Online Learning in Thoracic Surgical Training: Promising Results of Multi-Institutional Pilot Study

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Background. Cardiothoracic surgical education faces numerous challenges, including reduced duty hours and diminishing prioritization of teaching, in the setting of rapidly advancing knowledge, skills, and case complexity. Pass rates on the American Board of Thoracic Surgery exam remain suboptimal, and new training formats are being evaluated. We hypothesize that Internet-based courses can be developed and implemented to supplement learning of basic topics in cardiothoracic surgery.

Methods. After a needs assessment, 4 online self-study courses were developed by content experts using a Moodle (modular object-oriented dynamic learning environment) platform. As a pilot cohort, students from 4 thoracic surgery training programs participated, accessing courses at their own pace. Each course included general and detailed readings, multimedia content, discussion forum, and a question-bank supported quiz (90% required to pass, multiple attempts allowed). Utilization and exam data were tracked electronically. The t tests were used to compare first versus final-year traditional track trainees. Post-course surveys collected data on trainee attitudes.

Results. Nineteen students completed 4 courses on tracheal disease. Mean time spent per course and quiz attempts to pass were 1.35 hours and 2.86, respectively. Scores improved with successive attempts. Senior trainees showed a trend toward less time per course and fewer quiz attempts. Post-course surveys uniformly demonstrated perceived benefits from the content and quizzes in an easy-to-navigate format.

Conclusions. Online courses can be developed and integrated within cardiothoracic training programs. This pilot demonstrates evidence of active learning as shown through the embedded assessments. Internet-based courses may serve as a means of supplementing modern thoracic surgical training. Further development and evaluation are warranted.

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and in line with organized learning objectives. Utilization of the Internet as a repository for resources and a framework for curricular models has been shown to have remarkable success, and the concept of e-learning offers a number of benefits that may be highly attractive to the modern surgical trainee [11, 12]. Online resources have been particularly effective in supplementing on-the-ground clinical teaching efforts in the broad field of surgical education [13, 14]. Previous authors have shown promising results from the application of web-based educational models in thoracic surgery, although efforts have been limited [15–18].

A number of medical educators have shown interest in the use of Moodle (modular object-oriented dynamic learning environment) software (Moodleooms, Inc, Baltimore, MD), an open source course management system, also known as a Learning Management System or a Virtual Learning Environment. This system provides for augmentation of learning through several mechanisms, by serving as a repository for multimedia materials and providing basic structure to curricular formats. Moreover, the Moodle application possesses the capacity for an enormous number of interactive features such as quizzes, feedback pages, discussion forums, group projects, and wiki pages, as well as real-time tracking features, allowing instructors to monitor student engagement and success. With such a breadth of possibilities, Moodle has been successfully used throughout medical education, particularly in supplementing clinical learning in the surgical realm [19–23].

In this study we aimed to develop an Internet-based self-study pilot course using the Moodle format, implementing the curriculum in a multi-institutional setting with learners at various stages of cardiothoracic training. We hypothesized that such courses could be successfully executed, with objective evidence of learning in cardiothoracic surgical topics.

Patients and Methods

Course Design

A needs assessment was conducted with attention directed toward topics associated with poor performance on recent American Board of Thoracic Surgery (ABTS) qualifying and certifying exams. In verbal communications from the ABTS, we learned that questions addressing tracheal disease are associated with the highest errors on both the written and oral components of the board examinations. Consequently, for this pilot curriculum, tracheal disease was targeted as a subject of focus.

Using a Moodle-based platform, 4 online pilot courses were developed by content experts, intended for use as independent self-study exercises. The content experts were selected by 2 means. Thoracic surgeons were selected among those individuals who already engaged in trainee educational efforts nationally to generate initial content. In addition, the resultant content was reviewed and supplemented by established national experts, recognized for relevant publications in the field of tracheal disease. The 4 course titles were as follows: pulmonary physiology and assessment; radiographic and surgical anatomy of the trachea; disorders of the trachea and bronchus; and tracheal and bronchial surgery. Each course included general readings, detailed readings, multimedia content, an open forum, and a question-bank supported quiz. When copyright restrictions were present (ie, textbook chapters, some journals), only the references were provided. However, when open access was available the actual content was uploaded electronically into the Moodle course to provide instant online access to the reading material. Multimedia content included pertinent websites identified by content experts as well as relevant Thoracic Surgery Directors Association online lectures. The 4 courses all related to tracheal disease and collectively formed the pilot curriculum.

Students were assessed on each course through the question-bank supported quiz. Each quiz was comprised of a random selection of 10 questions from its associated bank, with the banks containing an average of 42.5 questions per course, with a range of 30 to 58. The questions were developed by the content experts and also gleaned from the applicable sections of Self Education Self Assessment in Thoracic Surgery (SESATS) 7 and 8. For each quiz attempt, the students were given an opportunity to answer 10 questions randomly selected from the larger quiz bank. In addition to the random selection of 10 questions, each time a specific question stem was used, the associated responses were additionally randomized with regard to the order in which they were listed. Students were given a 15-minute time limit to complete each quiz. They were required to achieve scores of at least 90% or greater on each of the course quizzes, with no limit on the number of attempts allowed. However, there was a mandatory 12-hour waiting period between quiz attempts in order to encourage further independent study and knowledge acquisition between attempts.

Students

The pilot curriculum was provided to cardiothoracic surgical trainees at 4 North American training programs, including both traditional track and integrated 6-year (1-6) residents. Potential programs were generated initially out of a sample of convenience by soliciting the ABTS, Joint Council On Thoracic Surgery Education, and the Thoracic Surgery Directors Association (TSDA) Executive Committee members, as well as collaborating investigators on this study. Final participant programs were selected in order to achieve regional diversity, variability in terms of clinical experiences, and to cover a spectrum of educational environments including newer as well as more established training programs.

Data Collection

With Institutional Review Board approval (M.D. Anderson Cancer Center Protocol ID #: PA13-0806) and consent from participating subjects, utilization and exam data were tracked electronically. Time spent per course was calculated by retrieving access data from the Moodle
program. Moodle collects information related to specific keystrokes with an exact time stamp of each keystroke or mouse click.

Time elapsed between clicks can be interpreted as either engagement on the site (e.g., reading an article) or absence from the site (i.e., individual has turned his or her attention elsewhere). In order to calculate time spent on the site by a learner we analyzed the data to estimate reasonable periods of time between clicks from a given Internet Protocol (IP) address that would suggest ongoing involvement of an engaged individual, rather than reflecting simply leaving the computer unattended.

A series of formulas were developed to divide the key strokes of each individual into specific study sessions based on various latency periods between clicks. Iterations were conducted using a wide range of proposed time between clicks from a given session times, de- fined utilizing SurveyMonkey (Portland, OR) and it was totally anonymous and not required for course completion. The instrument included both objective and subjective components. Using a 6-point Likert scale, individuals were asked to quantify their agreement with statements pertaining to ease of course navigation, efficacy of the course in learning the expected content, usefulness of the multimedia content, and educational benefit of the quizzes. Items were scaled as follows: 1 = strongly disagree; 3 = disagree; 4 = agree; and 6 = strongly agree. Respondents were also asked to provide free-text responses with regard to their perceptions of the best and least favorable elements of the course.

Data Analysis

Descriptive statistics were expressed as mean ± standard error and comparisons were made with paired, 2-tailed t tests for means of normally distributed continuous variables. Categoric data were expressed as counts and percentages, with the Fisher exact test and χ² testing used to analyze differences, with α = 0.05 considered significant.

Results

Students

Nineteen students at 4 training programs were enrolled into the pilot course, including 16 (84.2%) men. Additional demographic features are shown in Table 1. Among the participants, 9 (47.4%) were from traditional 2-year programs and 6 (31.6%) were from traditional 3-year programs, with course participants comprised of individuals from all levels of training within these programs; 4 (21.1%) were from I-6 programs, and included 1 each from postgraduate year (PGY)-1 to PGY-4.

Resource Utilization

Students spent a mean of 1.35 hours on each course, with a range of 0.18 to 3.40 hours (Table 2). Average time spent on the full curriculum was 6.40 hours, with a range of 2.75 to 9.30 hours. Among traditional-track trainees there was a trend toward more time spent per course for those individuals in their first year of training compared with those in their final year of cardiothoracic training (Table 2).

Table 1. Demographics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>15</td>
<td>84.2%</td>
</tr>
<tr>
<td>Training program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traditional 3-year</td>
<td>6</td>
<td>31.6%</td>
</tr>
<tr>
<td>Traditional 2-year</td>
<td>9</td>
<td>47.4%</td>
</tr>
<tr>
<td>I-6</td>
<td>4</td>
<td>21.1%</td>
</tr>
<tr>
<td>Level of training</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PGY-1</td>
<td>1</td>
<td>5.3%</td>
</tr>
<tr>
<td>PGY-2</td>
<td>1</td>
<td>5.3%</td>
</tr>
<tr>
<td>PGY-3</td>
<td>1</td>
<td>5.3%</td>
</tr>
<tr>
<td>PGY-4</td>
<td>1</td>
<td>5.3%</td>
</tr>
<tr>
<td>PGY-5</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>PGY-6</td>
<td>7</td>
<td>36.8%</td>
</tr>
<tr>
<td>PGY-7</td>
<td>6</td>
<td>31.6%</td>
</tr>
<tr>
<td>PGY-8</td>
<td>2</td>
<td>10.5%</td>
</tr>
</tbody>
</table>

I-6 = integrated 6-year program; PGY = postgraduate year.
Objective Knowledge Gains

Students required a mean 2.86 attempts (range 1 to 7) to pass each quiz (Table 2). Mean scores improved with subsequent attempts (Fig 1), demonstrating knowledge acquisition. More senior trainees demonstrated a trend toward fewer required quiz attempts than more junior individuals (Table 2). Trainees at all levels exhibited improvement over time. All students passed courses 1 to 3, and 95% completed course 4.

Trainee Perceptions

Post-course survey respondents generally found the courses to be easy to navigate and beneficial to learning the intended material (Table 3). Subjective commentary was overall quite positive; however, learners also provided valuable feedback for future course improvements. In general, the most favored elements of the course included the multimedia content, the quizzes as learning tools, and the self-paced nature of the courses. Dissatisfaction with the lock-out period between quiz attempts was the most frequently mentioned area for improvement. In addition, the lack of availability of all the content online was also a concern.

Comment

In this study we designed and implemented a web-based curriculum to supplement the education and training of thoracic surgical residents. We demonstrated the feasibility and efficacy of this educational modality. All trainees showed knowledge acquisition over time, demonstrated by a progression of quiz scores on each subsequent quiz attempt. The speed of knowledge acquisition was associated with increasing exposure to course material and the experience level of the trainees. Finally, overall global feedback was excellent and our participants provided us with helpful information for future iterations.

Table 2. Pilot-Course Utilization and Exam Performance

<table>
<thead>
<tr>
<th>Variable</th>
<th>Course 1: Pulmonary Physiology and Assessment</th>
<th>Course 2: Radiographic and Surgical Anatomy of the Trachea</th>
<th>Course 3: Disorders of the Trachea and Bronchus</th>
<th>Course 4: Tracheal and Bronchial Surgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of linked readings</td>
<td>7</td>
<td>7</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Number of linked + nonlinked readings</td>
<td>13</td>
<td>11</td>
<td>20</td>
<td>34</td>
</tr>
<tr>
<td>Mean time spent (hh:mm:ss), all comers</td>
<td>1:34:17</td>
<td>1:02:05</td>
<td>1:33:39</td>
<td>1:13:52</td>
</tr>
<tr>
<td>Mean time spent, first-year traditional track</td>
<td>1:45:50</td>
<td>1:09:03</td>
<td>1:37:23</td>
<td>1:24:16</td>
</tr>
<tr>
<td>Mean time spent, final-year traditional track</td>
<td>1:28:45</td>
<td>0:55:41</td>
<td>1:37:06</td>
<td>1:15:11</td>
</tr>
<tr>
<td>P-value (time spent, first vs final-year)</td>
<td>0.514</td>
<td>0.539</td>
<td>0.993</td>
<td>0.730</td>
</tr>
<tr>
<td>Mean exam attempts, all comers</td>
<td>2.58</td>
<td>2.79</td>
<td>3.63</td>
<td>2.42</td>
</tr>
<tr>
<td>Mean exam attempts, first-year traditional track</td>
<td>2.50</td>
<td>3.33</td>
<td>3.83</td>
<td>2.33</td>
</tr>
<tr>
<td>Mean exam attempts, final-year traditional track</td>
<td>2.17</td>
<td>2.17</td>
<td>3.17</td>
<td>2.17</td>
</tr>
<tr>
<td>p-value (exam attempts, first vs final-year)</td>
<td>0.583</td>
<td>0.120</td>
<td>0.531</td>
<td>0.756</td>
</tr>
</tbody>
</table>

hh:mm:ss = hours:minutes:seconds.
Courses were easy to navigate
Courses were overall beneficial in learning content
Multimedia curricular materials were beneficial in learning content
Quizzes were beneficial in learning content

Mean scores on 6-point Likert scale, where 1 = strongly disagree, 3 = disagree, 4 = agree, and 6 = strongly agree.
SEM = standard error of the mean.

While this course is the first multi-institutional application of a Moodle-based curriculum designed to specifically augment thoracic surgical training, its design and development have been based on a number of previous educational projects. Several learning curricular resources and repositories have been made available in the realm of general surgery, offering significant benefits and access to up-to-date materials in a setting where knowledge is constantly expanding and textbooks may be lacking the latest innovations by the time they are published [1]. Such resources include the Surgical Council on Resident Education (SCORE) Portal and the American College of Surgeons Fundamentals of Surgery. The SCORE was formed in 2006 by several organizations invested in national efforts toward improving trainee education in general surgery and related specialties through the development of a national curriculum. The SCORE Curriculum Outline identifies learning objectives, updated annually, and provides access to corresponding readings, videos, and self-assessment tools. While its development continues to be underway, feedback has been positive [24].

The American College of Surgeons Fundamentals of Surgery serves as another e-learning environment in general surgery training. Less expansive than the SCORE Portal, the Fundamentals of Surgery consists of 90 case scenarios within 11 modules aimed at engaging surgical interns in case-based patient management by identifying symptoms, ordering tests, and formulating treatment plans [25]. Outcomes studies validating the efficacy of these modules have not been performed extensively; however, this curriculum has been shown to promise as a knowledge preparatory tool for some categories of clinically related knowledge [25].

A number of past efforts have been put forth to utilize web-based resources for novel curricular endeavors in thoracic surgery. In 2002, the TSDA Prerequisite Curriculum (PRC) Committee developed content for a didactic curriculum to be mastered by the residents before starting their thoracic surgical residency. The committee assembled an innovative electronic format consisting of a CD-ROM/Internet Hybrid to teach the curricular material [17]. Advantages touted by the authors included the ability to store relatively dense high bandwidth multimedia portions of the curriculum on the CD-ROM, with the ability for constant updating and interaction of the other portions of the curriculum with the Internet. A follow-up study randomizing trainees to those who use used the PRC and those who did not found a positive correlation between in-training examination performance and access to the curriculum [15]. Another key finding from this experience was that as modules were revised and improved the average module rating rose, with increased utilization and decreased variability in ratings [16]. Importantly, these experiences have shown that online curricular models can be efficacious in thoracic surgical training and that web-based curricula offer the opportunity for continuous modification and adaptation, allowing opportunities to tailor the content to the needs of the trainee and the changing field of thoracic surgery. As the capacity for sharing large multimedia files through web-based environments has expanded exponentially, the same intentions can now be achieved through a web-based platform alone.

In 2005, The European Association for Cardio-Thoracic Surgery embarked upon a similar project, launching the Multimedia Manual for Cardiothoracic Surgery (MMCTS) as a novel educational tool for cardiothoracic surgeons, aiming to replace standard textbooks and surgical manuals with an internet-based educational tool, with a specific focus on surgical techniques [18]. The MMCTS consists of 8 sections, each one addressing a separate subfield within cardiothoracic surgery. While the MMCTS serves as an excellent repository of material, and is a great example of using web-based environments for sharing of multimedia educational materials, it differs from the TSDA PRC and the pilot curriculum described in this study in that it serves as a library of resources but it does not include any corresponding formal, structured curriculum.

Our study represents the first web-based curricular model for supplementing the clinical training of cardiothoracic residents. This study has several strengths. It was conducted in a multi-institutional environment and included participants across a broad range of training years and program formats. Most importantly we were able to provide some objective evidence of learning.

We recognize that the study is also subject to limitations. Our pilot cohort is small and was not randomly selected, both of which limit the validity of any conclusions. We developed a formula for calculating time on the site based upon time between clicks from a given IP address. It is feasible that our assumptions were erroneous and that some gaps between clicks represented absence from the site rather than time spent reading on the site.

Scores on the multiple-choice exams were used as markers of objective learning; however, the reliability and validity of the instruments have not yet been demonstrated. More importantly, the impact of these courses on clinical care is unclear. Additional endpoints investigating validated outcomes such as ABTS examinations will be targeted in future investigations.
Based upon this pilot study, the new Thoracic Surgical Curriculum was recently rolled out. The new curriculum, a collaboration of the ABTS, the Joint Council for Thoracic Surgical Education, and the TSDA, includes a detailed account of the cognitive skills expected of every thoracic surgical resident upon completion of training [9]. This curriculum serves as a guide for residents and program directors, and it includes an extensive collection of Moodle-based teaching modules developed and implemented as of August 2013. The editorial board of the new curriculum identified up-to-date content for each of the requisite topics outlined by the ABTS and organized the various forms of content, including textbooks, published literature, video recordings, online lectures, and websites, onto a separate content management system [1]. Incorporating the feedback obtained from this pilot project, all content on the new site is immediately accessible online. There are plans for eventual use of this curriculum as a resource for development of the ABTS written and oral examinations, which will be of significant benefit to those who use it [9]. This curriculum is considered to be an initial iteration, with plans for continuous improvement. Early feedback has suggested that the approach is well received, and future studies following the impact of the full curriculum are underway [1]. This pilot study demonstrated the feasibility and educational value of online curricular design and structure, and, with support from the thoracic surgical education community, continued efforts toward the improvement and evolution of e-learning will be fruitful.

References

ultime goal of eventually showing improvement in board exam pass rates.

DR NAHUSH A. MOKADAM (Seattle, WA): You should be congratulated on this effort. It is a great first step in this type of format.

Are you able to comment on the time that it took to develop this? I have heard stories of how long and how much effort this took for the group to develop, and I think that is an important element for us to consider if we are going to do this in other elements of cardiothoracic surgery.

DR ANTONOFF: Thank you for your question. You are correct in that this is a very time- and labor-intensive process. A number of educational leaders invested efforts in the initial development of the materials, followed by a thorough review from content experts, who were recognized for their expertise in the field based on publications within the discipline. This endeavor required energy and commitment from very busy individuals, many of whom are present at this forum, who devoted a considerable amount of time in developing the content. However, while we frequently tout that one of the many strengths of the online learning management system is that the materials can be continuously updated, it is our hope that most of the work will be front-loaded at the beginning, with smaller efforts aimed toward its maintenance as we move into the future.

DR R. ANTHONY PEREZ-TAMAYO (Maywood, IL): I have a simple question about the mechanics of the quizzes. Since the questions are randomly selected, each time that they took the quiz was there replacement of any of the questions, or were they seeing a completely new batch of questions?

DR ANTONOFF: Thank you for your question, and I'll be happy to clarify. Each of the courses had its own quiz bank, with the banks containing an average of 42.5 questions per course, and a range of 30 to 58. So there were quite a number of questions available for each quiz. While repetition of the questions was possible, considering that the average number of quiz attempts required was 2.9, it was also quite likely that the majority of the questions were new to the trainees with each quiz attempt. I should comment that not only were the questions randomized in terms of which questions the individuals received, but the order of the itemized answer choices were randomized within each question for each quiz attempt, as well. That is to say, the correct answer to a question varied as to whether it was listed as A, B, C, or D. Therefore, students were not able to just memorize for a particular question, "the answer is B." They really had to think about it, and, consequently, we are hopeful that there was some validity to our measurements of knowledge acquisition.

DR ANDREA J. CARPENTER (San Antonio, TX): To follow up on that, are you aware of any literature to support what size question bank is a minimum or appropriate average number of questions to be valid in this sort of environment so that it does become an effective assessment tool? Hopefully, our goal is strong enough to satisfy proof positive of having met specific milestones in the new paradigm of competency-based resident education and residency program accreditation.

DR ANTONOFF: Thank you for your question, Dr Carpenter. There are certainly data to support the length of the formal exams that we see throughout all of our training and certification, the number of questions that are required to actually measure someone's knowledge on an in-service exam or on a board exam. In terms of how many questions you need on a smaller-scale test like this to really tell the difference, this is a process in evolution.

We really do need to sort it out, and I think the best way to do that is, as we move forward, seeing how well these scores do validate and how well they do compared to the gold standard when we conduct our further studies.

DR CARPENTER: And, of course, the benefit that immediately comes to mind with online learning is that these courses can be maintained in a common bank and they can be used widely, not just around the nation but around the world. So although it is very time-intensive to create a specific course, once this course is created it can be used by everyone.

DR ANTONOFF: That is certainly a consideration, yes. Widespread availability would be a great advantage of these novel online resources, following the development of an appropriate means of managing access and dissemination.

DR SIDHU P. GANGADHARAN (Boston, MA): I have a question which I think somebody brought up; how this will translate into performance on in-training or board exams? It seems that one of the things that you have the capability to assess almost right away or given a period of time would be the effect of extinction of this knowledge. You clearly showed an increase in the performance on the quiz, but do you have plans to look at this again in another 6-month interval and see where those same learners score on the same sort of set of questions?

DR ANTONOFF: Thank you, I appreciate this insightful inquiry. Evaluation of the durability of the impact is certainly an incredibly important question. This will undoubtedly be a key component of our follow-up with future studies of this intervention.

DR CARPENTER: I can attest to the fact that the residents who took the first course around are going to hate you for asking that question.

DR ALLEN: I would like to make a comment. As the exam Chair, I don't know whether it's related to this or not, but on the most recent examination the trachea was not the worst-performing section of the exam. Hopefully that helped, but we'll have to see over time, obviously.

DR ANTONOFF: Thanks very much, Dr Allen. I appreciate your comment. I would like for us to be able to take credit for that effect; although, admittedly, this study included an N of 19, with only a handful of graduating individuals who may not have actually yet taken the most recent exam. Nonetheless, we are grateful for your support and belief in our efforts.

DR SOHAILA M. ALI (Westminster, MD): While the courses that you are developing seem to be developed for residents in training, et cetera, I think for those of us who have taken our board exams a long time ago, who do a recertification every 5 to 10 years, it would be good to have courses of this kind which are updated every year which one can take every year and sort of reiterate to ourselves the fact that our knowledge is current. I think more and more in the current environment, hospitals are going to require that you not only have your recertification validated every 5 years but something more current, which you can then say, yes, on a yearly basis you are keeping up with things, not just with Continuing Medical Education (CME) but with something which is more tangible and has a certificate attached to it.

DR ANTONOFF: Thank you for your comment. That is certainly the next frontier for these efforts, and we clearly have a lot of work to do to develop these courses in a lot of other realms as we move forward.