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Implementation of a 4-Year Point-of-Care Ultrasound Curriculum in a Liaison Committee on Medical Education– Accredited US Medical School

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Objectives—The established benefits of point-of-care ultrasound have given rise to multiple new and innovative curriculums to incorporate ultrasound teaching into medical education. This study sought to measure the educational success of a comprehensive and integrated 4-year point-of-care ultrasound curriculum.

Methods—We integrated a curriculum consisting of traditional didactics combined with asynchronous learning modules and hands-on practice on live models with skilled sonographers into all 4 years of education at a Liaison Committee on Medical Education–accredited US Medical School. Each graduating student was administered an exit examination with 48 questions that corresponded to ultrasound milestones.

Results—Ninety-five percent (n 5 84) of fourth-year medical students completed the exit examination. The mean score was 79.5% (SD, 10.2%), with mean scores on the ultrasound physics and anatomy subsections being 77.1% (SD, 11.0%) and 85.9% (SD, 21.0%), respectively.

Conclusions—A comprehensive 4-year point-of-care ultrasound curriculum integrated into medical school may successfully equip graduating medical students with a fundamental understanding of ultrasound physics, anatomy, and disease recognition.

Key Words—medical education; medical school; milestone; point-of-care ultrasound

The use of point-of-care ultrasound to screen, diagnose, and assist with procedures is well established.[1] As a result, the recognized need and integration of point-of-care ultrasound into undergraduate medical education has become increasingly prevalent. [2–11] Although the educational success of a 4-year longitudinal point-of-care ultrasound curriculum in medical education has not yet been evaluated, interest in learning ultrasound as part of their educational curriculum has been documented among medical students.[8–10] The implementation of ultrasound in medical education is a relatively new process; thus, substantial variability in the presence, quantity, delivery, and depth of ultrasound education remains across medical schools nationally.12 A recent effort by Dinh et al[13] aimed to help create a standardized approach to point-of-care ultrasound education by identifying 90 essential ultrasound milestones from a consensus of 34 current point-of-care ultrasound educators. We therefore sought to measure the efficacy of our comprehensive integrated 4-year point-of-care ultra- sound training program by assessing whether graduating medical students could demonstrate a basic understanding of ultrasound knowledge within these recently published ultrasound milestones.

Materials and Methods

Study Design and Setting

We conducted a cross-sectional study of all graduating medical students from the class of 2014 at a Liaison Committee on Medical Education–accredited US Medi- cal School with a newly established 4-year ultrasound curriculum. Per institutional and university guidelines, this study was approved by the Institutional Review Board through an exemption on an overarching study approval.

Ultrasound Educational Program

We implemented a comprehensive 4-year point-of-care ultrasound curriculum into our medical school education as part of the Introduction to Clinical Medicine course, specifically called Clinical Foundations of Ultrasound. Through a series of hands-on sessions led by trained instructors (senior medical students, residents, emergency ultrasound fellows, and faculty), our students were exposed to the mechanics, utility, and techniques of ultrasound. A total of 12 mandatory 1-hour hands-on educational sessions were held throughout the first 2 years. These sessions were supplemented with required asynchronous learning through open-access podcast lectures available on iTunesU (Apple Corporation, Mountain View, CA), which served as instructional guides before the students scanned live models.

The clinical foundations of ultrasound began in the first year of medical school, covering the physics and proper use of ultrasound equipment (termed "knobology"). This portion focused on conceptualizing how the physical parameters of frequency, depth, and gain affected image acquisition. Later sessions within the first year focused on the recognition of basic anatomic structures in the various body systems. Before each session, the main objectives along with specific goals and views to be obtained were outlined. During the second year, the curriculum focused on exposing students to pathologic findings identified with ultrasound and given more instruction on clinical applications of point-of-care ultrasound. During the third year, students underwent a mandatory 2-hour comprehensive review of basic ultrasound principles and image acquisition before beginning clinical clerk- ship rotations. A complete copy of the learning objectives for the Clinical Foundations of Ultrasound course is detailed in online supplemental Appendix 1.

Additionally, throughout the third year, students had access to ultrasound machines with supervised ultra- sound rounds while on internal medicine and surgery rotations. An ultrasound objective structured clinical examination) was also performed at the end of family medicine and surgery rotations. Once in the fourth year, students were offered an ultrasound elective, held in the emergency department, which primarily focused on the use of point-of-care ultrasound in the assessment of the undifferentiated patient but could also be tailored to each individual based on his or her own interest. This optional 4-week rotation gave students the additional opportunity to further develop their ultrasound knowl- edge, imaging technique, and interpretation.

Study Protocol

Before graduation, we administered an (ungraded) exit examination to all fourth-year medical students who participated in the comprehensive ultrasound curriculum. Graduating students of the MD/PhD pro- gram were exempt from taking the examination, as the ultrasound curriculum had not yet been established during their first 2 years of medical school. The original examination consisted of 61 multiple-choice questions written by the director of ultrasound education. These questions were designed to discern whether students could identify normal from pathologic findings on 6-second looping ultrasound videos. Before grading the examination, a fellow of emergency ultrasound reviewed the examination and identified the questions that corresponded to the ultrasound milestone categories (knobology, cardiac, thoracic, abdominal, vascular, genitourinary, and musculoskeletal) published by Dinh et al.[13] A complete copy of the exit examination with still images is available as online supplemental Appendix 2.

Data Analysis

Each examination and ultrasound milestone category was individually graded for the percentage of correct answers. We calculated the mean overall scores and milestone-specific scores with standard deviations using Microsoft Excel (Microsoft Corporation, Redmond, WA).

Results

Ninety-five percent (n 5 84) of fourth-year medical students completed the examination. The overall mean score for the initial examination was 76.9% (SD, 9.9%). Forty-eight questions (78.7%) were identified as corresponding to an ultrasound milestone,[13] of which 19 were related to knobology and 29 to an anatomic sys- tem. The breakdown of questions by anatomic ultra- sound milestone category were as follows: 9 cardiac, 2 thoracic, 3 abdominal, 9 vascular, 1 genitourinary, and 5 musculoskeletal. Of the 48 questions that tested an ultra- sound milestone, the overall mean score was 79.5% (SD, 10.2%), with mean scores for the individual knobology and anatomic ultrasound milestone categories being 77.1% (SD, 11.0%) and 85.9% (SD, 21.0%), respectively (Figure 1).

Within the ultrasound milestone anatomic categories, mean scores by individual system were as follows: cardiac, 95.2% (SD, 18.7%); thoracic, 89.7% (SD, 17.1%); abdominal, 80.0% (SD, 17.6%); vascular, 96.4% (SD, 18.9%); genitourinary, 74.5% (SD, 25.6%); and musculoskeletal, 77.9% (SD, 18.3%; Figure 2).

Discussion

We provided an immersive educational experience and promoted a basic understanding of point-of-care ultra- sound by a combination of instructive media and hands- on practice on live models with oversight by skilled sonographers. We suspect that much of the success of our students extended beyond just their academic ability, our curriculum design, or teaching. It is in part attributed to their interest in using ultrasound as a tool to augment the traditional physical examination. Although point-of- care ultrasound is recognized as its own diagnostic tool used to provide a directed clinical assessments, a more generalized concept of an "ultrasound stethoscope" has gained widespread popularity given the considerable ad- vantages that point-of-care ultrasound confers in addition to traditional techniques.[14] In 2014, Fox et al[15] described 30 essential bedside examinations that can be performed with point-of-care ultrasound, dubbed the "UCI 30," a reference to Stanford University's renowned physical examination curriculum known as the "Stanford 25."

Our institution is not alone in this endeavor; other medical schools have successfully implemented and evaluated formal ultrasound training in their curricula. In 2006, Wayne State University introduced a novel ultrasound curriculum into their basic science years and clinical clerkships with measurable success, achieving a mean class performance of 87% percent on an assessment of their technical skills.[2] The University of Arizona experimented with a "theme-based learning" curriculum in which fundamental applications of point-of-care ultrasound were taught in the context of a variety of scenarios, such as in the assessment of a traumatic injury.[16] Another study by Webb et al[10] called for ultrasound education in the preclinical years, citing a favorable response from first-year medical students during a pilot ultrasound curriculum at the University of California, San Francisco.

Other studies have examined the application of point-of-care ultrasound to specific modules or courses in medical school. A year-long study at Loma Linda University demonstrated that incorporation of point-of-care ultrasound into first-year medical student's physical examination training improved overall performance during an objective standardized clinical examination.[17] In the United Kingdom, point-of-care ultrasound has been identified as a useful adjunct in teaching the traditional anatomy course.[18] A study by DeCara et al[19] purported that fourth-year medical students given a portable ultra- sound device and 4 weeks of training increased the accuracy of their bedside cardiac examinations compared with traditional physical examination

techniques alone, although the study was limited by its sample size.

It has been identified that many specialties, including cardiology, emergency medicine, anesthesiology, pediatrics, and internal medicine, have a growing interest in point-of-care ultrasound.[20,21] As this trend continues, it may become reasonable for residency programs to start expecting graduating medical students to have some level of point-of-care ultrasound experience before starting their postgraduate training, especially as techno- logic advancements continue to improve the portability, resolution, and cost of compact of point-of-care ultra- sound devices.

There were many limitations to this study. First, the exit examination that we administered has not been externally validated as a tool to determine true medical student proficiency or understanding of ultrasound. Second, the original examination had been administered before publication of the ultrasound milestones, although hopefully it was mitigated by both the fact that most of the original examination questions were identified to be within the scope of the ultrasound milestones as well as the fact that each question was reviewed for inclusion as a category within the ultrasound milestones before grading. Third, an underlying assumption of this study was that most students had little to no prior experience or training with ultrasound before enrolling in the curriculum, therefore negating the need for a pretest and posttest. If in fact there were multiple students who had ultrasound experience before entering medical school, this factor potentially could have skewed the results of our examination. Fourth, we were unable to identify which students had participated in the ultra- sound elective to determine whether there was a substantial difference in scores between those who did and did not receive additional hands-on training and experience or whether this cohort with more training produced a skewed higher overall average score. Fifth, since we did not have a hands-on practical test, our assessment was limited to the knowledge of ultra- sound and not each individual's ability to independently perform a point-of-care ultrasound study. Last, the number of questions assessed within each ultra- sound milestone category was relatively small and not evenly distributed, therefore making it difficult to draw sound conclusions regarding the educational understanding of each milestone category.

In conclusion, after implementation of a 4-year ultrasound curriculum, medical trainees were able to demonstrate a basic understanding of ultrasound physics, machine use, and identification of normal anatomy and pathologic findings from point-of-care ultrasound images. As ultrasound continues to search for its place in medical education, there is a need for additional studies that can serve as guides for educators to identify optimal conditions while maximizing the benefits of ultrasound education and in turn prepare better clinicians for the future.

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