asks you to repeat the name of the patient and the value.

8. Regarding the call you received:
   a. Why were you called?
   b. Who decides which laboratory values have to be called to the health care provider?
   c. Are ''critical values'' part of the National Patient Safety Goals? Which other National Patient Safety Goals affect the laboratory?
   d. The College of American Pathologists is inspecting the laboratory and finds that there is no documentation of this incident being reported to the health care provider. What do you think will happen?
9. What is crucial to find in the chart in relation to this level?

The repeat value just 1 hour later is 20 ng/mL, still critical, and likely, the cause of the patient's vomiting. The nephrologist determines that the urinary tract infection likely interacted with the creatinine clearance of the tacrolimus and recommends that the levofloxacin be stopped, and the patient's tacrolimus dose be withheld for a day.

The hospitalist asks the resident to call the outside hospital microbiology laboratory to find out what grew in the blood cultures. The gram-positive cocci have been identified as coagulase-negative *Staphylococcus*. You comment that the blood cultures that were drawn on admission to the hospital have no growth so far.

10. Regarding the blood cultures:
    a. Should this patient be on vancomycin to treat this organism?
    b. If the patient's blood cultures are negative on admission, is that enough reason to discontinue the vancomycin that was started on admission?
11. Why does the laboratory keep count of coagulase-negative *Staphylococcus* growing from blood cultures that occur during a certain period?
    a. What happens when the number of coagulase-negative *Staphylococcus* growing from blood culture bottles increases?

The nephrologist changes the patient to everolimus and asks for a blood level test on that drug. The laboratory calls back saying that they cannot find a laboratory that can measure that drug. The nephrologist says that a research laboratory in Minnesota performs that study and wants it sent to that laboratory.

12. Should the University Hospital laboratory send the specimen to be tested by the Minnesota laboratory? What are requirements for a hospital to send specimens to another facility?

A basic metabolic panel was collected in the emergency department of the University Hospital. The specimen was grossly hemolyzed, and results for several analytes were not reported. Because you were in such a hurry to get the results back, you decide to collect the blood yourself. You ask a nurse for a blood tube and she hands you a potassium EDTA (purple top) tube. After you collect the blood, you realize that it should have been collected in a lithium heparin (mint-green top) tube, so you pour the blood from the purple top into the mint-green top tube and send it to the laboratory.

13. What analytes would you expect to be affected by this?

You decide that this was not a good idea, so you draw the tube again, but by now, the nurse tells you that your attending just called to add a complete blood cell count test.

14. In what order would you need to draw the 2 tubes?
15. You would like to add a differential test to the complete blood cell test that was requested. Would you choose an automated blood differential or a manual blood differential test? What is the difference in how those tests are performed?

Your attending has read in a respected scientific journal that there is a point-of-care test that can tell you whether the patient is experiencing organ rejection. You are asked to research the test and go through the steps required to bring the test into the hospital.

16. Who do you think you need to talk to in the laboratory for implementation? What steps are required to bring such a test in-house? If this was a clinic (not the hospital), would the steps be different? Why?

After 3 days, the nephrologist changes back to tacrolimus because he can monitor the drug, and the infection has been eliminated. The patient is discharged and is asked to return to the University Hospital for weekly monitoring of his tacrolimus level. A week later, the patient has the test performed at his local laboratory. His therapeutic values are 1.5 times higher than those determined at the University Hospital (without a change in dosing regimen or renal function), but they are within the therapeutic reference range listed at this hospital. The patient calls the nephrologist with the results.

17. What is likely the reason for the difference in therapeutic ranges?