There's an App for That: A Case Study on the Impact of Spaced Education on Ordering CT Examinations

Meaghan Magarik, MD, PhD, Leslie C. Fowler, MEd, Amy Robertson, MD, Jesse M. Ehrenfeld, MD, MPH, Matthew D. McEvoy, MD, Lori A. Deitte, MD

DESCRIPTION OF THE PROBLEM

CT examinations constitute a major source of medical radiation exposure in the United States [1]. The number of CT examinations performed in the United States increased from 3 million to 80 million between 1980 and 2010 [2]. The growth of radiologic imaging has outpaced other components of health care spending. Appropriate utilization of imaging is important not only to prevent unnecessary cost, but also to ensure patient safety [3,4]. Incorrectly or inappropriately ordered radiologic examinations may result in an increased radiation dose, unnecessary exposure to intravenous contrast administration, or an inferior examination that would have benefited from contrast administration when none was requested. The patient may experience a delay or cancellation at the time of his or her radiology appointment to clarify or correct an inappropriately requested examination or may need to return for further imaging.

Appropriate utilization and accurate ordering of radiology examinations remain a challenge for many health care organizations. Although the ACR Appropriateness Criteria guidelines are widely available, the rate of incorporation into clinical practice remains low [5,6]. In recent years, national campaigns, such as Choosing Wisely, have focused on high-quality care, cost-effective health care delivery, and patient safety to avoid wasteful or unnecessary medical tests, procedures, and imaging studies [7]. However, targeted educational and practice improvement strategies emphasizing appropriate ordering of CT examinations are needed, along with studies demonstrating the impact of these strategies on appropriate imaging practice.

It has been proposed that workplace-based learning will be essential to health care education in the future, allowing participants to acquire knowledge on their own time and in an efficient manner conducive to busy clinical schedules [8]. However, incorporating interdisciplinary and interprofessional learning in the midst of busy clinical practice remains challenging. A number of randomized trials have demonstrated that asynchronous "spaced education" paired with repeated testing can increase knowledge acquisition and retention [9-11]. The core principles of spacing and testing imply that a learner is presented with educational content at spaced intervals (eg, daily or weekly), and testing provides the means to "activate" the learning via the delivery of a question followed by education on the topic after a learner answers the question[12,13]. Several studies with practitioners, patients, and trainees have shown benefit to this approach, with this method of learning being well accepted and associated with enhanced participation and demonstrating an impact on physician behavior [14-16].

We hypothesized that utilizing spaced education by delivering questions to the learner via a web-based smartphone application (webapp) will increase the appropriate and accurate ordering of outpatient urologic CT examinations, as measured by greater adherence to published guidelines.

WHAT WAS DONE

Participants and Test Methods

Ethical approval was granted by Vanderbilt University Medical Center institutional review board (IRB) before commencement of this prospective study (blinded author's institution). This pilot study was conducted at a large, single urban academic medical center. Beginning 3 months before the intervention

1546-1440/18/$36.00 ■ https://doi.org/10.1016/j.jacr.2018.10.024

and continuing throughout the study, all outpatient CT examinations ordered by Vanderbilt University Medical Center's Department of Urology were reviewed and categorized as appropriately ordered or flagged for re-protocoling by a lead CT technologist based on a protocol algorithm developed from national guidelines including the ACR Appropriateness Criteria. Subsequently, an attending radiologist reviewed the flagged examinations and determined the protocol based on a review of the patient's clinical history. The ordering provider was contacted to clarify the order as needed on a case-by-case basis after the electronic medical record and other available information were reviewed.

Baseline measurements, which included the number and most frequent types of re-protocoled outpatient CT examinations during a 3-month time frame, were identified, analyzed, and indexed against the total number of CT examinations ordered during the same time frame (re-protocoled = 104, total ordered = 303). These data served as a needs assessment and were utilized to identify the top clinical indications that resulted in an incorrect CT order. The incorrect orders mostly related to contrast orders (with and without contrast versus with contrast). Representative examples include (1) ordering a CT of the chest, abdomen, and pelvis with and without intravenous contrast to assess for metastatic prostate or testicular carcinoma when a CT with contrast is sufficient and (2) ordering a CT of the abdomen with intravenous contrast to evaluate for renal cell carcinoma recurrence post-ablation when a CT with and without contrast is appropriate to assess for enhancement at the ablation site. Using the needs assessment and the ACR Appropriateness Criteria, 36 case-based multiple-choice questions for the spaced education learning activity were then developed by a fellowship-trained abdominal imaging radiologist. These questions were subsequently edited independently by two abdominal imaging radiologists and a urologist.

Before the educational intervention, a subspecialty radiologist in the abdominal imaging section at our institution delivered a 15-min introductory presentation on this project at the Department of Urology grand rounds. Participants attending the grand rounds included faculty members, residents, and advanced practice providers from the Department of Urology.

Urology outpatient CT examinations are typically ordered by urology nonphysician providers and urologists. A total of 28 urologists and nonphysician providers were enrolled as participants in the study. Residents were not included as study participants due to the described outpatient CT ordering workflow. Study participants were then placed into the automated system for receiving daily case-based questions via e-mail or text message through an institutional

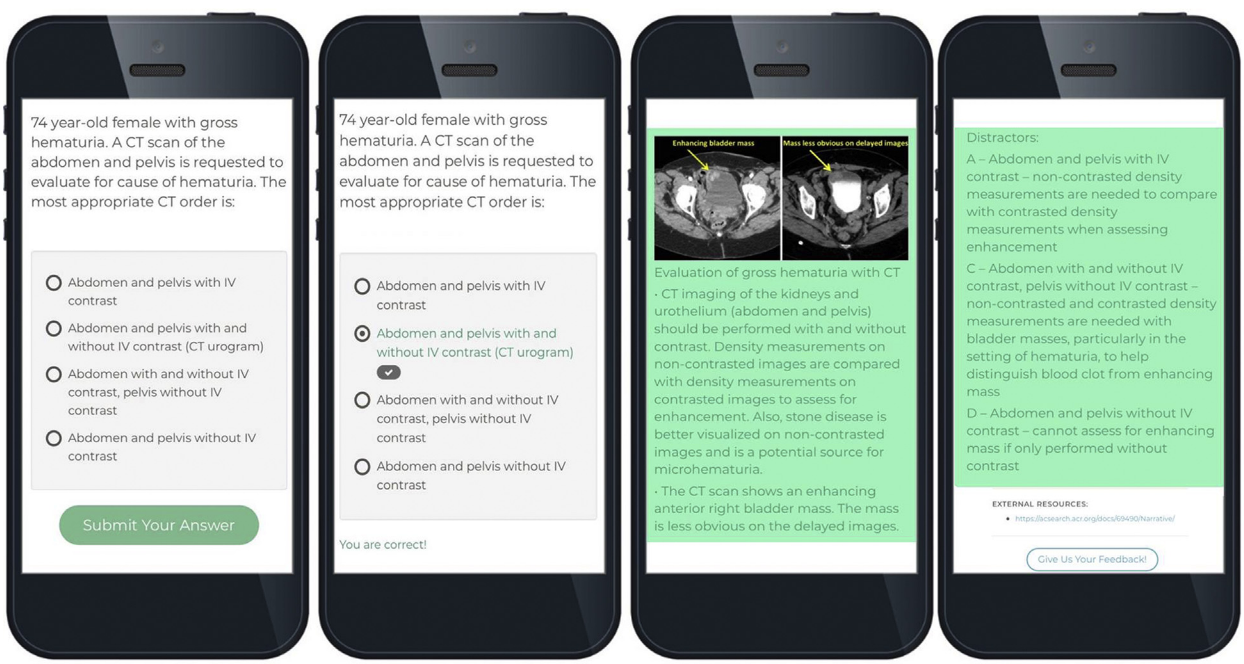

Fig 1. Mobile interface of a sample image-based question with answer choices and the correct answer highlighted and a detailed explanation of correct and incorrect answer choices, as well as a reference for further education.

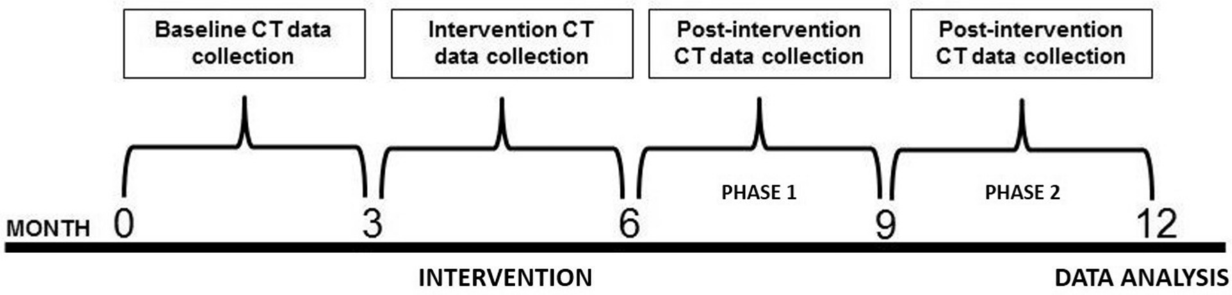

Fig 2. Study timeline and data points.

webapp. The mode of delivery, e-mail versus text message, was determined by individual participant preference. The 36 multiple-choice questions were delivered daily, Monday through Thursday, over a 3-month period (October to December). However, questions were not delivered on holidays or the days before or after holidays, to respect the wish of our participants to be question-free on these days. Participants' responses to the multiple-choice questions remained anonymous. Immediately after submitting an answer to a question, participants received feedback consisting of a detailed explanation of the correct answer as well as an explanation of each incorrect option. The explanations also referenced the ACR Appropriateness Criteria and included a link to the specific ACR Appropriateness Criteria for continued learning (Fig. 1). Each question expired after 24 hours. If a question was not answered, identical feedback information was provided to study participants after expiration of the question.

Intervention and Postintervention Data Collection

The following four sets of data were collected (Fig. 2):

1. Number of re-protocoled orders indexed against the total number of orders during the 3 months before the intervention
2. Number of re-protocoled orders indexed against the total number of orders during the 3-month intervention
3. Number of re-protocoled orders indexed against the total number of orders during the first 3 months after the intervention (postintervention phase 1)
4. Number of re-protocoled orders indexed against the total number of orders during the next 3 months after the intervention (postintervention phase 2)

Statistical Analysis

The percentage change of re-protocoled orders for CT before the intervention, during the intervention, and during both postintervention phases were compared using a one-way analysis of variance test. To then identify specific time periods during which the rates of re-protocoled orders CTs were different, a Tukey's range test with Bonferroni adjustment for multiple comparisons was performed.

OUTCOMES

A total of 28 urologists and nonphysician providers from the urology department participated in the study. Of the 28 study participants, 20 (71.4%) engaged in the asynchronous webapp case-based questions. Engagement was voluntary. However, all 28 participants received the questions, answers, rationale for answers, and links to references. Thus, there was an opportunity for learning for all participants.

The total number of CT examinations ordered and the number and percent requiring re-protocoling are shown in Table 1. Before the

Table 1. CT examinations requested by the urology department and number of CT examinations requiring re-protocoling by the abdominal radiology section

Data Type	Pre-Intervention (July to September 2016)	During Intervention (October to December 2016)	Post-Intervention January to March 2017)	Post-Intervention (April to June 2017)
Total no. of urologic CT orders	303	271	414	382
No. of orders re-protocoled	104	80	100	76
% orders re-protocoled	34.3	29.5	24.2	19.9

intervention, 34.3% of CT examinations ordered required re-protocoling by a radiology attending physician. During the educational intervention period, this number decreased to 29.5% and further dropped in both postintervention phases to 24.2% in postintervention phase 1 and 19.9% in post-intervention phase 2 (Fig. 3). The one-way analysis of variance test resulted in a P value of .0001, indicating that one or more of the rates were significantly different. Tukey's range test with Bonferroni adjustment revealed that the reductions in re-protocoled CTs were statistically different comparing the baseline group with the postintervention phase 1 group ($P = .012$) as well as when compared with post-intervention phase 2 group ($P < .01$). The rate of change was also statistically lower in the postintervention phase 2 group compared with the rate during the intervention ($P = .03$).

Incorrect ordering of CT examinations constitutes a multifaceted issue for many academic radiology departments. Not only do incorrectly ordered examinations place patients at risk for exposure to higher radiation doses, insertion of an intravenous catheter, and contrast administration, the incorrectly ordered examination may not accurately assess the clinical question of the ordering provider. Accordingly, we examined whether asynchronous spaced education with case-based questions could increase the number of appropriately ordered CT examinations in a single department at an academic medical center. This pilot study demonstrated that a 3-month intervention led to a significant reduction in incorrect CT orders requiring re-protocoling by the radiology department and thus represented a change in ordering behaviors.

The present study has some limitations. First, we present a relatively small sample size of participants without a control group because of the focus on one clinical department. These pilot data are an important first step in this quality improvement process and will guide future multi-departmental studies to assess the scope of the problem on the institutional level. Second, our study is from a single institution, and although our institutional protocols follow the ACR Appropriateness Criteria, there is variation in CT ordering protocols across institutions. Therefore, our results may not be generalizable to other centers. A multi-institutional study could be performed to better address this in the future. Third, we were not able to assess overall impact on radiation dose to patients, contrast dose, or scanner time. Alterations in the radiation dose between the original ordered study and performed study were not assessed because of multiple variabilities affecting accurate measurement. Similarly, contrast dosages were tailored to the individual patient based on renal glomerular filtration rate, and therefore these variables were not assessed. Lastly, it is possible there were confounding factors influencing ordering patterns that we were not aware of; however, potential confounders such as hospital-wide educational programs and departmental initiatives on

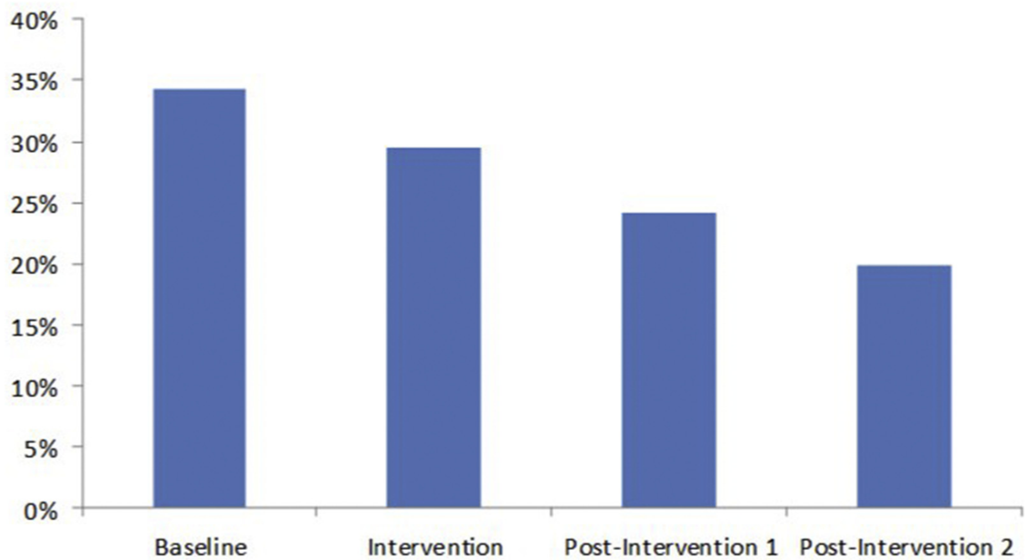

Fig 3. Change in percentage of CT scans requiring re-protocoling during the period of the study. Statistically significant differences were found when comparing the baseline group with the post-intervention phase 1 group, the baseline group with the post-intervention phase 2 group, and the intervention group with the post-intervention phase 2 group.

ordering urological CT scans would typically come from our radiology department, and thus, we would expect to be aware of such programs and initiatives. We are not aware of any such programs at our institution during the study period.

In summary, we found that asynchronous spaced interval education, specifically on the ordering of outpatient CT examinations by the urology department, improves the number of appropriately and accurately ordered examinations. This method of education is valuable and can be incorporated into clinical training, continuing medical education, and quality improvement projects.

REFERENCES

1. Johnson PT, Mahesh M, Fishman EK. Image Wisely and Choosing Wisely: importance of adult body CT protocol design for patient safety, exam quality, and diagnostic efficacy. J Am Coll Radiol 2015;12:1185-90.
2. Brenner DJ, Hricak H. Radiation exposure from medical imaging: time to regulate? JAMA 2010;304:208-9.
3. Lacson R, Ip I, Hentel KD, et al. Medicare imaging demonstration: assessing attributes of appropriate use criteria and their influence on ordering behavior. AJR Am J Roentgenol 2017;208:1051-7.
4. Ingraham B, Miller K, Iaia A, et al. Reductions in high-end imaging utilization with radiology review and consultation. J Am Coll Radiol 2016;13: 1079-82.
5. ACR. ACR Appropriateness Criteria. Available at: http://www.acr.org/quality-safety/appropriateness-criteria. Accessed April 2, 2016.
6. Sheng AY, Castro A, Lewiss RE. Awareness, utilization, and education of the ACR Appropriateness Criteria: a review and future directions. J Am Coll Radiol 2016;13:131-6.
7. Choosing Wisely. An initiative of the ABIM Foundation. Available at: http://www.choosingwisely.org. Accessed April 2, 2016.
8. Miller BM, Moore DE Jr, Stead WW, Balser JR. Beyond Flexner: a new model for continuous learning in the health professions. Acad Med 2010;85: 266-72.
9. Kerfoot BP. Learning benefits of on-line spaced education persist for 2 years. J Urol 2009;181:2671-3.
10. Kerfoot BP, Brotschi E. Online spaced education to teach urology to medical students: a multi-institutional randomized trial. Am J Surg 2009;197:89-95.
11. Kerfoot BP, Turchin A, Breydo E, Gagnon D, Conlin PR. An online spaced-education game among clinicians improves their patients' time to blood pressure control: a randomized controlled trial. Circ Cardiovasc Qual Outcomes 2014;7:468-74.
12. Matos J, Petri CR, Mukamal KJ, Vanka A. Spaced education in medical residents: an electronic intervention to improve competency and retention of medical knowledge. PLoS One 2017;12: e0181418.
13. Robinson T, Janssen A, Kirk J, et al. new approaches to continuing medical education: a QStream (spaced education) program for research translation in ovarian cancer. J Cancer Educ 2017;32: 476-82.
14. Kerfoot BP, Baker HE, Koch MO, Connelly D, Joseph DB, Ritchey ML. Randomized, controlled trial of spaced education to urology residents in the United States and Canada. J Urol 2007;177: 1481-7.
15. Kerfoot BP, Baker H. An online spaced-education game for global continuing medical education: a randomized trial. Ann Surg 2012;256: 33-8.
16. Kerfoot BP, Baker H, Pangaro L, et al. An online spaced-education game to teach and assess medical students: a multi-institutional prospective trial. Acad Med 2012;87:1443-9.

Meaghan Magarik, MD, PhD, and Lori A. Deitte, MD, are from the Department of Radiology and Radiological Sciences, and Leslie C. Fowler, MEd, Amy Robertson, MD, Jesse M. Ehrenfeld, MD, MPH, and Matthew D. McEvoy, MD, are from the Department of Anesthesiology, Vanderbilt University Medical Center, Nashville, Tennessee. Jesse M. Ehrenfeld, MD, MPH, is also from the Department of Biomedical Informatics, Department of Surgery, and Department of Health Policy, Vanderbilt University Medical Center, Nashville, Tennessee.

This work was supported in part by the Vanderbilt University School of Medicine Faculty Fellowship to Advance Medical Education grant. The funding source was not involved in the study design; collection, analysis, and interpretation of data; writing of the report; or decision to submit the article for publication. The authors state that they have no conflict of interest related to the material discussed in this article.

Lori A. Deitte, MD: Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center, 1161 21st Ave S, CCC-1118 MCN, Nashville, TN 37232; e-mail: lori.deitte@vumc.org.