Current Problems in Diagnostic Radiology

Reshaping Radiology Precall Preparation: Integrating a Cloud-Based PACS Viewer Into a Flipped Classroom Model

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A B S T R A C T

Preparing residents for the on-call experience in Radiology is one of the most important aspects of education within a training program. Traditionally, this preparation has occurred via a combination of case conferences and didactic lectures by program faculty, daily teaching at the workstation, and precall assessments. Recently, a blended curricular model referred to as the flipped classroom has generated a lot of attention within the realm of graduate medical education. We applied this technique to resident precall education in the subspecialty of Neuroradiology, and surveyed the participants about their perceptions of the course. The structure, implementation, and web-based platform used to create the flipped classroom experience is described herein.

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Introduction

Currently in a state of flux nationwide, the radiology residency on-call experience remains a critical progressive turning point for radiologists in-training and has a significant impact on the care of patients in the emergency department. Historically, the process of beginning on-call duties has been a rite of passage across a variety of fields of medicine. Within radiology, the on-call experience consists of residents interpreting a high volume of studies across most imaging modalities and providing independent preliminary reports to referring physicians without immediate attending oversight.[1,2] Though recently there has been a trend toward increasing 24-hour emergency radiology attending level coverage, the radiology resident continues to play a major role in the accurate diagnosis and treatment of patients in acute care settings nationwide.[3,4]

Over the past decade, radiology residency call structures have been adapting to address changes in ACGME duty hour requirements, ABR Core Exam, and growth of Emergency Radiology departments at academic centers.[1,2] Contemporaneously, the efficacy of traditional models of graduate medical education such as large group didactic lectures has been challenged.[5] A paradigm shift toward interactive problem-based learning has been occurring throughout medical education. A blended curricular model known as the flipped classroom allows learners to review relevant information, watch video lectures, complete interactive educational modules, and participate in preliminary assessments before a scheduled classroom session.[6-10] The noon conference (or other scheduled lecture time) is then used as an interactive learning session focused on relevant clinical applications and emphasizing the most important elements of the information covered. After the interactive sessions, learners participate in a post-test and have long-term access to the educational modules. This educational model may have unique applications to the area of radiology call preparation that complement traditional models.[6,8]

While call preparation education is variable across training programs, many institutions have utilized didactic lecture series, PACS simulation of call cases, and precall examinations.[11-13] While the on-call resident interprets exams across all organ systems, one of the most crucial areas of precall education is Neuroradiology. Central nervous system emergencies are of particular import in the on-call setting, as stroke and trauma can be imminently life threatening, and rapid diagnosis and intervention significantly affect patient outcomes.[14-16]

To our knowledge, no study has yet described the application of a flipped classroom curriculum to radiology precall preparation. We sought to incorporate a unique educational platform containing a cloud-based PACS viewer, fully integrated assessment tool, and result storage capacity with the aim of improving first-year resident comprehension and comfort level for neuroradiology cases on-call. This paper will describe the components of this curriculum, highlight the unique elements of this learning model, and present performance and survey data regarding the utility of the program.

Methods

This survey study met exemption criteria from formal Institutional Review Board evaluation.

Study Population

Twelve first-year radiology residents at a large ACGME accredited academic medical center.

Course Development

The institutional PACS and departmental teaching files were mined for instructive examples of common Neuroradiology emergencies. An approved list of neuroradiological critical findings was used to guide the types of cases included in this curriculum.[14,15] Relevant companion cases demonstrating normal appearances or important alternative diagnoses for comparison were also identified. A neuroradiology fellow and 2 neuroradiology attendings separately reviewed each case to ensure diagnostic accuracy, relevance, image quality, and incidental findings. Fifty cases were selected and imported into the online platform detailed below.

Web-Based Platform

A zero-footprint cloud-based PACS, pacsbin.com (Orion Medical Technologies LLC, Baltimore, MD), was used to create and deliver this flipped classroom experience. This publicly available resource leverages open source technologies allowing users to acquire de-identified studies onto their personal device for the purpose of HIPAA compliant image sharing and education. De-identified DICOM images were directly uploaded onto this platform. Subsequently, the content creators, which included the neuroradiology fellow and supervising neuroradiology attending, were able to annotate images and provide case-specific notes. A full range of image manipulation tools, including window and/or leveling, cross reference, and zoom functions were available for each case, thus simulating a true PACS workstation experience (Fig 1). Furthermore, guided tutorials through a specific case, highlighting relevant search patterns, pertinent findings, and multiple choice assessments were fully integrated into this platform.

Course Structure

During the second half of the academic year, the flipped classroom precall Neuroradiology curriculum was administered. Participants were given online access to the integrated self-testing modules approximately 2 weeks prior to the in-person educational session.

Participants were first encouraged to review 5 separate modules of normal examinations (CT Head, CT Soft Tissue Neck, CT Cervical Spine, MRI Brain, and CT Face) with accompanying annotated relevant anatomy and detailed descriptions of search patterns. These descriptions include a systematic approach to evaluating each study type, relevant structures to identify on all cases, proper window-level settings, and which MR sequences to evaluate for pertinent findings (Fig 2). Additionally, salient imaging pearls were included in each of these modules that relate to the pathologic cases presented.

Upon completing the normal modules, participants were able to begin progressing through the initial case-based imaging assessment in an asynchronous fashion. Each of the 25 cases administered in this "pre-quiz" centered on commonly encountered emergency department pathology, ranging from trauma, infection, stroke, to pediatrics. The assessment also included select normal cases and normal variants interspersed in order to limit potential biases and best reflect a call-type experience.

Each case was broken into 2 parts. The first part allowed users to scroll through each of the provided series and/or sequences with only the provided history, so as to encourage the participant to free text a differential diagnosis without bias of directed questions. Users would then advance to the second part of the case, which would display the same case with same scrollable capacity, though now a series of relevant stepwise multiple choice and/or region of interest questions (Fig 3). A timer was provided for each case (total of 12 minutes), in order to add to the simulation experience.

Each case consisted of 5-8 questions, with each question building off the prior in a methodical fashion to draw participants' attention to certain salient findings before arriving at a diagnosis. Additional questions assessed case-based scenarios and management questions.
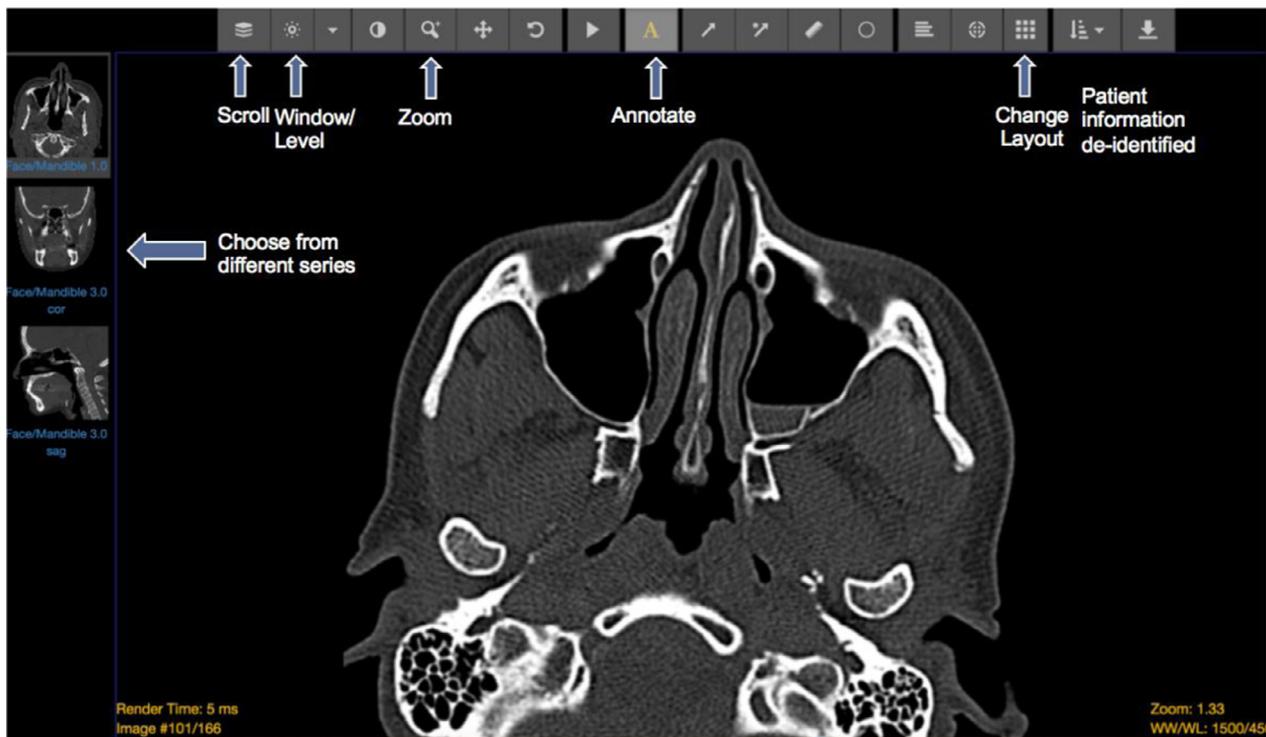
FIG 1. Fully functional cloud-based imaging viewer which acquires de-identified studies and offers a full range of image manipulation tools, including window and/or leveling, cross reference, and zoom functions.
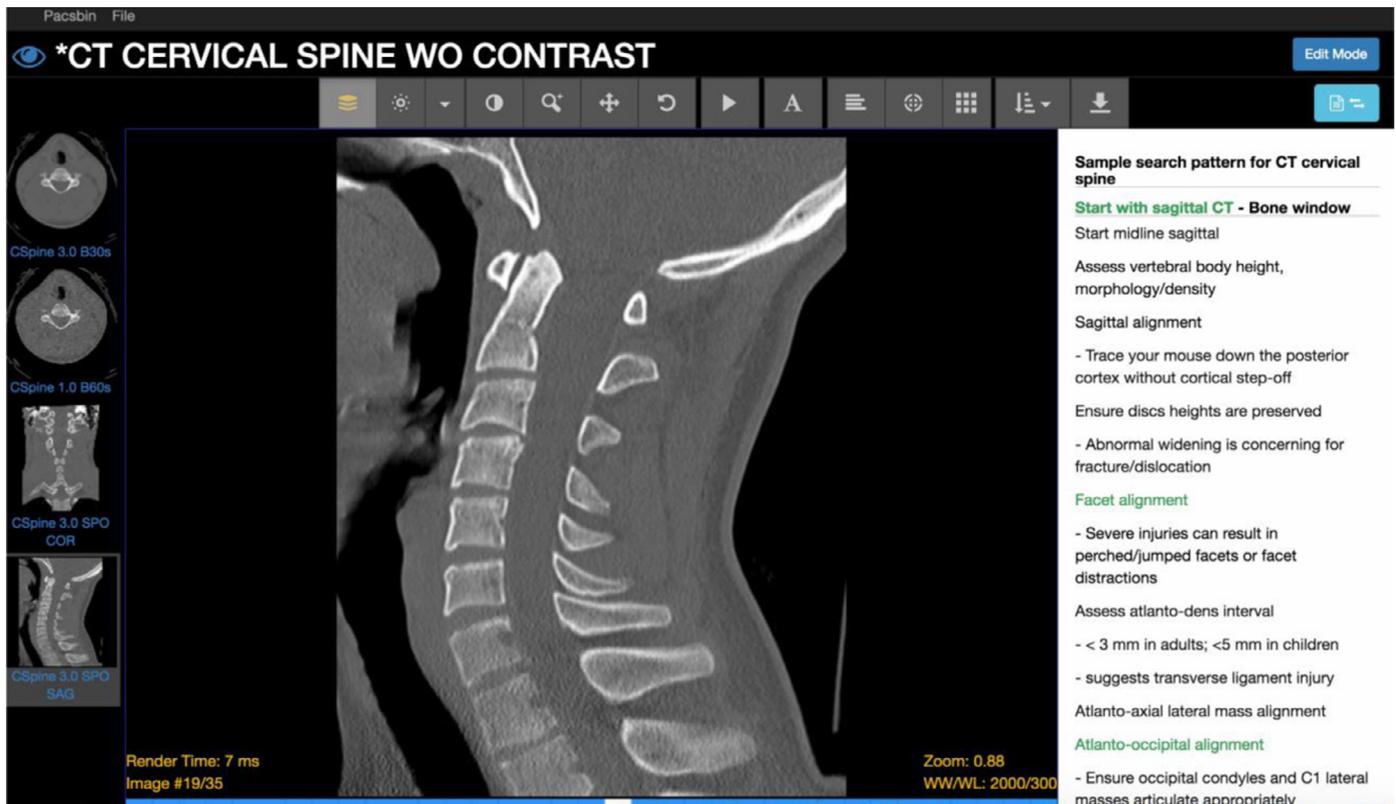
FIG 2. Screenshot of a sample search pattern provided for CT cervical spine studies.

Anatomy was also tested by allowing participants to place a cursor on a region of interest which was pertinent to the case. At the completion of the prequiz, detailed assessment results were automatically sent to the participant as well as the quiz proctor in order to address general deficiencies and monitor changes in user performance. This assessment included feedback for every question, including identification of the correct answer choice as well as a succinct description of why this answer was correct.

The in-person component of this program took place during a noon conference session with the first-year residents. The interactive in-person session was tailored to address specific knowledge gaps and/or deficiencies which were demonstrated using the results of the pretest. During this session, search patterns were reviewed, the most challenging cases were discussed in depth, differential diagnoses were brainstormed, and defining imaging characteristics were emphasized.

After the in-person session, a unique postquiz was administered composed of 25 new cases, the majority of which were companion cases to the prequiz. For example, during the prequiz, a case of a zygomaticomaxillary complex fracture was shown. On the subsequent quiz, a Lefort type injury was shown which served as the complementary case. Each case contained between 5 and 8 questions, as on the prequiz. The postquiz cases were intentionally chosen so as to reduce potential biases while still reinforcing general concepts introduced during the prequiz and consolidated during the flipped classroom session.

Upon completion of the postquiz, participants were asked to participate in a survey regarding this curriculum, which is described below.

Survey Instrument

We employed a rating scale ranging from 1-10, with 10 representing the most and 1 representing the least. We asked participants to

evaluate their personal level of anxiety in anticipation of neuroradiology on-call cases. We also asked participants to rate their personal level of comfort with interpreting each imaging modality and subspecialty within neuroradiology (CT, MRI, Head and Neck, Pediatrics, Spine, etc.). Participants were also asked to rate their estimation of the usefulness of this session as a whole on a scale of 1-10, 10 being extremely useful, 1 being not useful at all. Additional yes and/or no type questions were surveyed, including questions about whether participants would recommend this curriculum to next year's class, and whether they would be interested in using this platform for pre-call preparation in other radiology sections (Table 1).

Results

A total of 12 PGY-2 (R1) trainees participated in and completed this assessment during a month timespan which took place during the second half of the academic year. Each resident had completed at least 2 weeks of neuroradiology at the time of the session, ranging between 2 and 4 weeks. Although participants were encouraged to repeat the quizzes as many times as they required, only their first attempt was recorded for the purposes of the score results provided.

A substantial improvement was seen in overall performance. The average score on the prequiz was 65% (range 48%-85%), while the average score of the postquiz was 83% (68%-95%). Among the tested topics, the greatest improvement was appreciated with pediatric cases (average prequiz score 55%, average postquiz pediatric score 77%). The next greatest improvement in results was seen with head and neck cases (average prequiz score of 62%, average postquiz score 79%).

Survey results gathered from each participant, one prior to the initial prequiz and one following completion of the postquiz, reaffirmed the performance results. Specifically, the survey showed an overall decrease in participant anxiety for neuro call cases after completion of the session (Fig 4).
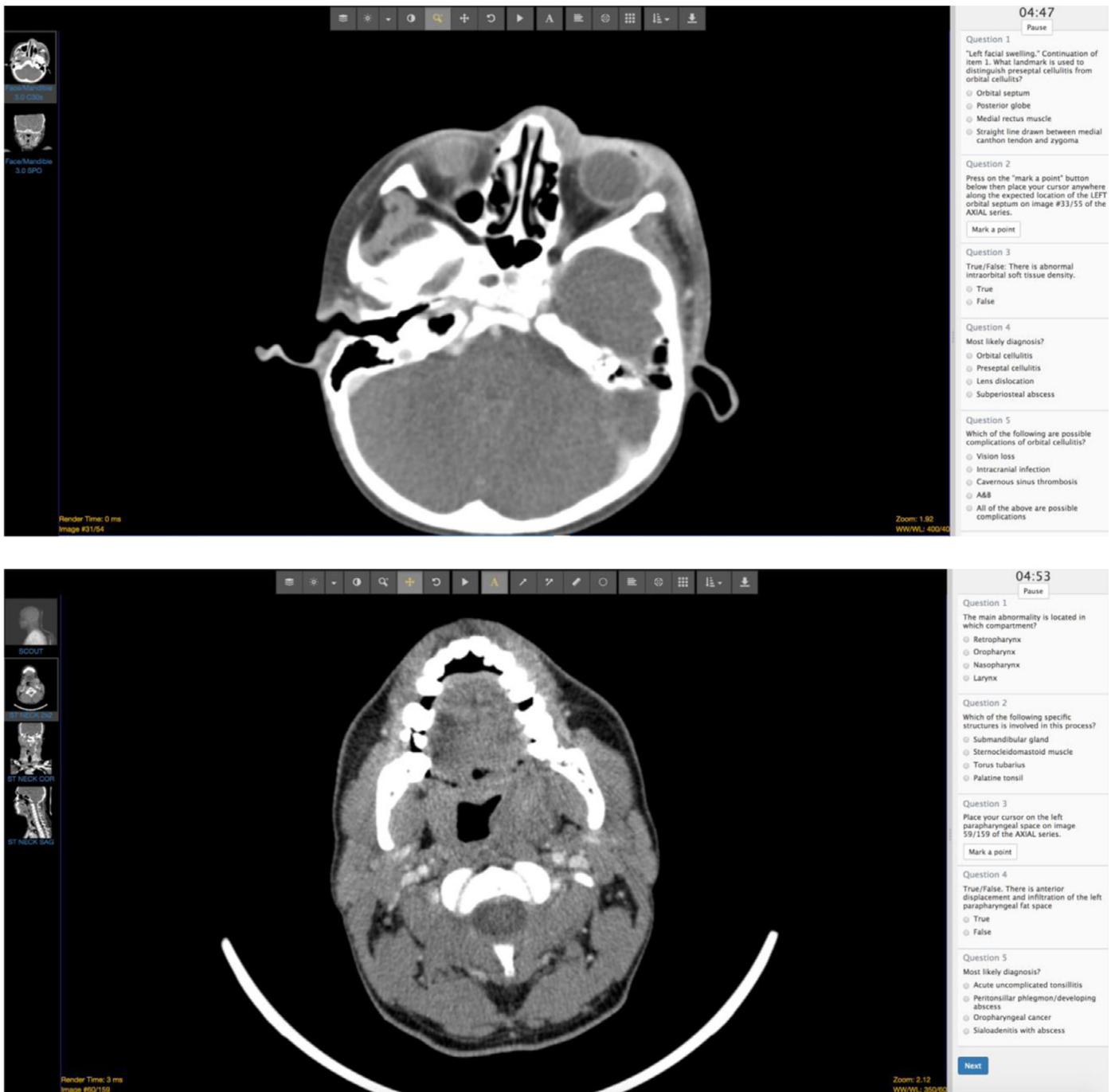
FIG 3. Sample case with sequential questions designed to train participants to work through a case methodically while on a fully functional image viewer.

The survey also showed an overall improvement in participant comfort level in interpretation of each of the tested topics, including pediatrics, head and neck, MRI brain, CT/MRI spine, and CTA head/neck (Fig 5).

Using a scale of 1-10, with 10 being "extremely useful," the average participant rated the overall precall experience as a 9 (range 7-10). Additional survey results showed that 100% (12/12) of participants found the cased based pre- and postquiz format of the session useful in learning and/or consolidating information. Furthermore, 100% (12/12) of the participants recommended the session for the following year's PGY2 class and expressed interest in using the platform for precall preparation in other radiology sections (Table 1).

Discussion

Interactive educational web-based programs provide a unique method of learning radiology and have become increasingly popular among trainees. While several programs currently exist, the cloud-based viewer used in our study (pacsbin.com) is unique in its capacity to simulate anonymized PACS quality studies with adjunct educational assessment tool on a personal device.

With the aid of this imaging platform to facilitate a flipped classroom session, our study shows overall improved comprehension amongst PGY2 radiology residents with common on-call neuroradiology cases after completion of this web-based teaching session. Specifically, each participant demonstrated an improvement in their scores

TABLE 1
List of survey questions and responses following completion of the postquiz

Survey questions	Survey responses (n =12) Yes/No
Was the case-based quiz format of the session useful in learning and/or consolidating material? (yes/no)	12/0
Were the sample search patterns provided useful? (yes/no)	12/0
Was the flipped classroom session helpful in consolidating material from the prequiz? (yes/no)	12/0
Would you recommend the session for upcoming classes? (yes/no)	12/0
Would you be interested in using the platform for other radiology sections? (yes/no)	12/0

between the pre- and postquiz. Just as importantly, there was notable improvement in participant comfort level with each of the tested topics and overall decrease in anxiety in anticipation for neuro call after the session was completed.

In our experience, the flipped classroom session using pacsbin. com has proven advantageous for both moderators and participants. The quiz-based portion of our session emphasized the importance of trainees viewing call-type cases on a PACS in a timed and simulated fashion, requiring trainees to make and interpret the findings. This is in contrast to the standard case conference format which often relies on select images, thus only requiring interpretation of findings which are already on display. The feedback from the trainees reinforced that this method was more relatable and essentially an extension of the daily PACS workstation experience.

The versatile capacity of the platform to allow for adjunct quiz questions next to each case provided us with an objective measure of assessing trainee performance. Questions were able to be posed in various ways (multiple choice, free text, mark image, etc.). Our quizzes were intentionally created to allow participants to work through each case in a methodical, stepwise fashion. Questions began by asking general concepts pertinent to each case, then becoming more specific to help lead to a diagnosis. In doing so, we were able to demonstrate the thought process of a trained neuroradiologist, while also appreciating the point in which a potential knowledge gap occurred.

The experience was also particularly useful in eliciting particular deficiencies among trainees, whether it be anatomy or pathology. For one, the trainees themselves became aware of certain gaps in their knowledge with thorough score reports providing answers with associated feedback for each question. Many of the participants praised this aspect of the session, stating that the instant feedback of the score reports provided incentive to refine their search pattern and add to their foundation. Meanwhile, moderators were automatically sent score reports of each participant, allowing for an objective measure to assess the knowledge a trainee may have in a particular subject. The score report, containing answers to each question as well as the time spent on each case, provides moderators with the opportunity to appreciate a trainee's deficiencies and analyze where the error in interpretation occurred prior to meeting in the classroom setting.

This information can then be processed to create an effective classroom session, catered to address the needs of the residents in a constructive, high-yield format. The residents left the session feeling they had consolidated the information established during the prequiz rather than being introduced to information for the first time, which would otherwise be the case for most didactic or case conferences. Subjectively, we also noted that the questions asked by the participants during the session demonstrated that they processed the information.

The postquiz piece of this experience provided an opportunity to determine the extent to which participants were able to consolidate the information they gained during the prior sessions. In addition to serving as a marker for user performance over time, the quiz exposed the trainees to 25 additional high-yield cases which further added to their foundation and volume in anticipation of call. Importantly, these quizzes were available to be repeated as many times as the participants desired, encouraging self-learning and repetition, while providing long-term storage capacity to allow user performance to be followed over time.

Ultimately, we foresee this platform translating into an enduring curriculum to train radiology residents and fellows with a unique approach emphasizing self-learning, simulation, and repetition. The use of a publicly available cloud-based PACS and ability to share resources also allows for the potential of multisite collaboration, with professional societies developing a universal curriculum which can then be optimized at each institution. We also believe this approach could be readily applied to other sections in radiology, whether for precall or boards preparation. We also see the utility of this platform with regard to result storage capacity. Currently, the only standardized means of tracking resident performance
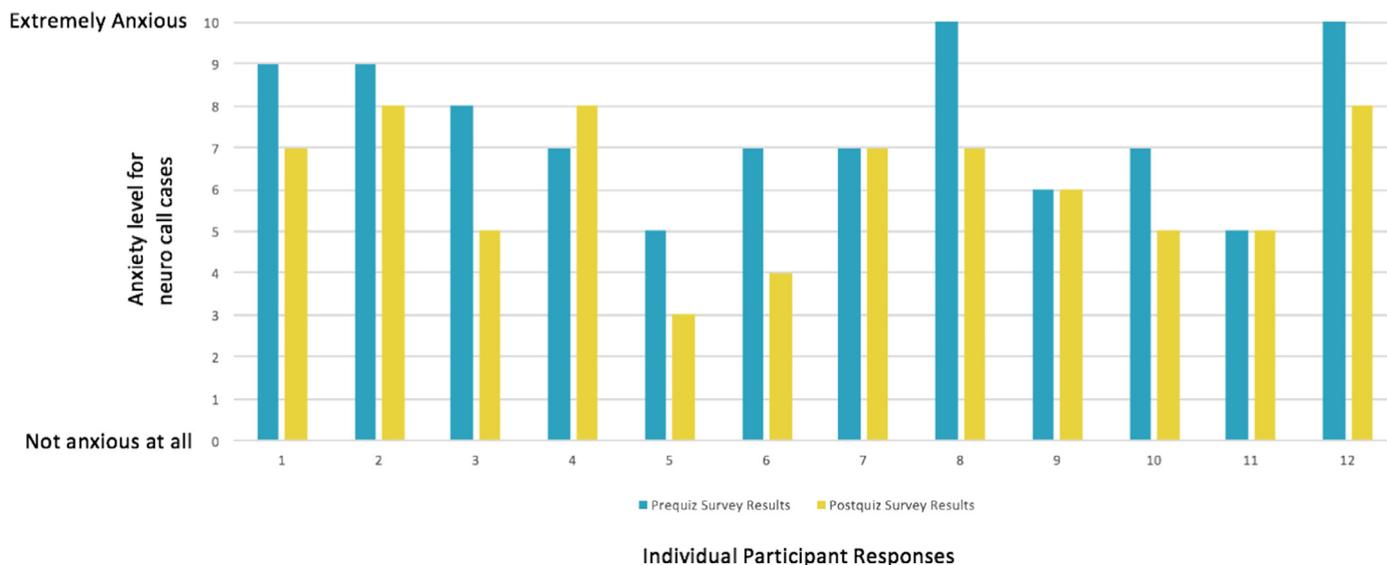
FIG 4. Individual resident responses regarding anxiety level. Initial survey performed prior to administration of the prequiz with subsequent survey following completion of the postquiz shows the majority of residents felt overall less anxious following completion of the session.

Average Resident Comfort Level with Tested Topics
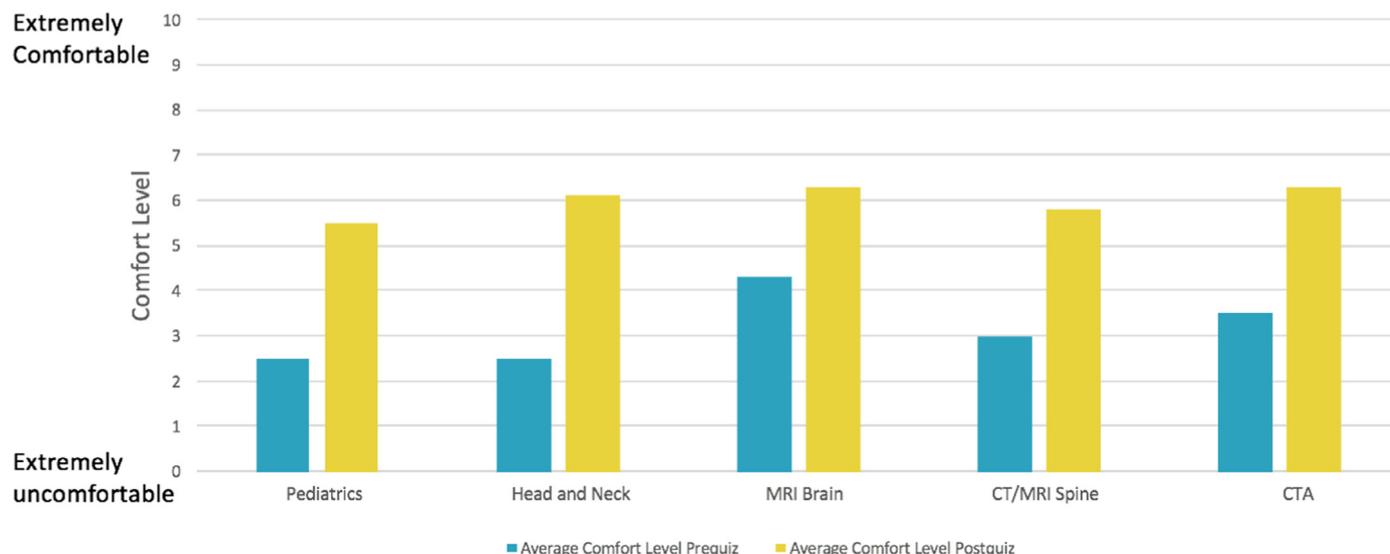
FIG 5. Cumulative average resident comfort level for each of the topics tested prior to the prequiz and following the completion of the postquiz. Residents as a whole felt more comfortable with each of the tested topics after completion of the session.

include in-service exams and the radiology CORE examination. This site also provides the means to track performance over time. Results for each assessment administered are stored indefinitely and easily accessible on the site, providing the means for both users and administrators to monitor progress over time.

Our study has several limitations. For one, our sample size is limited with 12 participants, reflecting our 1-year experience thus far. Similarly, this was a single site study, which may potentially limit the external generalizability of our findings. There is also the potential for response bias, as the residents surveyed were aware that the administrators of the survey had produced the educational content, and there may have been a conscious or subconscious bias to provide responses that the survey administrators would want to receive. Our session was also limited by the number of overall cases provided between the pre- and postquizzes, 50, and relatively few normal studies and/or normal variants compared to a typical on-call setting. Another limitation reflects the variability in the number of weeks each participant had been exposed to neuroradiology. While each trainee had completed at least 2 weeks of neuroradiology prior to taking the assessment, some had completed up to 4 weeks, thus creating a range of exposure and knowledge prior to the quizzes. In addition, the survey results rating anxiety and comfort levels are not a true outcome measure and possibly subject to response bias. However, our study did provide an objective outcome measure in terms of postquiz results, which demonstrated overall improved performance.

We demonstrate improved trainee comprehension and comfort level with common acute neuroradiology cases in preparation for overnight call using a flipped classroom session leveraging the versatility of a cloud-based PACS platform. There are a wealth of potential future applications of this approach to radiology education, and further study of its efficacy and feasibility appear warranted.

Relevant Disclosures

Dr. Jason Hostetter is the creator and owner of Pacsbin.com, the cloud-based PACS viewer platform used in this paper.

Submission Declaration

Information related to this topic was presented by Dr. Payam Sajedi at ASNR National Meeting 2018. This work has not been published elsewhere.

Supplementary materials

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1067/j.cpradiol.2018.07.014.

References

1. Dell CM, Deloney LA, Jambhekar K, et al. Preserving the educational value of call in a diagnostic radiology residency program. J Am Coll Radiol 2014;11:68–73.
2. Berko NS, Levin TL, Scheinfeld MH. The impact of on-site attending radiologist overnight coverage on radiology resident learning: a preliminary assessment. Emerg Radiol 2015;22:1–6.
3. Tublin M, Brown C, Pacella C, et al. Overnight subspecialty radiology coverage: review of a practice model and analysis of its impact on CT utilization rates in academic and community emergency departments. AJR Am J Roentgenol 2012;199:623–6.
4. Hammer MM, Shetty AS, Cisman Z, et al. Results of the 2015 survey of the American Alliance of Academic Chief Residents in Radiology. Acad Radiol 2015;22:1308–16.
5. Cook M, Irby DM, Sullivan W, et al. American medical education 100 years after the Flexner report. N Engl J Med 2006;355:1339–44.
6. Belfi LM, Bartolotta RJ, Giambrone AE, et al. "Flipping" the introductory clerkship in radiology: Impact on medical student performance and perceptions. Acad Radiol 2015;22:794–801.
7. Young TP, Bailey CJ, Guptill M, et al. The flipped classroom: a modality for mixed asynchronous and synchronous learning in a residency program. West J Emerg Med 2014;15:938–44.
8. O'Connor EE, Fried J, McNulty N, et al. Flipping radiology education right side up. Acad Radiol 2016;23:810–22.
9. Wittich CM, Agrawal A, Wang AT, et al. Flipped classrooms in graduate medical education: a national survey of residency program directors. Acad Med 2018;93(3):471–7.
10. Chen F, Lui AM, Martinelli SM. A systematic review of the effectiveness of flipped classrooms in medical education. Med Educ 2017;51:585–97.
11. Khan R, Krupinski E, Graham JA, et al. Assessing first year radiology resident competence pre-call: development and implementation of a computer-based exam before and after the 12-month training requirement. Acad Radiol 2012;19:752–8.

12. Towbin AJ, Paterson B, Chang PJ. A computer-based radiology simulator as a learning tool to help prepare first-year residents for being on call. Acad Radiol 2007;14:1271–83.

13. Ganguli S, Pedrosa I, Yam C-S, et al. Part 1: preparing first-year radiology residents and assessing their readiness for on-call responsibilities. Acad Radiol 2006;13:764–9.

14. Trotter SA, Babiarz LS, Viertel VG, et al. Determination and communication of critical findings in neuroradiology. J Am Coll Radiol 2013;10:45–50.

15. Honig SE, Honig EL, Babiarz LB, et al. Critical findings: timing of notification in neuroradiology. AJNR Am J Neuroradiol 2014;35:1485–92.

16. Agarwal V, Fitzgerald RT. Imaging of CNS injuries. In: Papadakos PJ, Gestring ML, (eds). Encyclopedia of Trauma Care; 2015. Springer: New York, NY: USA.