

Original Publication

OPEN ACCESS

Abdominal Anatomy Tutorial Using a Medical Imaging Platform

Madeleine J. Marsland, Dunya Tomic, Pamela L. Brian, MD, Michelle D. Lazarus, PhD*

*Corresponding author: Michelle.lazarus@monash.edu

Citation: Marsland MJ, Tomic D, Brian PL, Lazarus MD. Abdominal anatomy tutorial using a medical imaging platform. *MedEdPORTAL*. 2018;14:10748.
https://doi.org/10.15766/mep_2374-8265.10748

Copyright: © 2018 Marsland et al. This is an open-access publication distributed under the terms of the Creative Commons Attribution-NonCommercial-Share Alike license.

Abstract

Introduction: Easing students' transition to the clinical environment is vital in medical education. For anatomy, this can be achieved by incorporating medical imaging. Most resources for study of imaging solely cover structural identification, which does not adequately prepare students to interpret imaging in clinical practice. This resource adds to a series of tutorials incorporating clinical applications of anatomy. **Methods:** The tutorial was a self-administered PowerPoint that guided students through principles of abdominal anatomy. It integrated radiological images, including X-ray, computed tomography, and magnetic resonance imaging, plus clinical correlations and self-evaluation. It was evaluated as a review tool, using repeated-measures control/experimental design, on 100 Australian medical students in preclerkship years. Testing comprised knowledge-based questionnaires, a Likert self-efficacy scale, and open-ended evaluation questions. **Results:** Results suggest the tutorial significantly improved direct knowledge ($p < .001$), as the experimental group's posttutorial test scores were superior for direct questions by 32% on average. This difference was particularly significant for short-answer and multiple-choice questions. Students' confidence with anatomy and imaging was enhanced. **Discussion:** These results demonstrate the tutorial's strength as a review resource. Unlike our previous work, where students received tutorials alongside anatomy teaching, this tutorial was assessed after coursework completion with similar results. Direct knowledge significantly improved; however, indirect applications did not, perhaps due to complexity of the region. Nonetheless, the results reinforce the value of the series' tutorials as review tools, as well as adjunct tools alongside anatomy curricula. There is scope for further research into their use as stand-alone resources.

Keywords

Anatomy, Abdomen, Imaging, Radiology, Tutorial, Anatomy Review, Editor's Choice

Appendices

- A. Abdomen Imaging Tutorial .pptx
- B. Abdomen Imaging Tutorial Evaluation Pretest.docx
- C. Abdomen Imaging Tutorial Evaluation Posttest.docx
- D. Answer Guide to Pre- and Posttest.docx

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

Educational Objectives

Following use of the resource, learners will be able to:

1. Identify abdominal anatomical structures in a variety of medical imaging platforms.
2. Demonstrate comprehension of core abdominal anatomy.
3. Identify some abdominal pathology on medical images.
4. Compare and contrast the different medical imaging modalities presented in the tutorials and demonstrate basic understanding of medical imaging tenets.
5. Apply knowledge of abdominal anatomy to clinical scenarios and/or applications.

Introduction

Medical students traditionally receive their anatomy teaching through textbooks and laboratory classes; however, there has been a recent shift away from didactic approaches towards ones utilizing digital sources,¹ including those that draw upon radiologic imaging.²⁻⁵ One of the primary reasons for this shift is the current shortage of staff trained in gross anatomy⁶ combined with data suggesting improved learning using computer-aided instruction (CAI) in medical education.⁷ However, the desire to better prepare students for the clinical environment,^{8,9} which utilizes technology in day-to-day activities, remains a primary motivator.

A particularly challenging task for medical students is the transition from learning basic science in the classroom to applying this learned knowledge to patient scenarios in clinical practice.¹⁰ Having received the majority of teaching in the form of lectures and tutorials, students may then enter unfamiliar territory in hospital placements where they rely on resources such as biochemical testing and radiologic imaging. This explains the push for integrating clinically relevant information from the early years of medical school; in this scenario, students are eased into their transition from classroom to clinic. The benefits of introducing clinical concepts at an early stage have been explored in the fields of anatomy,^{11,12} histology,¹³ and neurobiology.¹⁴ The purpose of this tutorial is to contribute to the bridging between basic science teaching and clinical applications of medicine. As the latest instalment in our series of medical imaging tutorials,¹⁵⁻¹⁷ this educational resource fosters students' abilities to integrate anatomical principles with radiological imaging and commonly encountered clinical scenarios.

Where previous tutorials in the series have been developed for teaching of thoracic, upper limb, and lower limb anatomy,¹⁵⁻¹⁷ this work focuses on the challenging and multifaceted abdominal region that is essential in anatomical learning. As with the previously published tutorials in this series, this tutorial aims to broaden the scope of radiologic teaching, assisting early matriculating health care students' understanding of important anatomical relationships and their ability to apply this knowledge to clinical situations. These objectives are achieved through the teaching of anatomy using medical imaging. This tutorial explores several imaging modalities, including radiographs, computed tomography (CT), and magnetic resonance imaging (MRI). It exposes students to a diverse range of imaging techniques they are likely to encounter in clinical practice while covering abdominal anatomy in sound detail. The tutorial shares similarities to other published resources that endeavor to incorporate radiology into anatomy teaching, such as through team-based learning modules¹⁸ and self-guided anatomical atlases.¹⁹ It adds to the current literature through its versatility for use in a variety of settings.

Although the integration of ultrasound into medical anatomy curricula is an increasing trend,^{20,21} it was an executive decision to omit this modality from our tutorial due to the complexities of understanding how ultrasound works, an understanding required for its interpretation but beyond the scope of our hour-long review tool. However, the PowerPoint format enabled slides detailing exploration of ultrasonography to be added into the tutorial, allowing its use in a broader range of contexts and permitting not only novice learners but also more experienced students to expand their anatomical knowledge.

The research described below investigates the effectiveness of this imaging-based tutorial on medical students' knowledge of anatomical concepts and their preparedness for using imaging in clinical scenarios, primarily as a review tool for students who have already received standard abdominal anatomy teaching.

Methods

Tutorial Design

The tutorial (Appendix A) was a self-directed PowerPoint that guided learners through an overview of abdominal anatomy using a variety of radiologic images. PowerPoint was selected as the most appropriate tutorial program due to the flexibility it provides stakeholders (educators and students), as PowerPoint is compatible with virtually any digital device and allows stakeholders to take charge of their experience by choosing specific content on which to focus.

There were three main sections to the abdominal anatomy tutorial: (1) basic concepts in radiology, (2) the gastrointestinal tract, and (3) orientating abdominal anatomy. As with previous tutorials in the series, the images used included X-rays, CT, and MRI. Abdominal anatomy was taught using animations and text boxes to highlight structures for identification. Color-coded text boxes provided clinical correlations, radiological correlations, or self-evaluation quiz questions. Radiological images were obtained from a deidentified teaching database, as per all previous tutorials in this series.¹⁵⁻¹⁷

One of the tutorial's strengths is its flexibility for use in a variety of settings. Once students have access to the PowerPoint file, they can review the tutorial at their own leisure. Although we tested this tutorial specifically on Australian undergraduate medical students after their abdominal anatomy teaching program, the knowledge can be extrapolated to various health sciences anatomy curricula. The tutorial can be adapted for simplification or extended for use in a more comprehensive anatomy program with the removal or addition of PowerPoint slides. The tutorial explored several areas, beginning with an overview of the principles behind radiological imaging, which can be considered in further depth if required. All major areas of the abdomen and gastrointestinal tract were outlined, including the liver and biliary system, small and large intestine, renal system, spleen, and abdominal vasculature.

As the tutorial was not developed to serve as a stand-alone anatomy tool, it can be used at any point in the anatomy course, from an introduction to abdominal anatomy to revision for examinations, as well as in group tutorials. Facilitating the tutorial in a group setting would require minimal logistical effort, namely, a projector for students' collaborative viewing of the resource. Our testing of this tutorial involved a standard tutorial room setup where students brought their own laptops and worked independently over the course of 1 hour. However, several room arrangements would be appropriate for administering the tutorial. Basic room setup could include students seated in small groups, with a projector at the front and a computer for a facilitator to guide progression through the tutorial. Alternatively, students could work on individual computers at their own pace while a facilitator addresses particular anatomical areas using models or specimens. Finally, when the resource is used as a self-directed tutorial, students are able to access it on their own devices at any time, and thus, a formal room setup may be unnecessary as students can run the tutorial at home without a facilitator.

Although the pretest and posttest were developed for the purpose of testing effectiveness of the tutorial, they may also be used in anatomy programs to assess students' knowledge before and after reception of the tutorial. This would encourage discussion amongst students and facilitators to identify areas of abdominal anatomy knowledge that require particular focus. The timing of testing would vary according to facilitators' arrangements and how many sessions they would require to cover the tutorial in its entirety. Depending on the depth of coverage of each anatomical area and whether facilitators wish to explore the anatomy in greater detail, the tutorial could be delivered in a single session or multiple short teachings. The assessments (tutorial, pretest and posttest quizzes) provide an opportunity for learners to self-assess, giving educators the option to flip the classroom. Based on the length of the PowerPoint and student feedback, we recommend a 1-hour session to move through the PowerPoint.

Test Design and Evaluation

The pretest and posttest (Appendices B & C) administered to students featured multiple-choice questions

(MCQs), image identification, and short-answer questions (SAQs). Similar concepts were addressed in both tests, with each question on the pretest matched to a corresponding question on the posttest covering the same learning objectives. The matched questions were not identical, thus reducing the possibility of testing bias. Prior to distribution, the tests were administered to fourth-year medical students, who, being 2 years ahead of test subjects in their studies, had completed all of their core anatomy teaching. This ensured that there were no discrepancies between tests and that any questions with significant discordance were eliminated. An answer guide (Appendix D) was used in marking, with clearly specified answers, so there was consistency amongst markers. Students participated on a voluntary basis, and all information was deidentified, for both the test cases with fourth-year students and on the formal testing day. Participation had no positive or negative influence on academic progress.

Formal Tutorial Evaluation

Students were allocated randomly in a 1:1 ratio to experimental and control groups. A total of 100 students attended the session, meaning 50 were allocated to each group; two invigilators facilitated the session. The control group was given 30 minutes to complete the pretest and then completed the 30-minute posttest immediately after, before being given access to the abdominal anatomy tutorial. Experimental students were given the 30-minute pretest, then were allowed 1 hour to study the tutorial before being given the 30-minute posttest. Study of the tutorial was self-directed, and students were given no didactic teaching or direction for use of the tutorial. All students in both groups ultimately received access to the tutorial to ensure equal access to this learning tool and compliance with ethics.

Likert-Scale Evaluation

After completion of testing, students in both groups were given an online Likert-scale questionnaire to determine the impact of the tutorial on their knowledge of anatomy and radiology, as well as on their confidence in integrating these principles into their upcoming clinical placement.

Statistical Analysis

A two-tailed power analysis was performed prior to testing. Effects of currently published tutorials in the series¹⁵⁻¹⁷ were used in estimating an effect size of 0.8, and a significance level of .05. A total of 100 students voluntarily agreed to participate in the study, meaning that 50 students were randomly allocated to the experimental group and 50 to the control group. Based on these figures, an overall power of .977 was calculated for the study, indicating minimal chance of type II error.

The Monash University Human Research Ethics Committee approved this study.

Test results were compared between the experimental and control groups for both the pretest and posttest, using percentage change and a two-tailed paired *t* test, due to convention and the differences between the two tests. Analysis was conducted for each question type (MCQ, image identification, and SAQ). Analysis also distinguished direct questions, which assessed information that could be gained completely from the abdominal anatomy tutorial, from indirect questions, which extended beyond the scope of the tutorial and required students to draw on their preexisting anatomical knowledge (from the classroom and the tutorial) and clinical reasoning skills.

Results

With regard to direct questions, experimental group students performed significantly ($p < .001$) better on the posttest compared to the control group by an average of 32.0%. Interestingly, pretest results favored the control group, whose results were on average 3.3% higher, but this result was not statistically significant ($p = .75$). For indirect questions, a similar phenomenon was observed. On the posttest, the experimental group was superior by an average of 16.0%, but this was not a significant result ($p = .22$). On the pretest, the control group results were on average greater by 2.8%, but not significantly ($p = .85$).

Separate analysis was performed for each question type to determine which areas of knowledge were most considerably affected by the tutorial. There were no statistically significant differences for either question type, direct or indirect, on the pretest. On the posttest, the experimental group was significantly better on the direct SAQs ($t = 0.55$, $p < .001$) and MCQs ($t = 3.30$, $p = .008$). It was also superior to the control group on direct image identification questions, but not significantly ($t = 1.60$, $p = .15$). For indirect questions, the experimental group was superior for each question type, but none of the results, SAQ ($t = 0.50$, $p = .65$), MCQ ($t = 0.48$, $p = .64$), or image identification ($t = 1.30$, $p = .25$), were statistically significant.

The full set of results, in terms of percentage change, is shown in Figure 1.

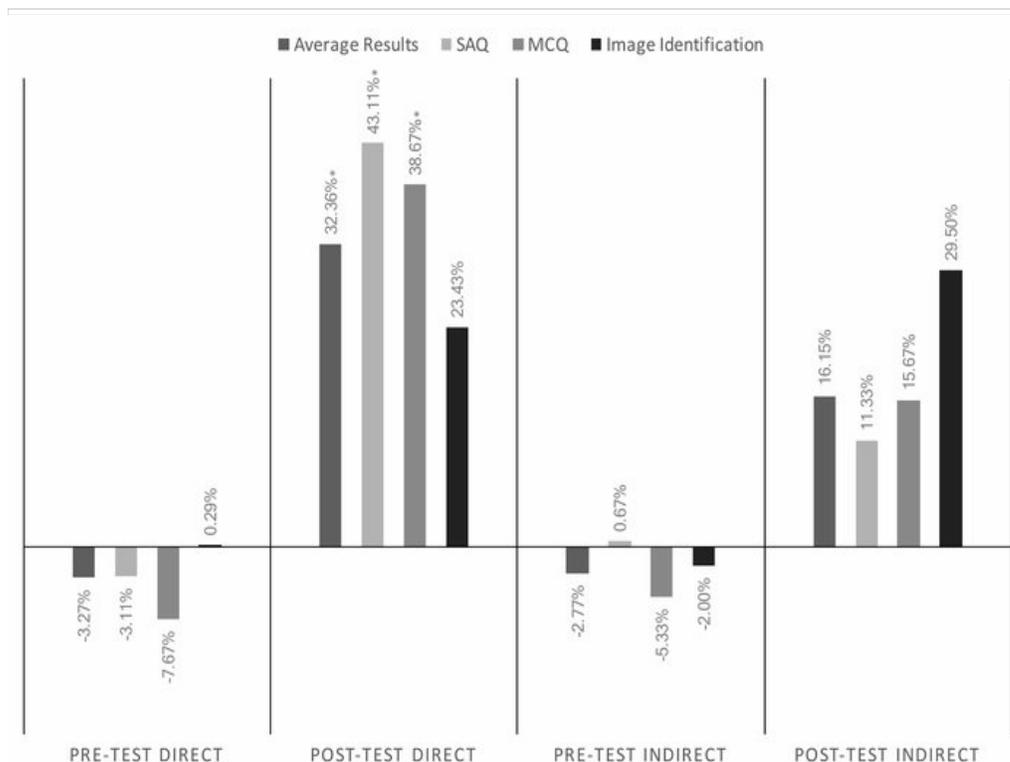


Figure 1. Percentage change comparing control to experimental groups. This figure demonstrates the difference in student performance between experimental and control groups in the anatomy pretest and posttest for both direct and indirect questions. Each bar represents performance in a particular question type as described in the legend, including total performance on all questions. Results favoring the experimental group are indicated above the baseline, with percentage change for each question type to two decimal places and statistically significant results ($p < .05$) marked with an asterisk (*). Cases where the control group performed better than the experimental group are represented by bars below the baseline, with the corresponding negative percentage change. Abbreviations: MCQ, multiple-choice questions; SAQ, short-answer questions.

A Likert scale was used for students' subjective assessment of the tutorial. The results of this assessment showed that the majority of students (57%) considered the tutorial to be somewhat good overall and

extremely good as a review tool (52%). Most students felt moderately more comfortable with abdominal anatomy and radiological concepts following completion of the tutorial. Nearly all students found that the 1-hour session gave them sufficient time to complete the tutorial.

The full set of responses to all questions is detailed in Figures 2-7.

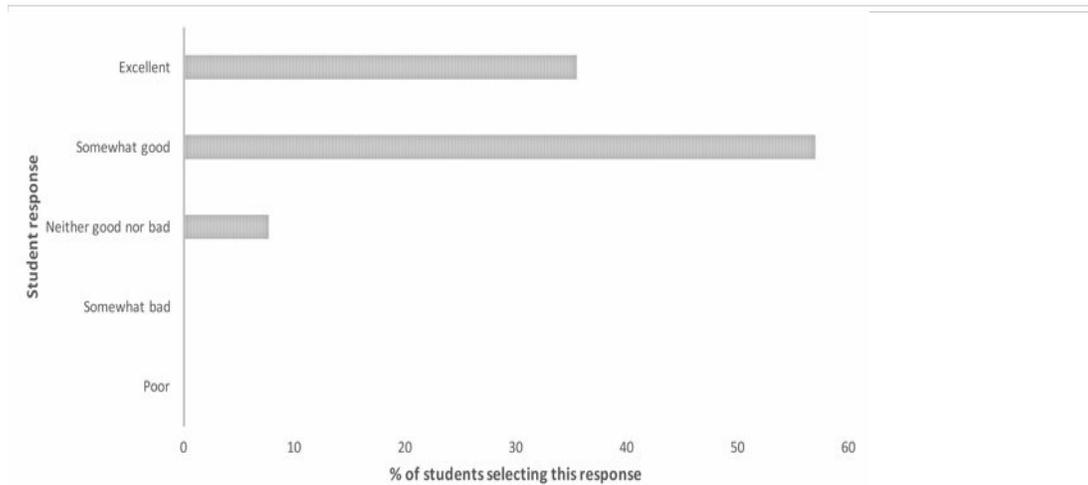


Figure 2. Student overall attitudes to the anatomy tutorial. This figure shows the full set of students' responses on the online feedback questionnaire regarding their overall perception of the abdominal anatomy tutorial. Each bar corresponds to the percentage of all students (both experimental and control groups) selecting the given answer. No bars are seen where no students selected a particular option.

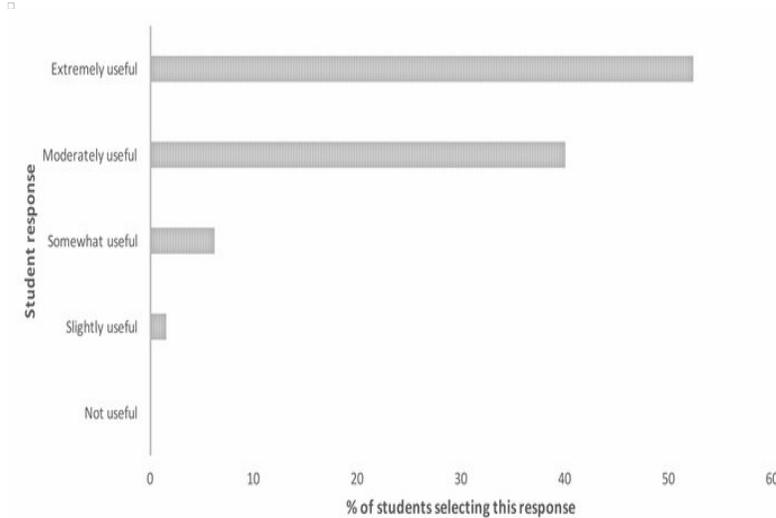


Figure 3. Student perception of the tutorial's effectiveness as a review tool. This figure details the students' responses on the online survey regarding their perception of the tutorial's effectiveness in providing revision of abdominal anatomy. The percentage of students selecting a particular response is detailed using bars.

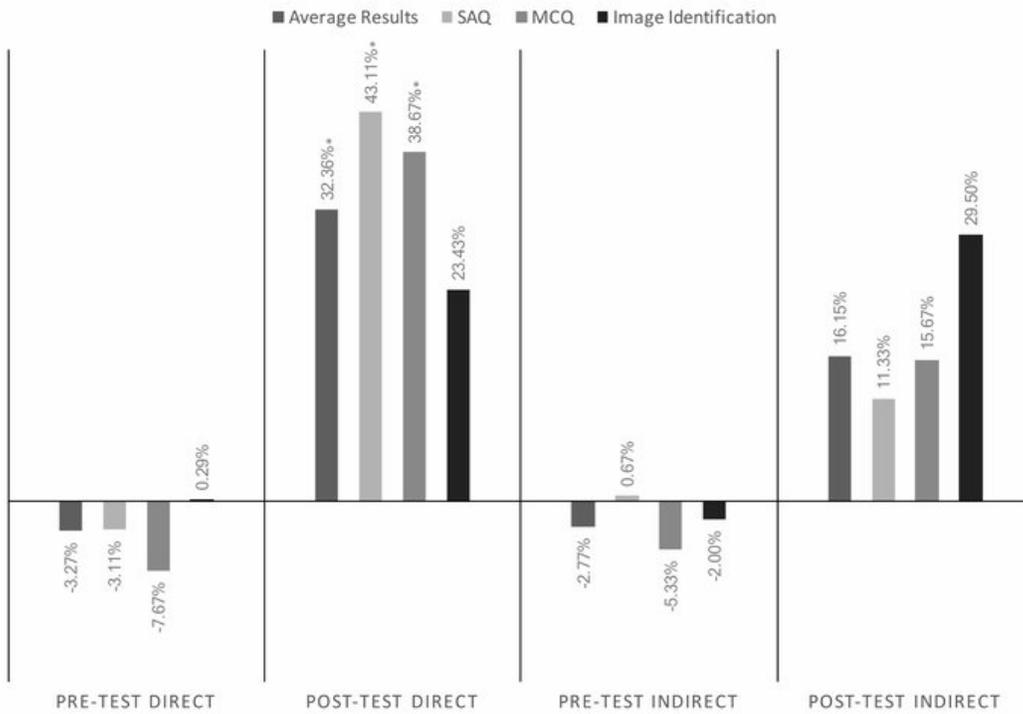


Figure 4. Student increase in confidence with abdominal anatomy after the tutorial. In this figure, students' changes in confidence regarding abdominal anatomy knowledge are recorded as extrapolated from the online questionnaire. Each bar shows the percentage of students selecting a particular option.

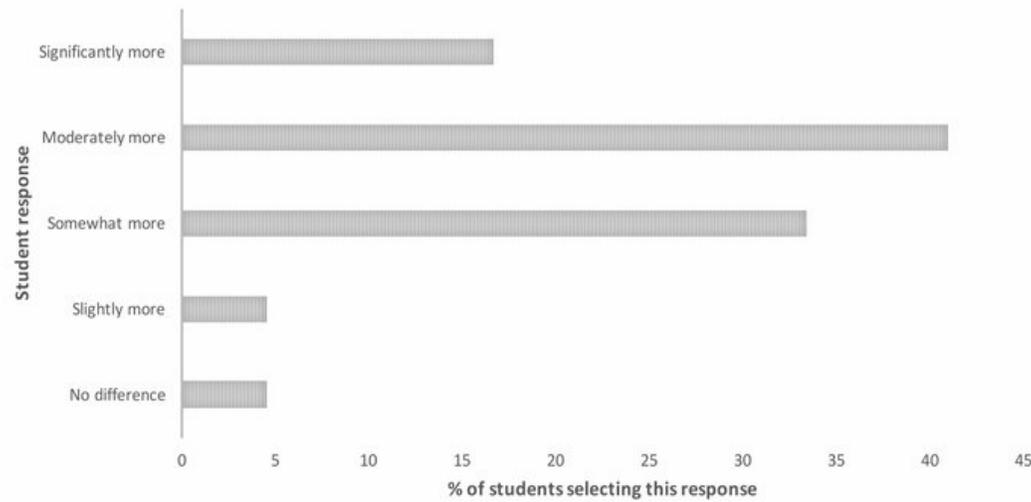


Figure 5. Student increase in confidence with radiology after the tutorial. This figure details the full set of student opinions on the online survey regarding their confidence with radiology following the abdominal anatomy tutorial. Bars illustrate the popularity of each response as a percentage of all student responses.

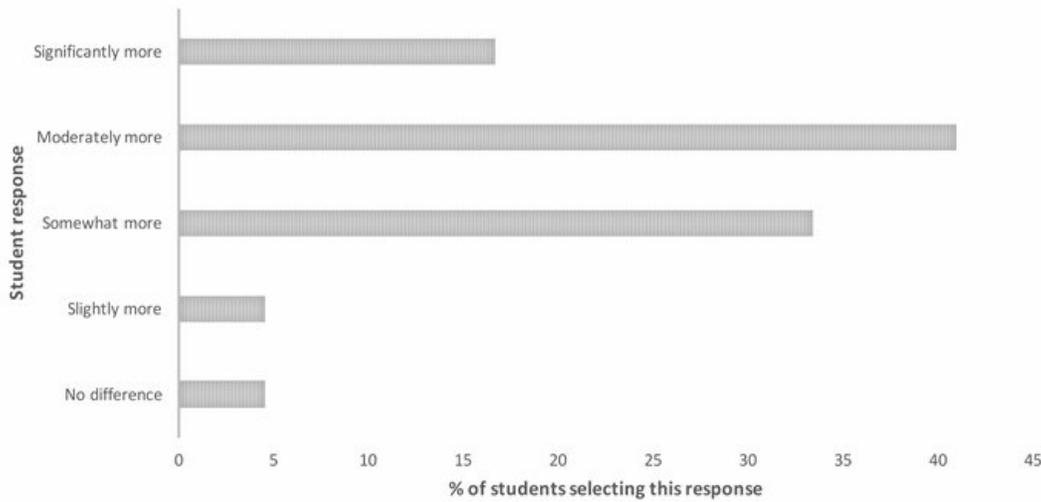


Figure 6. Student increase in confidence for starting clinical placements after the tutorial. This figure assesses the outcomes of the online survey question regarding students' confidence for undertaking clinical placement following the anatomy tutorial. The proportion of students selecting each response is detailed through bars.

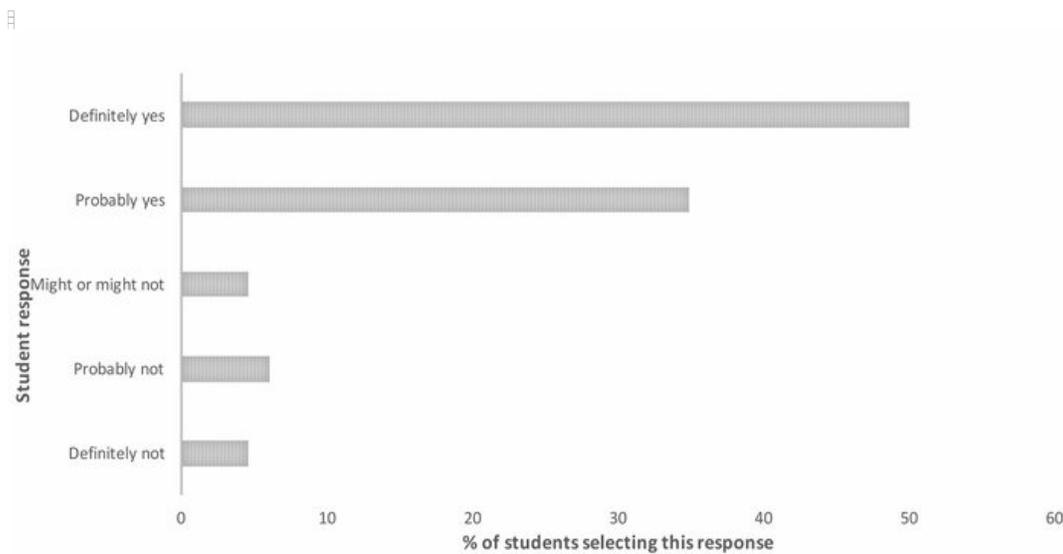


Figure 7. Student perceptions of adequacy of time given to complete the tutorial. In this figure, students' feedback from the questionnaire regarding sufficiency of time required to complete the abdominal anatomy tutorial is shown. Each bar relates to the proportion of all students choosing one of these options.

Discussion

In undergraduate medicine, a commonly faced challenge for students is the application of anatomical knowledge learned in the classroom to the clinical environment^{2,22}; one approach to tackling this deficit is to enrich basic science teaching with clinically relevant scenarios.²³⁻²⁵ This tutorial serves to teach core abdominal anatomy through the use of medical imaging, focusing on clinical examples as per previous resources in our series.¹⁵⁻¹⁷ It expands the scope of the series by focusing on a new and particularly difficult anatomical region, the abdomen and gastrointestinal tract, while also being tested in a manner different from our previously published work.

The selection of PowerPoint as the platform for tutorial delivery enables flexibility for learners to explore different anatomical areas, forms of imaging, and learning objectives at their own pace. It also gives educators the option of selecting particular sections or slides from the tutorial to be administered for teaching, allowing the tutorial to be worked into diverse anatomy curricula without the limitations of a rigid

structure. One of the major challenges in tutorial design was formatting the radiological images using the PowerPoint medium, particularly in ensuring that anatomical accuracy was upheld while making the images presentable and engaging to students. Another important decision was structuring the presentation; options here included segmenting according to type of radiological image, anatomical area, or learning style (e.g., structure identification, clinical applications, self-assessment). After experimenting with multiple options, we found that the most logical structure was according to abdominal organs, for example, focusing on the biliary system, stomach and duodenum, and small and large intestine separately in order for students to properly familiarize themselves with each region before moving onward.

This tutorial, by contrast to others in the series, was tested as a review tool for students who had already completed the abdominal anatomy section of their medical studies. However, the evaluation process was conducted similarly to our previous work, and in fact, the results did not differ largely. Once again, our research showed that exposure to the tutorial caused a significant improvement in students' knowledge of anatomical principles and in their familiarity with numerous forms of medical imaging. This resource was tested on students with sound preexisting knowledge in abdominal anatomy, having completed their study of this area, which suggests that this particular tutorial has a benefit that extends beyond the currently taught medical curriculum. This was a finding similar to others evaluating CAI interventions.²⁶ The evaluation process was limited in that the resource was not also tested as a stand-alone anatomical learning tool, meaning its efficacy in this regard cannot be commented on with certainty. Still, it would be likely that a resource that causes knowledge improvement in students familiar with abdominal anatomy would also do so in a group of novice students with minimal prior learning in this area.

Another aspect of the testing that highlights the value of this resource is that students' exposure to the tutorial was self-administered. As the testing showed that students' knowledge improved when the tutorial was used in this manner, this means it could be used beneficially without need for direct staffing or expert direction. The results suggest that the tutorial could be administered alongside the traditional, structured anatomical study program and still provide significant knowledge benefits without burdening academic time or resources. This finding is significant, given that the literature suggests that cost-benefit analysis must be considered when evaluating and developing CAI resources.²⁷ The tutorial also enables students to study at their own pace, spending time focusing on any particular gaps in knowledge they identify.

With regard to tutorial implementation, there were numerous challenges in ensuring that the testing and delivery of the resource to students ran smoothly. As there was a high volume of participants, we had to split them amongst several rooms, and with only two invigilators available, it was difficult to ensure the students all were focusing on the task required (e.g., tutorial, posttest) and not communicating with others. Ensuring each student worked independently was important yet difficult to control, as collaborative learning could have compromised the results and prevented testing the value of the resource as a review tool for individual students. However, the fact that students were eager to work collectively when going through the resource suggests that it is generalizable to group settings, perhaps in small-group teaching at university after delivery of the traditional anatomy course including laboratory work and lectures.

The tutorial had a clear positive effect on direct abdominal anatomy knowledge, as the experimental group that received the tutorial beforehand performed significantly better on the posttest than the control group, which had not yet received the tutorial. This result was not observed on the pretest where neither group had yet been exposed to the tutorial. In fact, the control group had superior results, albeit not significantly, on the pretest. This further emphasizes the benefits of the tutorial, as the experimental group with initially poorer scores was able to significantly outperform the control group after receiving the

tutorial. However, the testing indicated that this benefit of the tutorial did not extend to indirect clinical scenarios, as there were no statistically significant results favoring the experimental group for any of the indirect question types on the posttest. This is in contrast to our previous work in anatomical regions including the thorax and limbs,¹⁵⁻¹⁷ which showed promising results in terms of applied knowledge. One explanation for this discrepancy may be the significantly higher complexity of the abdominal region, especially compared to less complex areas such as the upper limb, where the most significant results were obtained.¹⁵ Application of knowledge is highly dependent on spatial and dynamic visualization,^{28,29} further explaining the disparity in results amongst study of various anatomical areas. Extensive evidence exists surrounding the difficulty in applying learning to clinical contexts,³⁰⁻³² which is particularly the case for novice learners such as the participants in our study.

Responses to the participant evaluation questionnaires confirmed the importance of preparing students for exposure to the health care environment, which was the ultimate purpose for the development of this learning resource. The literature clearly outlines the substantial lack of confidence students have with integrating anatomy in clinical scenarios.^{22,33-36} Considering that exposure to our tutorial for the short duration of 1 hour enhanced students' confidence in clinical anatomy and medical imaging, the students we tested align with those published sources. Our results thus reinforce the rapidly expanding literature surrounding the benefits of introducing clinical concepts from early stages of medical education, even in small quantities.³⁷

As previously alluded to, the suitability of our tutorial as a stand-alone learning tool is yet to be tested, limiting its evidence-based use in this manner. The tutorial was designed for use in revision for students with preexisting anatomy knowledge. It is reasonable to conclude that it would be of benefit as an adjunct to traditional teaching methods for novice students; however, the length of the tutorial and the depth to which anatomical principles are covered are unlikely to be adequate to permit students to rely solely on this resource for their abdominal anatomy teaching, nor was that our intention. Further work could expand the concepts in the tutorial so it may be used in a stand-alone capacity. Additionally, a more robust measure of the tutorial's effectiveness could involve assessing long-term knowledge retention and learner attitudes after students enter the clinical environment and determining if the knowledge gained translates to improvements in clinical reasoning and patient care.

Madeleine J. Marsland: Undergraduate Medical Student, Department of Medicine, Nursing and Health Sciences, Monash University

Dunya Tomic: Undergraduate Medical Student, Department of Medicine, Nursing and Health Sciences, Monash University

Pamela L. Brian, MD: Radiologist, Pennsylvania State University College of Medicine; Phase I Anatomy Course Co-Director, Pennsylvania State University College of Medicine

Michelle D. Lazarus, PhD: Senior Lecturer, Department of Anatomy and Developmental Biology and Affiliate, Monash Centre for Scholarship in Health Education, Monash University

Disclosures:

None to report.

Funding/Support:

None to report.

Prior Presentations:

Tomic D, Marsland MJ, Lazarus MD, Brian PL. Development and learning impact of abdominopelvic medical imaging tutorial platforms. Poster presented at: ANZACA 2017 Conference; December 4-6, 2017; Auckland, New Zealand.

Ethical Approval:

The Monash University Human Research Ethics Committee approved this study.

References

1. Massa LJ, Mayer RE. Testing the ATI hypothesis: should multimedia instruction accommodate verbalizer-visualizer cognitive style? *Learn Individ Differ*. 2006;16(4):321-335. <https://doi.org/10.1016/j.lindif.2006.10.001>
2. Norman G. Teaching basic science to optimize transfer. *Med Teach*. 2009;31(9):807-811. <https://doi.org/10.1080/01421590903049814>
3. Grignon B, Oldrini G, Walter F. Teaching medical anatomy: what is the role of imaging today? *Surg Radiol Anat*. 2016;38(2):253-260. <https://doi.org/10.1007/s00276-015-1548-y>
4. Jack A, Burbridge B. The utilisation of radiology for the teaching of anatomy in Canadian medical schools. *Can Assoc Radiol J*. 2012;63(3):160-164. <https://doi.org/10.1016/j.carj.2010.11.005>
5. Pathiraja F, Little D, Denison AR. Are radiologists the contemporary anatomists? *Clin Radiol*. 2014;69(5):458-461. <https://doi.org/10.1016/j.crad.2014.01.014>
6. McCuskey RS, Carmichael SW, Kirch DG. The importance of anatomy in health professions education and the shortage of qualified educators. *Acad Med*. 2005;80(4):349-351. <https://doi.org/10.1097/00001888-200504000-00008>
7. Berman NB, Fall LH, Maloney CG, Levine DA. Computer-assisted instruction in clinical education: a roadmap to increasing CAI implementation. *Adv Health Sci Educ Theory Pract*. 2008;13(3):373-383. <https://doi.org/10.1007/s10459-006-9041-3>
8. Fincher R-ME, Wallach PM, Richardson WS. Basic science right, not basic science lite: medical education at a crossroad. *J Gen Intern Med*. 2009;24(11):1255-1258. <https://doi.org/10.1007/s11606-009-1109-3>
9. Heath C, Luff P, Svensson MS. Technology and medical practice. *Social Health Illn*. 2003;25(3):75-96. <https://doi.org/10.1111/1467-9566.00341>
10. Reidenberg JS, Laitman JT. The new face of gross anatomy. *Anat Rec (Hoboken)*. 2002;269(2):81-88. <https://doi.org/10.1002/ar.10076>
11. Drake RL. Anatomy education in a changing medical curriculum. *Kaibogaku Zasshi*. 1999;74(4):487-490.
12. Holla SJ, Ramachandran K, Isaac B, Koshy S. Anatomy education in a changing medical curriculum in India: medical student feedback on duration and emphasis of gross anatomy teaching. *Anat Sci Educ*. 2009;2(4):179-183. <https://doi.org/10.1002/ase.79>
13. Heidger PM Jr, Dee F, Consoer D, Leaven T, Duncan J, Kreiter C. Integrated approach to teaching and testing in histology with real and virtual imaging. *Anat Rec (Hoboken)*. 2002;269(2):107-112. <https://doi.org/10.1002/ar.10078>
14. Haines DE, Hutchins JB, Lynch JC. Medical neurobiology: do we teach neurobiology in a format that is relevant to the clinical setting? *Anat Rec (Hoboken)*. 2002;269(2):99-106. <https://doi.org/10.1002/ar.10073>
15. Lazarus M, Fanelli M, Stanley A, Brian P. Upper limb anatomy tutorial using an imaging platform. *MedEdPORTAL*. 2015;11:10167. https://doi.org/10.15766/mep_2374-8265.10167
16. Lazarus M, Stanley A, Smith L, Brian P. Thoracic anatomy tutorial using an imaging platform. *MedEdPORTAL*. 2014;10:9828. https://doi.org/10.15766/mep_2374-8265.9828
17. Lazarus M, Smith L, Hoover A, Brian P. Lower limb radiology tutorial designed to enhance anatomy education and medical application of anatomy. *MedEdPORTAL*. 2013;9:9466. https://doi.org/10.15766/mep_2374-8265.9466
18. Bass RZ, Morgan DE, Brooks WS. A case of pancreatic cancer: abdominal anatomy team-based learning module for medical students. *MedEdPORTAL*. 2018;14:10700. https://doi.org/10.15766/mep_2374-8265.10700
19. Phillips A, Thurber B, Teven C, Wortman J, Soneru A, Straus C. Self-guided study module for head and neck radiological anatomy. *MedEdPORTAL*. 2014;10:9891. https://doi.org/10.15766/mep_2374-8265.9891
20. Blackstock U, Carmody K. Transforming learning anatomy: basics of ultrasound lecture and abdominal ultrasound anatomy hands-on session. *MedEdPORTAL*. 2016;12:10446. https://doi.org/10.15766/mep_2374-8265.10446
21. Moscova M, Bryce DA, Sindhusake D, Young N. Integration of medical imaging including ultrasound into a new clinical anatomy curriculum. *Anat Sci Educ*. 2015;8(3):205-220. <https://doi.org/10.1002/ase.1481>
22. Lazarus MD, Chinchilli VM, Leong SL, Kauffman GL Jr. Perceptions of anatomy: critical components in the clinical setting. *Anat Sci Educ*. 2012;5(4):187-199. <https://doi.org/10.1002/ase.1281>
23. Smith CF, Mathias HS. Medical students' approaches to learning anatomy: students' experiences and relations to the learning environment. *Clin Anat*. 2010;23(1):106-114. <https://doi.org/10.1002/ca.20900>
24. Bergman EM, Van Der Vleuten CPM, Scherpbier AJJA. Why don't they know enough about anatomy? A narrative review. *Med Teach*. 2011;33(5):403-409. <https://doi.org/10.3109/0142159X.2010.536276>
25. Gregory JK, Lachman N, Camp CL, Chen LP, Pawlina W. Restructuring a basic science course for core competencies: an example from anatomy teaching. *Med Teach*. 2009;31(9):855-861. <https://doi.org/10.1080/01421590903183795>
26. Wilson AB, Brown KM, Misch J, et al. Breaking with tradition: a scoping meta-analysis analyzing the effects of student-centered learning and computer aided instruction on student performance in anatomy [published online ahead of print April 16, 2018]. *Anat Sci Educ*. <https://doi.org/10.1002/ase.1789>
27. Maloney S, Haas R, Keating JL, et al. Breakeven, cost benefit, cost effectiveness, and willingness to pay for web-based versus face-to-face education delivery for health professionals. *J Med Internet Res*. 2012;14(2):e47. <https://doi.org/10.2196/jmir.2040>
28. Berney S, Bétrancourt M, Molinari G, Hoyek N. How spatial abilities and dynamic visualizations interplay when learning functional anatomy with 3D anatomical models. *Anat Sci Educ*. 2015;8(5):452-462. <https://doi.org/10.1002/ase.1524>
29. Guillot A, Champely S, Batier C, Thiriet P, Collet C. Relationship between spatial abilities, mental rotation and functional anatomy learning. *Adv Health Sci Educ Theory Pract*. 2007;12(4):491-507. <https://doi.org/10.1007/s10459-006-9021-7>

30. Beck J, Rooholamini S, Wilson L, Griego E, McDaniel C, Blankenburg R. Choose your own adventure: leading effective case-based learning sessions using evidence-based strategies. MedEdPORTAL. 2017;13:10532. https://doi.org/10.15766/mep_2374-8265.10532
 31. Zuo SW, Cichowitz C, Shochet R, Venkatesan A. Peer-led, postanatomy reflection exercise in dissection teams: curriculum and training materials. MedEdPORTAL. 2017;13:10565. https://doi.org/10.15766/mep_2374-8265.10565
 32. Haque F, Daniel M, Clay M, Vredeveld J, Santen S, House JB. The Interprofessional Clinical Experience: introduction to interprofessional education through early immersion in health care teams. MedEdPORTAL. 2017;13:10564. https://doi.org/10.15766/mep_2374-8265.10564
 33. Fitzgerald JEF, White MJ, Tang SW, Maxwell-Armstrong CA, James DK. Are we teaching sufficient anatomy at medical school? The opinions of newly qualified doctors. Clin Anat. 2008;21(7):718-724. <https://doi.org/10.1002/ca.20662>
 34. Gupta Y, Morgan M, Singh A, Ellis H. Junior doctors' knowledge of applied clinical anatomy. Clin Anat. 2008;21(4):334-338. <https://doi.org/10.1002/ca.20628>
 35. Bhangu A, Boutefnouchet T, Yong X, Abrahams P, Joplin R. A three-year prospective longitudinal cohort study of medical students' attitudes toward anatomy teaching and their career aspirations. Anat Sci Educ. 2010;3(4):184-190. <https://doi.org/10.1002/ase.165>
 36. Lazarus MD, Kauffman GL Jr, Kothari MJ, et al. Anatomy integration blueprint: a fourth-year musculoskeletal anatomy elective model. Anat Sci Educ. 2014;7(5):379-388. <https://doi.org/10.1002/ase.1439>
 37. Kelly M, Bennett D, Bruce-Brand R, O'Flynn S, Fleming P. One week with the experts: a short course improves musculoskeletal undergraduate medical education. J Bone Joint Surg Am. 2014;96(5):e39. <https://doi.org/10.2106/JBJS.M.00325>
-

Received: May 8, 2018 | Accepted: August 2, 2018 | Published: August 30, 2018