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Longitudinal cohort study on medical student retention of anatomical knowledge in an integrated problem-based learning curriculum

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ABSTRACT
Background: When modifying a curriculum to accommodate changes in the methods of subject matter presentation or fit within a shortened time frame, student retention of knowledge remains an important issue.
Aim: This study evaluates medical student retention of anatomical knowledge as they matriculate through an anatomy curriculum where the instruction hours are less than half of the current national average.
Method: Medical students completed an assessment tool developed to evaluate their baseline level of anatomical knowledge at the beginning of the first year. They then completed the instrument at the end of their 1st, 2nd, 3rd, and 4th years to assess their retention of anatomical knowledge during medical school. Data collection began in September 2010 and concluded in June 2015.
Results: Results demonstrate that students began medical school with a low level of anatomical knowledge (baseline), that knowledge increased during their first year ($p<0.001$), continued to increase during their second year ($p<0.001$), but was over 90% maintained through years 3 and 4.
Conclusion: In conclusion, an anatomy course with reduced hours ($/24$), using active learning methods, contextual learning, cadaver demonstrations, increased exposure to imaging, and longitudinal reinforcement can help students build a strong foundation of anatomical knowledge.

Introduction
Medical education has changed, is changing, and will continue to change. Reasons include moving from a teacher-centered to a student-centered approach (active learning), less compartmentalized teaching and testing (integration), the introduction of clinical medicine/clinical problems at earlier stages (contextual learning), and learning across the curriculum (a longitudinal approach). As medical education moves in these new directions, it is clear that presentation of core content and overall course structure will change. This is especially true as it relates to education in the anatomical sciences. The impact of curricular reform on this discipline has included shortened course hours (Drake et al. 2014), the need to prepare students differently to match clinical demands (Dangerfield et al. 2000; Stalburg & Stein 2001), and the use of different educational approaches to address student learning styles (Fleming 1995).

Specific pedagogical changes in anatomy courses have included: the use of active versus passive learning formats such as team-based learning (Vasan et al. 2011; Huit et al. 2015), small group interactive sessions (Zumwalt et al. 2010), peer-facilitated teaching (Bruno et al. 2016), and the use of audience response systems (Wait et al. 2009). Technology has also increased in these courses with incorporation of web-based instructional materials (Green et al. 2014; Stirling & Birt 2014) and simulators. Furthermore, cadaver laboratories now use a combination of student dissections and prosections (previously dissected cadavers) (Marshak et al. 2015) and include increased exposure to imaging through ultrasound demonstrations, CT’s of cadavers (Drake 2007; Lufler & Zumwalt 2014; Nwachukwu 2014) and more emphasis on imaging in general. These imaging modalities aid in the students understanding of anatomy in the context of clinical medicine (Drake 2007; Rizzolo et al. 2010; Bockers et al. 2014). A final and more recent change is the longitudinal integration of an educational activity in anatomy across the curriculum including during clinical rotations (Drake 2007; Custers 2010). All of these activities are available to enhance and stimulate student learning, retention, and the application of knowledge.

The question is, are these new approaches facilitating student learning and supporting their retention and application of knowledge? Reports in the literature seem to suggest that, at least for anatomy, the answer to this question

Practice points
- Medical education is moving from a teacher-centered to learner-centered approach.
- Utilization of active learning methods and integrated curricular content support diverse learning styles and strengthen problem-solving skills.
- Longitudinal integration of educational content stimulates student learning, retention, and the application of knowledge.
may be no. Poor retention (Prince et al. 2005; Zumwalt et al. 2010; Bhangu et al. 2010; Jurjus et al. 2014), inadequate anatomy knowledge of medical students (Waterston & Stewart 2005; Staskiewicz et al. 2007), and poor knowledge transfer from the classroom to the clinic (Lazarus et al. 2012) are indications that approaches used in some anatomy courses may not be providing medical students with the anatomical knowledge and the learning environment they need to succeed in a clinical setting.

In this study, we investigated medical student retention of anatomical knowledge as they progress through the unique and innovative curriculum at the Cleveland Clinic Lerner College of Medicine (CCLCM).

Curricular/course organization

The educational program at the CCLCM of Case Western Reserve University is a problem-based, organ-systems structured, integrated curriculum with interactive seminars (Fishleder et al. 2007). It spans approximately 34 weeks in the first year and approximately 32 weeks in the second year not counting the summer sessions, which are more research oriented. There are three 2-hour problem-based learning (PBL) sessions and four 2-hour interactive seminars each week. The purpose of this design is to provide the students with a learning environment that prolongs their exposure to the nuances of each body system in a context-based format. Discussion of these systems occurs within 8 first and second year courses, which include Cardiovascular and Respiratory Sciences, Gastrointestinal System, Endocrinology and Reproductive Biology, Renal Biology, Musculoskeletal Sciences, Neurosciences, Behavioral Sciences, and Hematology/Immunology/Microbiology.

Courses in the first year focus on normal structure and function, while the second year examines the pathophysiology of disease.

Student assessment and evaluation of progress through the entire curriculum is competency based and there are no examinations or grades. The competencies on which students are evaluated include: research, medical knowledge, communication, professionalism, personal development, reflective practice, health care systems, clinical reasoning, and clinical skills (Dannefer & Henson 2007). These are similar to those mandated by the Accreditation Council for Graduate Medical Education (ACGME). Given the robust advising system necessary for this type of evaluative process, the incoming class size is limited to 32. To gain a better understanding of the unique structure of this curriculum and assessment methods mentioned, refer to the references mentioned earlier.

The anatomy course/program spans the entire CCLCM curriculum and totals approximately 66 h (Drake 2007). Students meet for 2 h on Monday mornings for 26 weeks in the first year (52 h), for one 2-hour session approximately every 4 weeks in the second year (12 h), and a 2-hour anatomy session at the beginning of their surgery rotation in the third/fourth year. During the first and second years, the content of each anatomy seminar corresponds to the theme of the week, PBL case and other scheduled seminars. Students prepare for the anatomy seminar, which is a case presentation by a clinical faculty member, by reviewing the clinical case, which includes guiding questions and learning objectives, and completing a required reading assignment. At the conclusion of the case discussion, students transition into a laboratory activity consisting of fresh tissue cadaveric dissections and an imaging station facilitated by a radiologist. In this context, anatomical knowledge is gained in the first year, reinforced in the second year, and further strengthened in the 3rd and 4th years. Additionally, across the entire medical curriculum, learning and retention of anatomical knowledge is reinforced through its application in clinical case studies in PBL sessions, physical diagnosis sessions, and experiences in clinical settings (1st and 2nd year office experiences and 3rd and 4th year discipline rotations).

The question of interest in this study is – What is the retention of anatomical knowledge as students’ progress through this longitudinal educational program?

Methods

Assessment tool

An assessment tool was developed and used to evaluate the retention of anatomical knowledge during medical school. Medical students filled out the instrument at the beginning of the first year to determine a baseline level of knowledge. They then completed the instrument at the end of their 1st, 2nd, 3rd, and 4th years. Data collection began in fall 2010 and concluded in summer 2015.

The development of the assessment tool was a multi-step process. Initially, the investigators identified a large number (~100) of questions constructed following National Board of Medical Examiners (NBME®) guidelines (Case & Swanson 2002). Content wise, the assessment questions represent the knowledge base a medical student should be familiar with after completing a typical gross anatomy course taken during the first/second year of medical school. As a second step in this process, two anatomy educators evaluated the large pool of questions and reduced it to a number that the students could complete within 60 min. These evaluators also made sure there was an adequate representation of questions from each region of the body and that the imaging questions were appropriate and clinically relevant.

The final assessment tool consisted of 45 questions that, according to Bloom’s taxonomy, would assess knowledge, comprehension, and/or application (Bloom 1956). Forty-one of the questions were of the one-best-answer style commonly referred to as multiple-choice questions. They also conformed to the NBME® style with the stem being a short clinical problem, followed by a question and five choices. There were also four identification questions that asked participants to name a structure or several structures indicated in an image. The regional breakdown of the questions was seven head, four neck, five upper limb, six lower limb, eight thorax, nine abdomen, seven pelvis/perineum, and one back.

This study took place at the Cleveland Clinic after approval from the Institutional Review Board (IRB).

Assessment distribution

Each cohort of students received an email regarding the study purpose and instructions for participation.
Student instructions included a request not to prepare for the assessment individually. Students could access the assessment tool through Moodle version 2.8.7 (Moodle Pty Ltd, Perth, Australia). The authors received the results of student performance but did not report them to the students.

**Data analysis**

Only summary measures of cohort performance were available for analyzes (mean, standard deviation, and sample size). Thus, we compared each assessment score mean to that of the previous assessment score mean within the same cohort using a two-tailed, two-sample t-test. To adjust for multiple comparisons, Bonferroni’s correction was applied and statistical significance was set at a \( \alpha = 0.05/13 = 0.0038 \) level. Cronbach’s alpha was calculated to quantify the test reliability. Analyses were conducted using SAS version 9.3 (SAS Institute, Cary, NC).

**Results**

Four different cohorts of CCLCM medical students participated in this study anonymously. We made the assessment tool available to them at the beginning and end of their first year (four cohorts), the end of their second year (four cohorts), the end of their third year (three cohorts), and the end of their fourth year (two cohorts). Results in Table 1 demonstrate that students began medical school with a low level of anatomical knowledge (baseline), that knowledge increased during their first year \( (p < 0.001) \), continued to increase during their second year \( (p < 0.001) \), with no evidence of a difference in the mean scores between the third and fourth years.

A graphical representation of the data in Figure 1 shows that retention of anatomical knowledge ranged from 91% to 95% over the three to four year time points.

**Discussion**

In the current study, retention of anatomical knowledge is 91–95% through year 4 of medical school for two cohorts and 91% through year 3 of medical school for another cohort. Students began medical school with a low level of anatomical knowledge. Their knowledge increased during the 1st year, continued to increase during year 2 after additional anatomy sessions, and remained above 90% during years 3 and 4. This high level of retention occurred within an anatomy program with clinically oriented seminars, using prossected/previously dissected cadavers, and a longitudinal format (Drake 2007) with a total of 66 h, well below the national average for an anatomy course of 147 h (Drake et al. 2014).

The retention of knowledge during medical school has been a topic of debate for more than 75 years (Cole 1932) and these discussions have intensified since the start of the twenty-first century when curricular reform in medical schools became a common event. An excellent review by Custers discusses numerous aspects of this question not only from a historic perspective, but also by comparing retention of knowledge in general education to retention of basic science knowledge in medical education (Custers 2010). His summary of the historical data suggests that while there is a significant loss in the retention of general education knowledge: 70% retained after 1 year of nonsense; 40–50% after 2 years; 30% after 4 or more years, the situation regarding the retention of basic science knowledge learned in medical school is better and appears to be subject related. A summary of data in the Custers review suggests that over time the loss of knowledge in Pharmacology and Pathology is very small; Physiology, Microbiology, and Gross Anatomy are small; Neuroanatomy is large; and Biochemistry is very large. The review ends by suggesting there is little problem with retention if knowledge is frequently used after initial instruction and Custers provides a list of instructional approaches taken from available literature that can optimize long-term retention.

In another series of studies spanning 30 years, the National Board of Medical Examiners evaluated retention of basic science information between the period when medical students took the Step 1 exam and the Step 2 exam (Kennedy et al. 1981; Dillon 1988; Dillon et al. 1991; Swanson et al. 1996; Ling et al. 2008). Since the last of these studies occurred after the period of initial curricular reforms, there was interest in whether changes in educational approaches would affect retention rates. This may have occurred with decreased retention in Pharmacology and possibly Pathology, compared to previous results, and increased retention in Behavioral Sciences, compared to previous results, but the typically observed trend of large retention losses in Biochemistry and Microbiology and smaller drops in Physiology and Anatomy still occurred (Ling et al. 2008).

The current study looked at retention of anatomy knowledge in an innovative curriculum that uses active learning formats, less student dissection, more cadaver demonstrations in the laboratory, an increased exposure to imaging, contextual learning throughout the curriculum, and continued exposure to basic sciences into the clinical rotations. Along these lines, Norman’s (2009) review identifies several teaching strategies available to optimize transfer, a phenomenon defined by cognitive psychologists as the ability to apply a concept learned in one context to solve a problem in a different context (Norman 2009). While beyond the scope of this study, several of the strategies discussed by Norman are integral and consistent parts of the CCLCM curriculum and may have played a role in the significant level of knowledge retention reported in this study.

A possible limitation in this type of study is the assessment tool. The instrument used in this study was prepared.

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Table 1. Medical student performance on assessment tool.

<table>
<thead>
<tr>
<th>Cohorts</th>
<th>Sept Yr 1</th>
<th>June Yr 1</th>
<th>June Yr 2</th>
<th>June Yr 3</th>
<th>June Yr 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class of 2015</td>
<td>10%±9%</td>
<td>46%±12%</td>
<td>63%±12%</td>
<td>60%±11%</td>
<td>60%±9%</td>
</tr>
<tr>
<td>n = 30</td>
<td>n = 28</td>
<td>n = 27</td>
<td>n = 26</td>
<td>n = 22</td>
<td></td>
</tr>
<tr>
<td>( \alpha )</td>
<td>( \alpha = 0.74 )</td>
<td>( \alpha = 0.77 )</td>
<td>( \alpha = 0.71 )</td>
<td>( \alpha = 0.59 )</td>
<td></td>
</tr>
<tr>
<td>Class of 2016</td>
<td>13%±15%</td>
<td>58%±14%</td>
<td>77%±10%</td>
<td>72%±13%</td>
<td>70%±13%</td>
</tr>
<tr>
<td>n = 28</td>
<td>n = 24</td>
<td>n = 23</td>
<td>n = 21</td>
<td>n = 19</td>
<td></td>
</tr>
<tr>
<td>( \alpha )</td>
<td>( \alpha = 0.93 )</td>
<td>( \alpha = 0.76 )</td>
<td>( \alpha = 0.72 )</td>
<td>( \alpha = 0.83 )</td>
<td></td>
</tr>
<tr>
<td>Class of 2017</td>
<td>13%±9%</td>
<td>63%±15%</td>
<td>81%±9%</td>
<td>74±12%</td>
<td>74±11%</td>
</tr>
<tr>
<td>n = 30</td>
<td>n = 25</td>
<td>n = 18</td>
<td>n = 14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \alpha )</td>
<td>( \alpha = 0.79 )</td>
<td>( \alpha = 0.84 )</td>
<td>( \alpha = 0.67 )</td>
<td>( \alpha = 0.81 )</td>
<td></td>
</tr>
<tr>
<td>Class of 2018</td>
<td>17%±12%</td>
<td>61%±17%</td>
<td>77%±10%</td>
<td>71%±9%</td>
<td>65%±11%</td>
</tr>
<tr>
<td>n = 25</td>
<td>n = 24</td>
<td>n = 17</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \alpha )</td>
<td>( \alpha = 0.86 )</td>
<td>( \alpha = 0.88 )</td>
<td>( \alpha = 0.75 )</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Data represents the mean ± SD of the % correct on the assessment tool. \( \alpha \)-Cronbach’s alpha for each administration of the assessment tool. *Cronbach’s alpha not available for this administration.
as described in “Methods” section and used throughout the entire study period. Confidence in the utility of the assessment tool comes from various sources. First, questions chosen for inclusion in the assessment all ranked in the middle to high range for level of item difficulty and item discrimination. Second, from the student’s point of view this was a low stakes progress based test with no individual identifiers, unlike a traditional high stakes test, which also provokes feelings of significant stress. Third, the students only saw the assessment tool once in a 12-month period and were never supplied with the correct answers. Fourth, the use of the same assessment tool at various time points has been reported in previous studies (Feigin et al. 2007; O’Day 2007; Darland & Carmichael 2012).

Future studies exploring individual factors that reinforce student knowledge are of interest to the authors. Previous studies have identified the importance of clinically based learning experiences. Sarkis et al. found that surgeon-facilitated anatomical teaching significantly improved long-term retention of topographical anatomical knowledge (Sarkis et al. 2014). In addition, Kondrashov et al. showed that incorporation of ultrasound laboratories significantly improved anatomical knowledge of second year medical students (Kondrashov et al. 2015). It appears that the context provided by the incorporation of clinical modalities and staff members is a valuable component of the CCLCM curriculum. Identifying the specific modalities that are most beneficial to student learning and at what time in their education is a question that needs further study.

Conclusion

This report provides evidence that a shortened course, using a nontraditional format for learning, can help build a strong foundation of anatomic knowledge that will support a medical student as they progress toward the completion of their educational program.

Acknowledgements

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Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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