The Murmur Online Learning Experience (MOLE) Curriculum Improves Medical Students' Ability to Correctly Identify Cardiac Murmurs.

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Abstract

Introduction

Physical examination skills are receiving less attention in curricula and clinical practice, being supplanted by imaging and other technologies. We developed an online module to introduce auscultation of common cardiac murmurs to second-year medical students.

Methods

The Murmur Online Learning Experience (MOLE) curriculum focused on nine common, unique, or highly testable cardiac murmurs, chosen collaboratively by the authors. The curriculum consisted of (1) a nine-item multiple-choice pretest containing a clinical vignette, a photo of stethoscope location, and an auditory clip; (2) nine modules each containing a several-minute-long auditory clip and a written description (location, quality, radiation, change with exam maneuvers); and (3) a nine-item multiple-choice posttest, identical to the pretest but randomly ordered. All second-year medical students at the University of Louisville were given access to MOLE during their cardiovascular curriculum and given an incentive to complete the ungraded activity.

Results

One hundred forty-seven (91.8%) students voluntarily completed the pretest and posttest. The mean pretest score was 3.76 out of 9 ($SD = 1.77$). The mean posttest score was 7.14 out of 9 ($SD = 1.78$). Paired t-test results demonstrated a p value of <.001.

Discussion

An online murmur curriculum consisting of repetitive auditory murmurs and narrative description of murmurs improved second-year medical students' ability to correctly identify common cardiac murmurs. This method of learning murmurs via online curriculum is a practical and effective way to hone students' physical exam skills in the modern era.

Keywords: Auscultation, Murmur, Cardiac, Heart, Stenosis, Regurgitation, Ventricular Septal Defect, Patent Ductus Arteriosis, Hypertrophic Cardiomyopathy, Friction Rub

Educational Objectives

By the end of this activity, learners will be able to:

1. Correctly identify nine basic cardiac murmurs (aortic stenosis, aortic insufficiency, hypertrophic obstructive cardiomyopathy, mitral stenosis, mitral regurgitation, tricuspid regurgitation, patent ductus arteriosis, friction rub, and ventricular septal defect).

2. Differentiate between systolic and diastolic cardiac murmurs.

3. Identify anatomic locations of basic cardiac murmurs.

4. Recognize maneuvers used to exacerbate cardiac murmurs.

Introduction

As physical examination skills receive less attention in curricula and clinical practice, being supplanted by imaging and other technologies, medical students, residents, and practicing physicians recognize less than 40% of abnormal heart sounds.[1,2] However, physical exam skills remain vitally important even in the era of technology-enabled health care. Particularly in resource-poor settings and in the era of appropriate use criteria, adequate cardiac auscultation is a cost-effective method to make important diagnoses and limit inappropriate, more expensive imaging tests.[3,4] A vital aspect of the physical exam, the need for efficient and accurate cardiac auscultation skills is ubiquitous across medical education—and medical practice—in order to diagnose common conditions such as aortic stenosis, congestive heart failure, and congenital pathologies.

To address this need for cardiac auscultation teaching for modern learners, we developed the Murmur Online Learning Experience (MOLE), focusing on the invaluable and inexpensive art of cardiac auscultation. Rather than using the outdated pedagogical technique of a lecture-based curriculum, MOLE is an internet-based, self-study resource that combines auditory and visual learning to achieve multisensory learning. Such multisensory learning has been demonstrated to be superior to unisensory learning in terms of knowledge/skill retention.[5] MOLE encourages medical students to practice their cardiac auscultation skills using clinical vignettes and repetition of common murmurs. The purpose of the curriculum is to teach introductory-level cardiac auscultation skills to medical student learners, teaching them to distinguish between nine basic cardiac murmurs. MOLE has been designed to be used concomitantly with classroom education during time dedicated to learning about the cardiovascular system in the first 2 years of medical school. The purpose of the corresponding study is to evaluate the impact of this online murmur curriculum on second-year medical students' ability to recognize common cardiac murmurs.

As a learning module, MOLE implements an audiovisual tutorial, clinical vignettes, and self-assessments to promote self-guided learning, which has been shown to improve auscultation skills in medical students.[6] The program has been designed based on previous research showing that the ability of medical trainees to correctly identify murmurs by auscultation is poor but can be improved with repetition. Each murmur is repeated approximately 200 times in a 5-minute period in the learning module, modeling previous studies showing retention of material at these rates.[7,8] The murmurs used in MOLE are actual physiologic recordings, as opposed to simulated sounds, and have been standardized with regard to rate and volume in order to maximize learners' ability to distinguish between different murmurs. While there are many available online libraries of cardiac murmurs, this curriculum is unique as it is a curated collection of murmurs deemed appropriate for early medical student learners by our developers (including a nationally recognized expert on teaching cardiac auscultation, a cardiovascular curriculum course director, and a recent medical student learner). Furthermore, our curriculum combines auditory learning with visual cues (location of stethoscope), physical exam maneuvers, phonograms, and clinical vignettes to give a comprehensive, multisensory learning experience that is still limited to approximately 1 hour's duration. By choosing to focus on nine murmurs, the curriculum is focused yet thorough, as well as being accessible to the modern learner. Lastly, our pre- and posttest format allows students to self-evaluate, an important step in self-directed learning.

Methods

MOLE was developed to teach the basics of cardiac murmurs and auscultation to medical students. For these early learners, MOLE focused on three elements considered key to identifying a murmur: timing, location, and quality—in that order. We chose to adjust real audio recordings of murmurs to a heart rate of 55–60 beats per minute where systole was approximately one-third of a second. This choice was made in order to allow students to focus on the above-mentioned elements of the murmur and carefully consider each one with adequate time between each repetition of the murmur. Furthermore, this technique of standardizing the rate and of murmurs has been utilized when teaching high-level learners, such as practicing cardiologists. Coauthor and developer of the curriculum Dr. Michael J. Barrett serves as the editor of the American College of Cardiology Heart Songs learning module and is considered an expert on teaching cardiac auscultation. The Heart Songs murmur clips also have been standardized in the above manner. Previous randomized studies have demonstrated the effectiveness of this method of teaching cardiac auscultation, showing a marked improvement in ability of practicing cardiologists to correctly identify common murmurs.[8,9] Therefore, we chose to utilize the same technique when creating our medical student MOLE curriculum and to evaluate its effectiveness in the context of a broader cardiovascular curriculum.

The MOLE curriculum was designed to be completed by students during their preclinical (first- or second-year) cardiovascular curriculum as an interactive, self-directed learning activity outside of the classroom. In the University of Louisville program where the MOLE curriculum was implemented and evaluated, students were given two 1-hour didactic lectures on common valvular disorders, separated into aortic/pulmonic valves and mitral/tricuspid valves. Other relevant didactics included lecture topics on hypertropic obstructive cardiomyopathy, congenital cardiac disease (including patent ductus arteriosis and ventricular septal defect), and pericardial effusion. Students were also introduced to the basics of cardiac auscultation in a separate physical exam course. However, students' only exposure to auditory murmur clips was during the MOLE curriculum. Prior to development and implementation of the MOLE curriculum at the University of Louisville, students did not receive formal instruction in auscultation of the common cardiac murmurs, and their exposure to these murmurs was at random during their clinical rotations.

We chose the following nine cardiac murmurs to include in the MOLE curriculum based on several factors, including prevalence, relevance to medical student learners, unique differentiating features (e.g., aortic stenosis vs. hypertrophic obstructive cardiomyopathy), correlation with important clinical diagnosis (e.g., friction rub, patent ductus arteriosis), frequent testing on standardized exams, and correspondence to disease states taught in the University of Louisville cardiovascular curriculum. The following murmurs were included in the MOLE curriculum:

• Aortic stenosis.
• Aortic regurgitation.
• Friction rub.
• Hypertrophic obstructive cardiomyopathy.
• Mitral stenosis.

• Mitral regurgitation.

• Patent ductus arteriosis.

• Tricuspid regurgitation.

• Ventricular septal defect.

The tutorial contained three components: a pretest (Appendix A), the learning module (Appendix B), and a posttest (Appendix C). Learners completed a short multiple-choice-question pretest asking them to identify nine common cardiac murmurs based on sound and a clinical vignette. The learning module then focused on providing audiovisual associations for each murmur. Each murmur was repeated approximately 200 times at standardized rate and volume. After the learning module, a posttest, similar to the pretest but with questions/vignettes in random order, was completed for self-evaluation.

Cardiac Auscultation Pretest (Appendix A; 10 Minutes)

The pretest consisted of nine computer-randomized multiple-choice-question vignettes, one for each of the murmurs above. A photo of the auscultation site was provided, along with a short vignette with pertinent information regarding the associated murmur. Below the written vignette was a button that played the murmur that would be heard at the above auscultation site. The student was then asked to identify the murmur in a computer-randomized, multiple-guess fashion. Both vignettes and answer choices were randomized by the computer program separately for each pretest that was completed. At the end of the pretest, a score was provided so that the learner could compare it to the future posttest score.

Cardiac Auscultation Learning Module (Appendix B; 60 Minutes)

This audiovisual-based module began by considering the three elements key to identifying a murmur: timing, location, and quality, in that order. For timing, students were asked to identify the murmur as occurring either during systole or diastole, thus narrowing the choices. As noted above, our murmurs were created with systole fixed at one-third of a second, in order to allow adequate time for active learning. Students were then instructed that "the loudest location of the murmur is key." The quality of the murmur was considered last in the identification process.

At this point, the learner proceeded into the heart of the learning module. For each of nine murmurs, MOLE included both a several-minute-long auditory clip and a written description featuring location, quality, radiation, and change with exam maneuvers. Visuals during the narration included phonocardiograms and auscultatory sites. The murmur was introduced and then repeated until the student had listened to it 200 times. At that point, the student proceeded to the narration regarding another murmur.

Cardiac Auscultation Posttest (Appendix C; 10 Minutes)

The MOLE posttest was identical to the pretest, but with questions/vignettes occurring in a random order.

All 160 second-year medical students at the University of Louisville were given access to the MOLE curriculum including pretest, learning module, and posttest. Following completion of these three components, students had unlimited access to the online learning module. This cardiac auscultation tutorial was run from an online platform called SoftChalk Cloud (www.SoftChalk.com) so that learners could access the three components online via links sent in email. Although original materials were hosted by SoftChalk, they are also available as webpage files in *MedEdPORTAL*; thus, materials can be utilized without the SoftChalk application.

Results

Results from medical students at the University of Louisville Medical School demonstrated the value of the MOLE curriculum. The vast majority of students completed the module within the allotted 2-week time frame. One hundred forty-seven (91.8%) students voluntarily completed the pretest and posttest. The mean pretest score was 3.76 out of 9 ($SD = 1.76$). The mean posttest score was 7.14 out of 9 ($SD = 1.77$; Figure 1). The mean increase in test scores between pretest and posttest was 2.96 ($SD = 2.63$), with a range between −2 and 7. The time spent by students on the learning module did not correlate with either their posttest scores or the change in score from pre- to posttest (Figure 2). Paired *t*-test results demonstrated a *p* value of <.001.
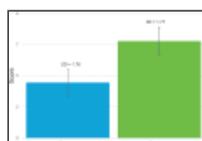

Figure 1.
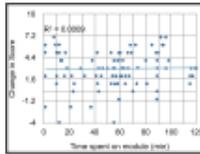**Change in pretest and posttest scores.**

Figure 2.

Change in student score versus time spent on module.

Discussion

Implementation of this educational innovation occurred at the University of Louisville in fall 2017 (data presented from the inaugural class of students participating in MOLE) with second-year medical students during their integrated cardiovascular system curriculum, an 8-week-long course. Based upon the success of the curriculum and student enjoyment, it was continued in fall 2018 with plans to continue utilizing it as a required portion of the cardiovascular curriculum indefinitely. To entice participation, students were given 2 bonus points on their final exam if they completed the curriculum, regardless of score. Therefore, this was an ungraded but mandatory activity. Students were given access to the MOLE curriculum via links to their individual email accounts at the time of the valvular disorder lectures. They were given 2 weeks to complete the module, and adequate time was allowed within their schedule for this 1-hour activity occurring outside the classroom. Students had no time limits as to how long they could spend on each vignette, each murmur, or the pre- and posttests.

This online murmur curriculum consisting of repetitive auditory murmurs and narrative description of murmurs improved second-year medical students' ability to correctly identify common cardiac murmurs. While the median score increased from 4 to 7 out of 9, there was a small proportion of students (4%, $n = 6$) who scored lower on the posttest compared to the pretest. There are several possibilities for why these students' scores did not improve following the module. Data regarding the students' overall course performance were not available, but these may have been low-performing students. The pre- and posttests were not compulsory, and therefore, some may not have put full effort into the posttest, causing scores to be artificially low. Students were given credit for completing the course online, but some may not have attempted to learn the material since the exercise was not graded. Overall, the large majority of learners showed an improvement between pre- and posttest scores, evidencing the effectiveness of this online curriculum.

It is important to note that there did not appear to be any correlation between time spent on the module and either posttest absolute score or change in score. We suspect that study times may not have been accurately recorded through the online platform. Based on some of the study times recorded, it is possible that students were not logging out of the module or that students may have had the learning module and posttest modules open simultaneously. These issues may have confounded length of study time recorded, thereby impacting our ability to correlate study time and posttest score improvement accurately. In the future, we hope to find a way to record study times more accurately and produce a correlation between study times and score increases.

Our experience implementing this curriculum was overwhelmingly positive. Students reported enjoyment of the activity and found it useful for their future clinical practice. Instructors in the course found the format particularly effective since attempting to teach murmurs during a short didactic session does not allow for the repetition that the online module provides. The results of our study demonstrate that auscultation is a technical skill that can improve within a short time period. With the permeation of technology throughout medicine, using online learning modules allows students to readily access auditory learning at their convenience.

There are several limitations to our study. First, it is not possible to definitively identify which aspect of the MOLE curriculum led to improved auscultatory skills. Students were not required to listen to the entire module/auditory clip, so we cannot correlate, in this data set, whether repetition was the key factor in auscultatory skill improvement. However, previous studies have identified repetition as the key component in auscultation skill improvement.[6,7] Second, pre- and posttest auditory clips were identical. However, even if students had both pre- and posttests open in different browser windows simultaneously, they were given only a composite score and not individual correct/incorrect answers, so they would not be able to use pretest clips to identify posttest clips. Additionally, students were not graded on this exercise, so the motivation to cheat in this fashion would be minimal. Third, students completed the posttest immediately after the module. Therefore, we assessed only immediate auscultation skill improvement, not skill retention. It would be useful in the future to assess long-term retention of auscultation skills following this curriculum, as well as whether spaced repetition of cardiac auscultation practice would improve long-term skill retention. Fourth, the pre- and posttest questions included a clinical vignette in addition to the murmur clip. Students may have relied on their knowledge of the clinical vignette, rather than the sound, to identify the murmur. However, we find this an acceptable limitation to the study, as clinicians utilize both clinical context and murmurs in diagnostic decisions. The goal of the curriculum was to teach students how to integrate auscultatory skills into their clinical skill set. We accept the possible confounding to our data since the primary purpose of this educational innovation was to create and implement a murmur curriculum within the broader context of medical education, rather than our primary goal being purity of data collection.

The applicability of this curriculum is broad, as it can be easily extended to learners across the medical education continuum and across disciplines. The curriculum can be provided for nursing students and cardiac nurses, who often perform bedside physical examination and assessment. Medical students, residents, fellows, and even faculty can all benefit from this interactive auscultation curriculum to improve their cardiac examination skills for this set of important cardiac murmurs.

Appendices

A. MOLE Pretest folder

B. MOLE Learning Module folder

C. MOLE Posttest folder

Click here to view.(28M, zip)

All appendices are peer reviewed as integral parts of the Original Publication.

Article information

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