

The Effects of an E-learning Module on Medical Trainees Rotating on a Perioperative Medicine Clinical Service

Lauren E. Wegner, MS, Jason F. Shiffermiller, MD, MPH*, Chad W. Vokoun, MD, Michael J. O'Rourke, MD, Cory J. Rohlfen, MD

*Corresponding author: jshiffermiller@unmc.edu

Abstract

Introduction: Dedicated perioperative care can be cost-effective and improve patient outcomes. Training future physicians to practice perioperative medicine is an important responsibility of medical educators. An e-learning module delivered asynchronously during clinical rotations in perioperative medicine may help to better satisfy this responsibility. **Method:** Articulate software was used to create an interactive, 1-hour e-module based on six educational objectives. The e-module was offered as an elective self-directed learning experience to trainees on perioperative medicine clinical rotations, including third- and fourth-year medical students as well as residents from internal medicine, anesthesiology, neurology, and physical medicine and rehabilitation training programs. We assessed the effectiveness of this learning strategy as a complement to real-time clinical experiences by measuring the knowledge, confidence, and satisfaction of trainees before and after completion of the e-module. **Results:** Of 113 trainees invited to participate, 75 completed the module and were included in our analysis. Knowledge scores improved for student ($p < .001$), intern ($p < .001$), and resident ($p < .001$) subgroups. Confidence ratings also improved for student ($p < .001$), intern ($p < .001$), and resident ($p < .001$) subgroups. Trainees reported high satisfaction with the e-module, and 60 (87%) reported that it would alter their practice. **Discussion:** An e-module presenting evidence-based, interactive education to trainees during clinical rotations in perioperative medicine was an effective learning strategy. Sharing e-learning tools across institutions may help to deliver standardized education on core clinical topics, including perioperative medicine.

Keywords:

Perioperative Care, E-learning Module, Anesthesiology, Hospital Medicine, Internal Medicine, Surgery - General

Educational Objectives

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

1. Understand the role that a primary care physician or hospitalist plays in the perioperative period.
2. Develop an approach to preoperative risk assessment based on functional status, comorbidities, and surgery-specific risks.
3. Select appropriate lab and ancillary testing to further risk-stratify patients with an emphasis on cost-conscious care.
4. Compare the utility of various modalities of cardiac stress testing.
5. Identify common complications of surgery (e.g., postoperative nausea, fever, obstructive sleep apnea).
6. Gain the knowledge required to manage high-risk medications in the perioperative period (e.g., insulin, anticoagulants).

Introduction

As risk factors for poor surgical outcomes such as obesity, chronic kidney disease, and diabetes rise in prevalence, primary care physicians, hospitalists, and anesthesiologists are becoming increasingly important to perioperative care.¹ Internal medicine consultation in the perioperative setting has been found to improve the management of medical conditions,² and the implementation by anesthesiologists of Enhanced Recovery After Surgery programs has resulted in reductions in the occurrence of postoperative complications.³ A growing body of literature demonstrates that dedicated perioperative care can be cost-effective, reduce hospital stay, and decrease patient mortality.⁴⁻⁶ Training future physicians to practice perioperative medicine is

Citation:

Wegner LE, Shiffermiller JF, Vokoun CW, O'Rourke MJ, Rohlfen CJ. The effects of an e-learning module on medical trainees rotating on a perioperative medicine clinical service. *MedEdPORTAL*. 2023;19:11325. https://doi.org/10.15766/mep_2374-8265.11325

an important responsibility of residency programs as it directly impacts societal needs. Unfortunately, the medical educational system is not currently well equipped to prepare physicians for the practice of perioperative medicine.⁷ Trainees commonly learn practices from peers, mimic the behavior of attendings, or develop necessary knowledge and skills after they begin practice. As a potential solution to fill this training gap, we created a perioperative medicine e-module designed for trainees undergoing dedicated clinical experiences in the perioperative setting.

Instructional methods that utilize electronic resources have been shown to be an effective approach to educating health professionals.⁸ Innovative learning tools such as this interactive e-learning module are in alignment with several adult learning theories. Specifically, this e-module's didactic content is rooted in cognitivism,^{9,10} while its embedded case-based quizzes pair cognitivism with experiential learning.¹¹ Our e-module can also be delivered to participants without time constraints or due dates and thus is in line with self-directed learning theory, which states that adults can plan, manage, and monitor their own education.¹² This type of education is a preferred, commonly utilized method of learning in current medical trainees.¹³ It seems, however, that relatively few e-modules have been delivered in the context of a clinical rotation.^{14,15} Our primary aim was to develop an e-learning module on perioperative medicine and evaluate its impact by assessing the knowledge, confidence, and satisfaction of trainees completing it during a perioperative medicine clinical experience.

Methods

Our e-learning module (Appendix A) was designed to address knowledge gaps related to the delivery of evidence-based perioperative care. Three internal medicine physicians collaborated to create the e-module, which was edited by a multi-institutional team with representation from anesthesiology and surgery. The focus areas, organization of information, and educational objectives were developed by the e-module creators using clinical and teaching experience. E-module content (Table 1) was based on published evidence and, where available, consensus guidelines. We created the e-module on the Articulate Storyline 360 platform (Articulate). Content design utilized brief audiovisual didactics with a variety of embedded interactive elements such as drag-and-drop surgical risk categorization and case-based clinical decision prompts. In addition, content included frequent self-assessment quizzes. Self-assessment quiz questions provided immediate feedback with explanations. The content was mapped to six educational objectives. We revisited

a single case vignette at multiple points throughout the e-module to help place the educational objectives into clinical context. The e-module was designed to require approximately 1 hour for the learner to complete. We utilized a pre-post test design to evaluate the impact of this e-module.

The e-module was offered as an elective self-directed learning experience to be completed by trainees during a perioperative medicine clinical rotation between July 2018 and March 2021 at one of the three participating institutions. E-module content was not presented in any other formal learning experience during the perioperative medicine rotation. Trainees were third-year medical students rotating on a perioperative medicine service during their internal medicine clerkship, fourth-year medical students taking an elective rotation in perioperative medicine, and both interns (PGY 1) and residents (PGY \geq 2) from internal medicine, anesthesiology, neurology, and physical medicine and rehabilitation training programs. The e-module was hosted on Canvas (Instructure). Trainees were advised during orientation that they would receive an email invitation from Canvas to participate in the e-learning curriculum. They were encouraged to complete the e-module, including the postmodule knowledge test and survey, in the first week of the rotation. Instructions on navigating the e-module were contained within the module itself. Trainees provided consent to participate in the e-module evaluation on the Canvas platform. As a part of the consent process, we informed trainees that participation in the e-module evaluation would not affect their end-of-rotation evaluations. Attending physicians were not informed of the participation status of their trainees. The project was approved by the local governing institutional review board at each of the three participating institutions.

To be included in the analysis, trainees were required to complete premodule (Appendix B) and postmodule (Appendix C) knowledge tests (Kirkpatrick level 2¹⁶), each consisting of a set of 20 questions. The pre- and postmodule knowledge tests assessed similar knowledge areas based on the educational objectives but used unique questions so that each trainee completed a total of 40 knowledge questions separate from the quiz questions contained within the e-module itself. All questions on the pre- and postmodule knowledge tests and embedded within the e-module were written by the e-module creators. Additionally, we used Canvas to request that trainees complete premodule (Appendix D) and postmodule (Appendix E) surveys that included self-assessments of their confidence in making perioperative care decisions on a 10-point scale (1 representing the lowest and 10 the highest level

Table 1. E-module Content

Section	Content	Questions and EOs
Pretest	Quiz containing embedded orientation to e-module interactive elements and feedback	Q1: EO6 Q2: EO2 Q3: EO3 Q4: EO5 Q5: EO2 EO1-EO6
Table of contents	Interactive visual representation of e-module organization with narrated introduction to EOs and e-module navigation	EO1
EO 1	Animated didactic: role of the primary care provider or hospitalist in the perioperative period Quiz: scope of perioperative practice, role of Revised Cardiac Risk Index	Q1: EO1
EO 2	Interactive element: introduction to case vignette, preoperative risk stratification Animated didactic: preoperative risk stratification Interactive element: surgery-specific risk Animated didactic: preoperative cardiac risk stratification algorithm and risk calculators Quiz: preoperative cardiac risk stratification cases	EO2 EO2 EO2 EO2 Q1-Q9: EO2
EO 3	Interactive element: continuation of case vignette, preoperative lab, EKG, and chest X-ray Animated didactic: preoperative lab, EKG, and chest X-ray Quiz: preoperative lab, EKG, and chest X-ray cases	EO3 EO3 Q1-Q6: EO3
EO 4	Animated didactic: preoperative cardiac stress testing Video clip: abnormal stress echocardiogram Quiz: preoperative stress testing cases	EO4 EO4 Q1-Q6: EO4
EO 5	Interactive element: continuation of case vignette, preoperative X-rays Animated didactic: medical complications of surgery Quiz: sleep apnea, fever, and alcohol withdrawal cases	EO5 EO5 Q1-Q4: EO5
EO 6	Interactive element: continuation of case vignette, preoperative medication management Animated didactic: high-risk medications in the perioperative setting Quiz: perioperative medication management cases	EO6 EO6 EO6
Bonus questions	Quiz: summative review of e-module content	Q1: EO2 Q2: EO6 Q3: EO2, EO3 Q4-Q6: endocarditis prophylaxis Q7: EO1, EO2, EO4 Q8: EO6 Q9: EO2, EO6 Q10: EO1, EO2, EO6

Abbreviation: EO, educational objective.

of confidence). The postmodule survey also assessed participant satisfaction with the e-module (Kirkpatrick level 1¹⁶). Parameters of satisfaction included conciseness, clarity, level of detail, and perceived relevance to future clinical practice.

Data analyses were conducted using Stata version 15.1 (StataCorp). We compared pre- and postmodule knowledge and confidence using Wilcoxon rank sum tests. We otherwise used descriptive analyses to summarize participant training level and postmodule satisfaction.

Results

We invited 113 trainees to take part in the analysis of the perioperative medicine e-module. We included the 75 trainees (66%) who consented to the research project and completed both the pre- and postmodule knowledge tests in our analysis. Of these 75 trainees, 39 (52%) were medical students (38 third-years and one fourth-year), 18 (24%) were interns, and 18 (24%) were residents (15 second-years and three third-years). Of the interns and residents, 22 (61%) were from anesthesiology, 12

(33%) from internal medicine, and one (3%) each from neurology and physical medicine and rehabilitation programs. Most participants—67 (89%)—reported completing more than 75% of the e-module content. Only two (3%) reported completing 25%-50% of the curriculum, while six (8%) did not report their completion.

Across all participants, the median premodule knowledge test score was 10 out of 20 (50%), with an interquartile range (IQR) of 8.0-12.0. Median premodule knowledge test scores and IQRs for students, interns, and residents were 9 (7.0-11.0), 9 (8.7-12.2), and 11.5 (10.0-14.2), respectively. Following the e-module, median postmodule knowledge test scores improved significantly across all participants (16 vs. 10, $p < .001$) as well as within student (16 vs. 9, $p < .001$), intern (15 vs. 9, $p < .001$), and resident (15.5 vs. 11.5, $p < .001$) subgroups. Figure 1 displays pre- and postmodule knowledge scores by training level.

Prior to engaging with the e-module, the median rating of confidence in making perioperative management decisions on

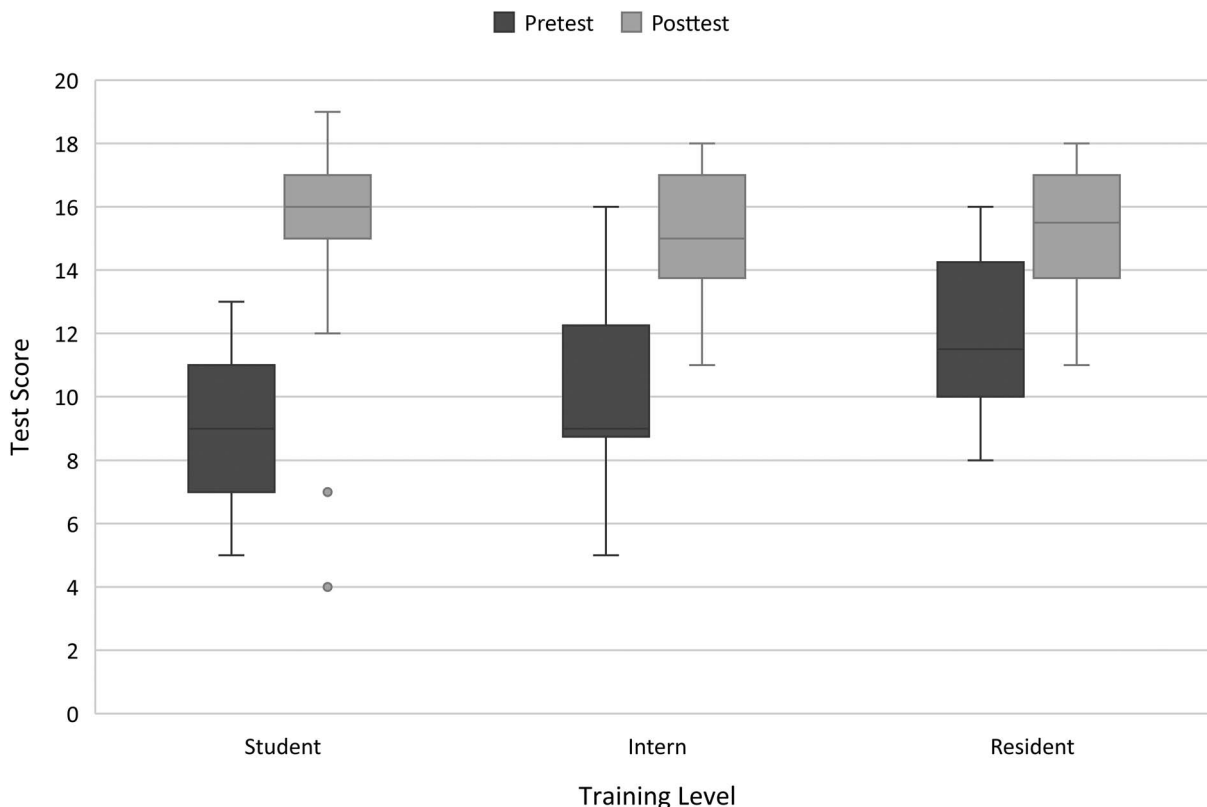


Figure 1. Pre- and postmodule knowledge test scores by training level. Scores represent the total correct out of 20; box plots depict medians and interquartile ranges. In the box plots, the line inside the box indicates the median, the top of the box indicates the 75th percentile, the bottom of the box indicates the 25th percentile, the top of the whisker indicates the maximum, the bottom of whisker indicates the minimum, and dots are outliers greater than 1.5 times the interquartile range above the upper quartile or below the lower quartile.

a 10-point scale was 4, with an IQR of 2-6. Median ratings and IQRs for students, interns, and residents were 3 (2-4), 5 (4-6), and 7 (6-7), respectively. Following the e-module, confidence ratings improved significantly across all participants (7 vs. 4, $p < .001$) as well as within student (7 vs. 3, $p < .001$), intern (8 vs. 5, $p < .001$), and resident (8 vs. 7, $p < .001$) subgroups. Eight participants did not report their postmodule confidence. Figure 2 displays pre- and postmodule confidence ratings by training level.

On our postmodule satisfaction survey, more than 75% of trainees either agreed or strongly agreed that the time to complete the module was acceptable and the material was concise, easy to understand, presented in sufficient detail, and relevant to future practice. Specific responses to these items are reported in Table 2. When asked whether participants planned to alter previous practice patterns based on the material presented in the module, 60 (87%) said yes, five (7%) said no, and four (6%) did not respond. Of those answering yes, 19 (32%) provided comments about how the e-module would specifically alter their future clinical practice. Responses included the following:

- “Less preoperative lab orders. Improved ability in risk stratification with RCRI [Revised Cardiac Risk Index] criteria using strategies presented in this material.”
- “Better understanding of cardiac workup needed for certain patients.”
- “All considerations will effect my practice changes.”
- “Just starting so will alter my practice accordingly.”
- “I’m just starting out so I don’t have any changes necessarily, but this module was extremely helpful in teaching me about what and when preoperative testing should be performed and which medications should be held prior to surgery.”
- “I’m a prelim for diagnostic radiology, but this was instructive and will help when considering interventional radiology procedures.”
- “General knowledge for pre-ops.”
- “Be more judicious in choosing necessary pretests prior to surgery.”
- “Reduced testing for low risk procedures.”
- “Analysis of RCRI.”

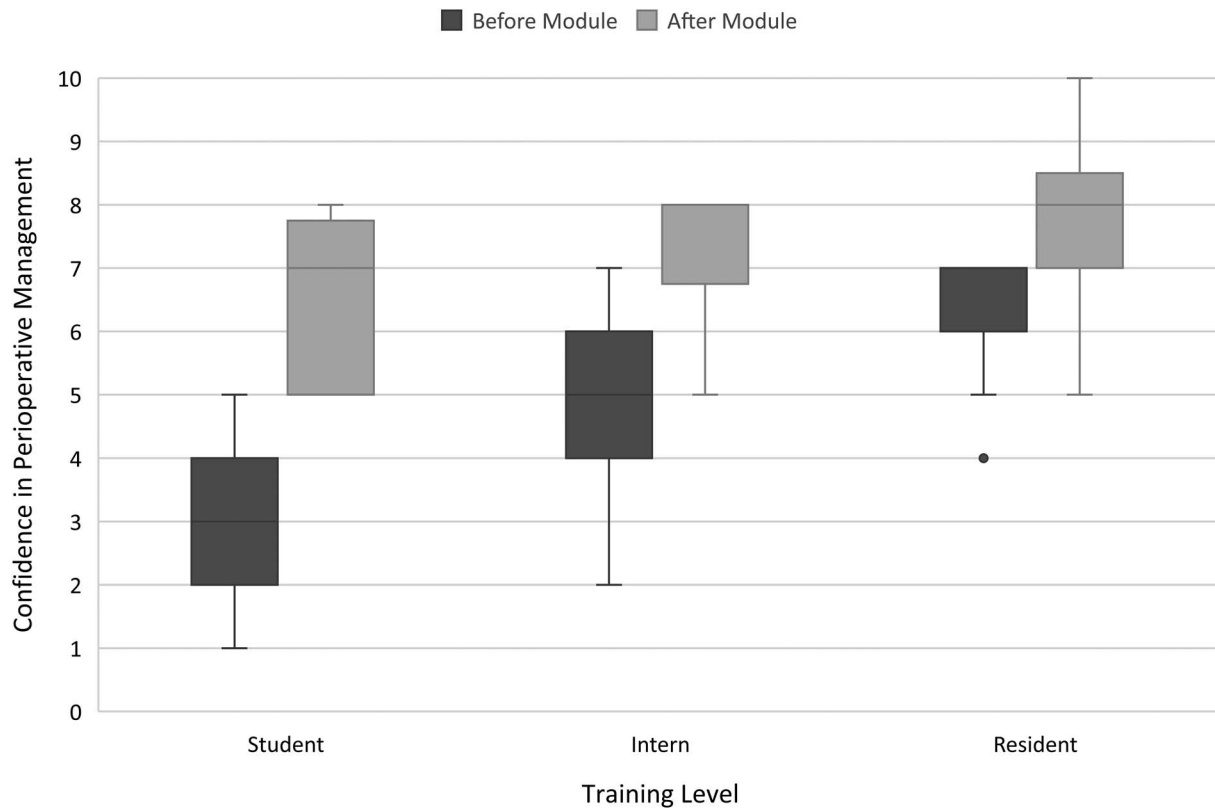


Figure 2. Pre- and postmodule confidence ratings by training level. Confidence rated on a 10-point Likert-like scale (1 = lowest, 10 = highest); box plots depict medians and interquartile ranges. In the box plots, the line inside the box indicates the median, the top of the box indicates the 75th percentile, the bottom of the box indicates the 25th percentile, the top of the whisker indicates the maximum, the bottom of whisker indicates the minimum, and dots are outliers greater than 1.5 times the interquartile range above the upper quartile or below the lower quartile.

- “Increased awareness of risk factors prior to surgery. Implement the proper medication protocols prior to surgery.”
- “Order fewer unnecessary tests.”
- “I know now to limit ordering of tests and which tests and labs are relevant for which patients.”
- “It is difficult to say how I would change my practice because this was my first rotation, but I believe this helped shape how I will practice going forward.”
- “This module was definitely helpful. I did have to watch it more than once to fully understand and grasp the concepts

but this is probably due bc this is my first time being exposed to peri-operative medicine. Thank you!”

- “Improving Assessments and Plans for pre and post op pt recommendations.”
- “Selection criteria for pre-operative lab testing and the medications to stop around the time of surgery.”

Discussion

We found that medical students, interns, and residents rotating on a perioperative medicine clinical service gained knowledge and confidence following completion of a perioperative medicine

Table 2. Postmodule Satisfaction Survey Responses

Survey Item	No. (%)			
	Strongly Disagree or Disagree	Neutral	Agree or Strongly Agree	No Response
The time required to complete this module was acceptable.	5 (7)	9 (12)	54 (72)	7 (9)
The material in this module was presented concisely.	1 (1)	8 (11)	58 (77)	8 (11)
The material presented in this module was easy to understand.	2 (3)	10 (13)	55 (73)	8 (11)
The material in this module was presented in sufficient detail.	2 (3)	9 (12)	56 (75)	8 (11)
The material presented in this module is relevant to my future practice.	1 (1)	10 (13)	54 (72)	10 (13)

e-module. Our findings demonstrate that incorporating an asynchronously delivered e-module into a clinical rotation is an effective learning strategy for medical trainees. Trainees who completed the postmodule survey indicated that it was concise and likely to alter future clinical practice.

We suspect that the flexible, self-directed nature of a blended learning strategy facilitated a convenient, positive, and low-stakes learning experience for our trainees. Previous research has demonstrated high medical trainee satisfaction with e-learning methods, citing flexibility, interactivity, ease of use, and access as positive characteristics of these learning methods.^{13, 17-19}

We found improvements in knowledge and confidence at all levels of training, but the largest effect was seen in students and the smallest in residents. This differential magnitude of effect is likely the result of applying a single educational intervention to trainees with different levels of experience. However, we also observed that postmodule knowledge test scores were similar across levels of training. Any implication these findings might have for the deployment of e-learning strategies across the educational continuum requires further study.

Our results are encouraging to educators who seek to incorporate consistent, high-quality perioperative education into medical student and resident curricula. As perioperative education is pertinent to multiple specialties, our e-learning tool could be used to expand access to high-quality education for medical students or residents in a variety of fields. To our knowledge, there are limited other educational initiatives focused on perioperative medicine, and those that have been published in the literature vary significantly from our e-module. Hudspeth and colleagues²⁰ created a 2-hour, case-based perioperative teaching session designed for PGY 2 internal medicine residents and delivered in person at a monthly resident education day. This experience was dependent on facilitator knowledge and did not include online materials that could be widely disseminated or utilized at other institutions. McDonald and colleagues²¹ developed a 1-week perioperative management elective designed for senior medical students matching into surgical or anesthesiology programs. Although this course utilized an interactive, online tool to help students apply knowledge to case-based scenarios, the curriculum was tailored to surgical specialties. In another publication, Ozturk and colleagues²² described an interactive, online course delivered in the Netherlands over 6 weeks to 260 participants, the majority of whom were residents in anesthesiology, gynecology, and surgery. This educational program was delivered entirely online and thus, like our e-module, had the potential to reach wide audiences. It

required a more substantial time commitment (4 hours weekly over 6 weeks) than our course, which could limit its applicability to clinical rotations. Several organizations, such as Trainees with an Interest in Perioperative Medicine,²³ the American College of Perioperative Medicine,²⁴ and Evidence Based Perioperative Medicine,²⁵ have online platforms that can deliver perioperative medicine content to a wide audience. These platforms feature selected webinars, podcasts, links to resources, and registrations for conferences but do not provide interactive learning tools similar to our e-module.

Few other studies have evaluated e-learning tools employed to address competencies in the setting of clinical rotations. One paper demonstrated the efficacy of an e-module in addressing geriatrics competencies in medical students undergoing a neurology rotation.²⁶ Another found high satisfaction among medical students using a self-directed e-module on nutrition and obesity during their third-year primary care rotation.²⁷ Our findings add to this evidence, supporting the effectiveness and feasibility of e-learning as a supplement to clinical rotation experience. Furthermore, e-learning collaborations like the one employed for our project offer an innovative solution for delivering content to trainees at multiple institutions.

Our design has several limitations. We assessed the effect of the e-module only on trainees who completed the premodule knowledge test, the module itself, and the postmodule knowledge test. Excluding those who did not complete all steps may have introduced selection bias toward greater e-module effectiveness and higher satisfaction. Although trainees were encouraged to complete the e-module early in their clinical rotation, they were not required to do so. Clinical rotation experiences likely had some influence on postmodule knowledge and confidence ratings that we were unable to separate from the effect of the e-module. Of note, our confidence survey did not include anchors, leaving interpretation of the numerical rating up to the learner. Our data did not include a control group without e-module exposure. Future endeavors could compare clinical rotation experiences with and without e-learning supplementation to isolate the effect of the e-learning component. Future analyses might also measure the effect of e-module completion on trainee grades or patient care, which are outcomes we did not capture. Although we asked trainees whether they planned to alter practice patterns based on material presented in this e-module, we were not able to assess the actual impact on clinical practice (Kirkpatrick level 3¹⁶). We did not assess the impact of the e-module within resident specialties (internal medicine, anesthesiology, neurology, physical

medicine and rehabilitation), so we are unable to claim that improvements in knowledge or confidence are generalizable to each discipline. Finally, we measured postmodule knowledge and confidence at one time point soon after e-module completion. We did not assess retention of these benefits over time.

An e-learning tool presenting evidence-based, interactive education to trainees undergoing a clinical rotation in perioperative medicine was an effective learning strategy. Voluntary completion of the e-module increased trainees' knowledge of the material and confidence in making perioperative management decisions. Asynchronously delivered learning strategies that employ shared e-learning tools across multiple institutions can take advantage of available technological resources to deliver standardized education on topics less commonly addressed in medical training.

Appendices

- A. Perioperative Medicine E-Learning Module folder
- B. Premodule Knowledge Test.docx
- C. Postmodule Knowledge Test.docx
- D. Premodule Confidence Survey.docx
- E. Postmodule Confidence and Satisfaction Survey.docx

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

Lauren E. Wegner, MS: Fourth-Year Medical Student, College of Medicine, University of Nebraska Medical Center

Jason F. Shiffermiller, MD, MPH: Assistant Professor, Division of Hospital Medicine, University of Nebraska Medical Center; ORCID: <https://orcid.org/0000-0003-2674-5441>

Chad W. Vokoun, MD: Associate Professor and Chief of the Division of Hospital Medicine, University of Nebraska Medical Center

Michael J. O'Rourke, MD: Professor, Department of Anesthesiology and Perioperative Medicine, Loyola University Medical Center; Anesthesiologist, Edward Hines, Jr. VA Hospital

Cory J. Rohlfen, MD: Assistant Professor, Division of General Internal Medicine, University of Nebraska Medical Center

Acknowledgments

We acknowledge Edie P. Shen, MD, for e-module testing and study site coordination.

Disclosures

None to report.

Funding/Support

None to report.

Ethical Approval

The University of Nebraska Medical Center Institutional Review Board, Loyola University Institutional Review Board, and University of Washington Human Subjects Division deemed further review of this project not necessary.

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https://doi.org/10.15766/mep_2374-8265.10497
- Received:** October 11, 2022
Accepted: April 6, 2023
Published: July 25, 2023