Web-based Radiology Subspecialty Training Program: Pilot Feasibility and Effectiveness Analysis on Ethiopian Radiologists

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Abbreviations

ABR
American Board of Radiology
ACGME
Accreditation Council for Graduate Medical Education
IRB
Institutional Review Board
LMS
Learning Management System
Johns Hopkins University (JHU)
St. Paul's Hospital Millenium Medical College (SPHMMC)

Rationale and Objectives: To investigate the feasibility and effectiveness of a novel web-based radiology subspecialty training program.

Materials and Methods: Ten Ethiopian general radiologists were enrolled; each participant selected two out of four available subspecialty training programs including abdominal imaging, neuroradiology, chest imaging, and musculoskeletal imaging. Participants were trained simultaneously in 4-stages over 20-months remotely. The program contains online lectures (previously recorded), online interactive case reviews, learning modules, and one-month observership at Johns Hopkins University. Each subspecialty training program consisted of nearly 50 recorded lectures, 26 case reviews, and 40 modules, all provided by subspecialty-trained radiology faculty. Trainees were evaluated using pre- and postcourse multiple choice questions, and the effectiveness of the program was assessed by comparing pre- and postcourse performances using paired *t* test or Wilcoxon signed-rank test. Regression analysis was conducted to determine the association between the magnitude of score change and trainees' age and years after graduation.

Results: All programs including abdominal imaging ($p < 0.001$), neuroradiology ($p < 0.001$), chest imaging (p: 0.001), and musculoskeletal imagining ($p = 0.001$) led to significant improvements in participants' knowledge (overall mean ± standard deviation of score change: +18.4% ± 11.4%). All stages of training including stage-1 (+29.3% ± 8.4%), stage-2 (+21.0% ± 8.0%), stage-3 (+15.0% ± 13.7%), and stage-4 (+17.0% ± 7.9%) significantly improved trainees' scores; and the percent score change decreased with each stage. Regression analysis revealed that score improvement was not associated with age and years after residency training.

Conclusion: Our newly developed web-based radiology subspecialty training program results in improved knowledge of radiologists. Implementation of web-based subspecialty training could be an effective and feasible method for institutions without subspecialty faculty and programs.

Keywords: Education; Radiology; Web-based Training; Radiology Subspecialty Training.

INTRODUCTION

Over the past two decades, there is a growing trend of radiology subspecialization following increased utilization and complexity of diagnostic radiology (1,2). It is not possible to acquire and retain expertise in all radiology subspecialties due to increasing knowledge in image interpretation along with rapid developments in imaging techniques (3,4). In this regard, nine diagnostic subspecialties were developed by the American Board of Radiology (ABR), and all the Accreditation Council for Graduate Medical Education (ACGME) accredited radiology residency programs are required to have faculty responsible for educating each of these subspecialties (5). Despite the pivotal role of subspecialization, the availability of subspecialty training programs is limited in many countries (2). Subspecialty training is offered in 0% of African, 55% of European, and 74% of Asian countries (6−8). In a study performed in Ghana and Nigeria, nearly all radiology residents reported the urgent need for subspecialty training (9). Regarding the lack of resources and fellowship-trained radiologists in these countries, subspecialty training needs collaborations from well-established training programs.

Teleradiology is a pioneering component of telemedicine and is widely used for service delivery in clinical practice (10).

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Despite the popularity of teleradiology in clinical practice, this method has not been widely used for subspecialty training. Web-based training has also become an essential, accessible, efficient, and cost-effective method in medical education (11,12). However, this tool has not been employed for performing a standardized radiology subspecialty training program.

Due to high demand for radiology subspecialty training in many countries and the availability of web-based training and teleradiology, we aimed to develop a web-based radiology subspecialty training program. Using our newly developed training program, we sought to train Ethiopian radiologists in this pilot study and assess the effectiveness and feasibility of our program.

MATERIALS AND METHODS

Participants

As of February 2016, we enrolled 10 general radiologists for our training pogrom at St. Paul's Hospital Millenium Medical College (SPHMMC), Addis Ababa, Ethiopia. To be eligible, each candidate had to fulfill the following criteria: Doctor of Medicine degree from an Ethiopian Medical Association recognized university and registered as a general radiologist by the Federal Ministry of Health of Ethiopia; at least two years of work experience as a general radiologist; no previously completed subspecialty training; no physical, mental, socio-emotional health problems or job/family/other issues which make it impossible to adhere to the program (confirmed by candidates' immediate supervisor or head of the department); willing to commit to training period of 20-months. The availability of our program was announced to all general radiologists of SPHMMC. Interested radiologists were asked to send their Curriculum Vitae and then underwent an interview with a panel of experts from Johns Hopkins University (JHU) and Ver2 Digital Medicine. The comprehensive online evaluation was then conducted which comprised 80 multiple choice questions and image interpretation of 20 cases. These assessments were performed to make sure that each candidate would have a minimum knowledge as a general radiologist and was well-versed in English language. We did not select only those who did well in these initial assessments to avoid selection bias. After evaluating all candidates, we included 10 radiologists out of the 12 candidates. Two candidates were excluded because of logistic issues including inability to commit to 20-months training because of other work commitments.

Development of Web-based Subspecialty Training Program

The curriculum of the program was designed by the lead trainers of JHU (subspecialized radiologists responsible for providing subspecialty training to the fellows in their respective fields at their parent hospital) based on the radiology subspecialty training syllabus at JHU incorporated with the ABR and ACGME standards including medical knowledge, patient care and technical skills, interpersonal communication, professionalism, practice-based learning, systems-based practice (13,14). Since the Ethiopian radiology training is based on the European system, the quality assurance team from Ver2 Digital Medicine reviewed all details to ensure alignment with European Society of Radiology Level III curriculum (15). The final draft of curriculum was prepared and approved by JHU faculties and the quality assurance team. All parts of the program were provided and delivered in English.

Structure and Content of Web-based Subspecialty Training Program

Our program included four subspeciality disciplines including abdominal imaging, neuroradiology, chest imaging, and musculoskeletal imaging. Each trainee selected two subspecialties out of the four and was trained only for the selected subspecialties. The curriculum was conducted in four-stages over 20-months (average of 4-months per stage). All participants of each subspecialty discipline were trained simultaneously with the same educational materials. Structure, content, and timeline of the program are presented in Figure 1. The education delivery comprised of **(a)** online lectures (previously recorded), **(b)** online interactive case reviews, **(c)** learning modules, **(d)** self-studying, and **(e)** observership. Details of the program content were presented in Supplementary Tables 1a−d.

(a) Previously recorded lectures were provided by JHU faculty responsible for subspecialty training at their institution. Each lecture was 45−60 minutes and focused on a single topic. **(b)** Interactive case reviews were also presented by JHU faculty using online screen sharing tool. In each session, multiple cases (5−10 cases per 60 minutes session) including anonymized images and clinical information were presented, and trainees were quizzed on the case which was followed by relevant discussion. **(c)** For learning modules, educational materials were selected from the Integrated Training Initiative from eIntegrity and CTisus which are web-based public access educational tools (16,17). **(d)** Books and scientific articles that are used by JHU radiology fellows were also provided for a required 10-hours self-studying per week. **(e)** Each trainee also had one-month of observership at the radiology department at the JHU, Baltimore, USA. During the observership, trainees participated in lectures, case reviews, and journal club meetings with one-on-one interactions with the JHU faculty.

In general, each subspecialty training program contained nearly 39−50 lectures, 25−28 case reviews, 37−41 learning modules, 3−19 books, 14−17 articles, one-month observership; amounting to almost 150 hours of web-based training over the entire program, and 160 hours of observership for each participant.

All parts of training were conducted in the Learning Management System (LMS) medium software (Fig 2) (18). Prior

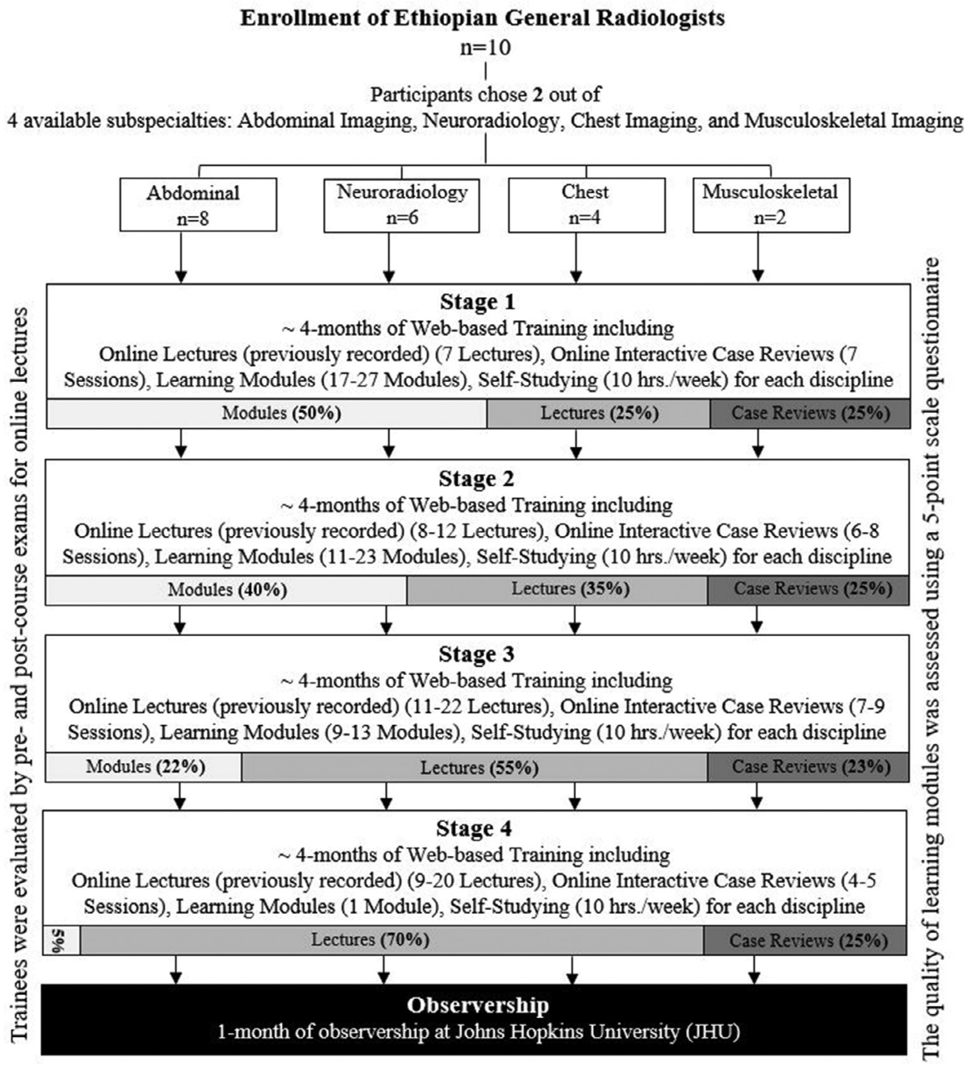

Figure 1. The flow diagram of the web-based radiology subspecialty training program: the total number of 10 Ethiopian general radiologists were enrolled. There were four available subspecialty training programs including abdominal imaging, neuroradiology, chest imaging, and musculoskeletal imaging. Each radiologist chose two subspecialties for the training. Each of these programs contains four stages (stages 1–4) including online lectures, online interactive case-reviews, learning modules, self-studying, and one-month observership at Johns Hopkins University (JHU). The impact of each online lectures on trainees' knowledge was evaluated using pre- and postcourse multiple choice questions. The quality of learning modules was assessed using a five-point scale feedback questionnaire.

to course commencement, all trainees were trained to achieve familiarity with LMS. All case reviews were conducted in secure rooms at the SPHMMC using screen sharing tool.

Program Evaluation and Assessment

In order to assess the impact of each lecture on trainee's knowledge, participants were evaluated using pre- and postcourse multiple choice questions which were created based on the validated protocols of self-assessment (19). Based on these protocols, questions were preliminarily drafted by JHU radiology residents, and then were modified and approved by the faculty. For each lecture, seven multiple choice questions (covering both clinical knowledge and image interpretation skills) focusing on the topic were provided. Trainees were asked to take pre- and postcourse tests, immediately before starting and after completing each lecture (Fig 2). We used similar questions for both pre- and postcourse exams with slight modifications.

Furthermore, the quality of each learning modules was assessed using a 5-point Likert scale, with five as the highest and one as the lowest score. The overall level of satisfaction and the quality of content, presentation, interactivity, and self-assessments were separately scored at the end of each module.

Statistical Analysis

All pre- and postcourse scores of each trainee were extracted from LMS after getting Institutional Review Board (IRB) approval for using recorded data (approval number: IRB00161536). The score change was defined as

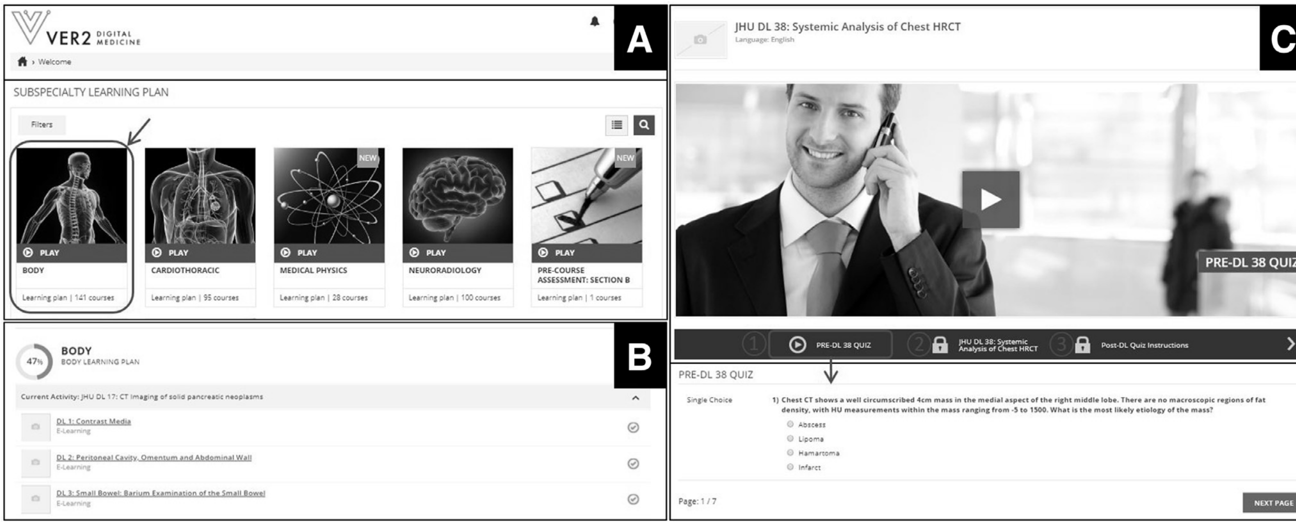

Figure 2. Learning Management System (LMS), a web-based program for conducting web-based radiology subspecialty training program: **(a)** Homepage includes links to each training program (marked by rectangle and arrow). **(b)** Homepage of each training program containing online lectures, learning modules, etc. **(c)** Sample page of online lectures (previously recorded) which includes with 1) precourse exam including seven questions (marked by a rectangle and arrow), 2) online lecture, 3) postcourse exam.

the differences between post- and precourse scores for each lecture. Quantitative before-after study using paired *t* test (for normally distributed) or paired Wilcoxon signed-rank test (for non-normally distributed) was performed to assess the impact of online lectures on trainees' knowledge. It should be noted that all pre- and postcourse scores were included in our analyses, and we did not pool the data. To compare the magnitude of score change between the different stages of training (stage 1−4), we used analysis of variance followed by Tukey's posthoc tests. Furthermore, univariable/multivariable linear regression analysis was conducted to assess the association between trainee's characteristics (age and years after graduation) and score change.

All analyses were performed in SPSS package (v.24, Chicago, IL). A two-tailed value of $p < 0.05$ was considered to be statistically significant.

RESULTS

Enrolled trainees had a median age of 47 years (range: 37−53) and had completed their general radiology residency training 11.5 (range: 5−19) years before the commencement of the program, with at least two years of experience of clinical practice (Table 1). Each trainee selected only two subspecialty training programs; total number of eight, six, four, and two trainees were enrolled in abdominal imaging, neuroradiology, chest imaging, and musculoskeletal imaging training programs, respectively (Fig 1). Trainees completely adhered to all parts of the program.

The effectiveness of previously recorded online lectures was assessed by pre- and postcourse exams, with no missing data. Results showed that trainees' scores significantly improved in all subspecialties including abdominal imaging (mean ± standard deviation of score change: +23.4% ± 10.3%, p: < 0.001), neuroradiology (+19.1% ± 12.3%, p: < 0.001), chest imaging (+13.5% ± 13.3%, p: 0.001), and musculoskeletal imaging (+23.3% ± 11.6%, p: 0.001) (Table 2 and Fig 3a−b). Similarly, online lectures in all stages of training resulted in significant score improvement (Table 2 and Fig 4a). Results showed a learning plateau as online lectures in the first stage of training lead to greater improvement than those in the latter stages, and the score change decreased with each successive stage of training ($F_{(3,76)} = 4.05$, p: 0.010, Fig 4b).

The degree of score change for each online lecture is presented in Supplementary Tables 2a−d. The quality assessment score of each learning module is also presented in Supplementary Tables 3a−d. The average feedback score for all subspecialties regarding content, presentation, interactivity, self-assessment, and overall-score was recorded as 4.12, 4.11, 4.17, 4.06, and 4.11, respectively.

Results of the regression analyses revealed that score improvement was not associated with trainees' age, years since medical school graduation or completing residency training (Supplementary Table 4).

TABLE 1. Characteristics of the Trainees

Characteristics	Value/Percentage
Total number	10
Gender (female %)	2 (20%)
Age (years)	47 (37−53)
Year after medical diploma	23.5 (11 − 28)
Year after radiology residency training	11.5 (5 − 19)
Subspecialty trained (%)	0 (0%)

Baseline characteristics of enrolled trainees (10 Ethiopian general radiologists).

Data were presented as number (percentage) or median (range: minimum−maximum).

TABLE 2. Impact of Online Lectures on Trainees' Knowledge (Quantitative Before and After Study)

	Precourse score	Postcourse score	Δ Change	*p-value*
Overall	69.6% ± 13.4%	88.0% ± 7.8%	+18.4% ± 11.4%	<0.001
Categorized based on topic				
Abdominal imaging	58.3% ± 10.4%	81.7% ± 14.5%	+23.4% ± 10.3%	<0.001
Neuroradiology	65.6% ± 12.4%	84.8% ± 8.8%	+19.1% ± 12.3%	<0.001
Chest imaging	63.3% ± 19.0%	76.8% ± 23.6%	+13.5% ± 13.3%	0.001
Musculoskeletal imaging	53.3% ± 13.5%	76.5% ± 4.9%	+23.3% ± 11.6%	0.001
Categorized based on stage				
Stage 1	55.0% (11.8%)	87.5% (12.5%)	+29.3% ± 8.4%	<0.001
Stage 2	58.6% ± 11.6%	79.5% ± 9.3%	+21.0% ± 8.0%	<0.001
Stage 3	59.5% (12.5%)	77.5% (26.3%)	+15.0% ± 13.7%	0.001
Stage 4	69.1% ± 10.8%	86.1% ± 6.4%	+17.0% ± 7.9%	<0.001

Data were presented as mean ± standard deviation for normally distributed, or median (interquartile range) for nonnormally distributed variables. Δ Change was defined as the differences between post- and precourse scores in each subject (post- minus precourse score). Data were compared using paired *t* test (normally distributed) or paired Wilcoxon signed rank test (nonnormally distributed), and final *p*-value was reported. Score change was separately calculated for each training program (abdominal imaging, neuroradiology, chest imaging, and musculoskeletal imaging) and each stage of training (stages 1−4).

DISCUSSION

To the best of our knowledge, our study is the first attempt to develop a multi-specialty web-based radiology subspecialty training program. We demonstrated that 20-months of web-based training resulted in improved knowledge in abdominal imaging, neuroradiology, chest imaging, and musculoskeletal imaging subspecialties. The web-based subspecialty training program could be considered as an effective and feasible educational tool for expanding radiology subspecialization across the world.

With the rapid advancements in radiological sciences, subspecialty training is becoming a high priority to ensure that all radiologists have the depth of knowledge required for optimizing health-care outcomes (1−4). However, the availability of subspecialty training programs is limited in many countries (especially in Africa), and training abroad is not cost-effective (6,7). For this reason less than 50% of European radiologists with no available local subspecialty training program travel outside their countries for training (6). Subspecialty training in Ethiopia has been limited to scattered short lecture series and symposia provided by radiologists from other countries which does not provide adequate and sustained training and may not be effective for long-term impact (20). Furthermore, efforts regarding curriculum design for subspecialty training in radiology in Ethiopia have been limited to pediatric radiology (21).

Over the past years, web-based training has become a promising alternative to traditional training methods and is more accessible, flexible, and cost-effective (11,12). To date, several web-based learning tools have been developed for

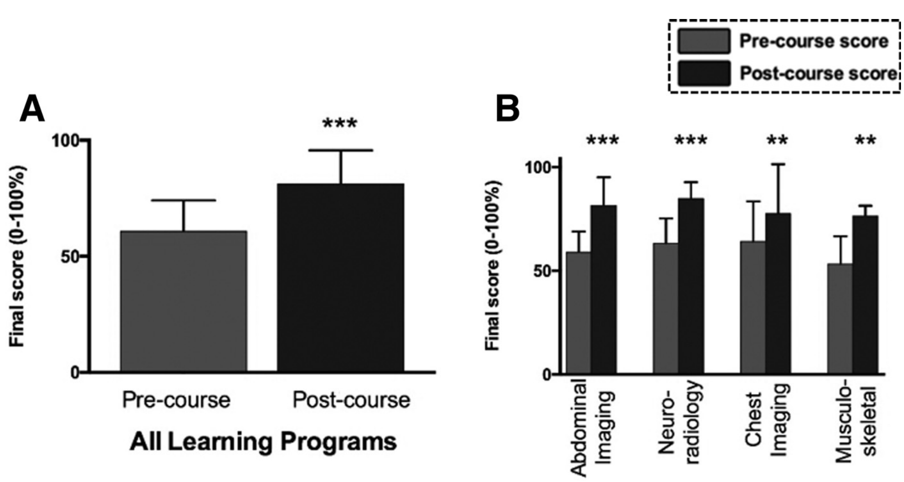

Figure 3. Impact of online lectures on trainees' knowledge by comparing pre- and postcourse scores: **(a)** Overall effect of all online lectures (previously recorded) on score change. **(b)** Effect of online lectures of each subspecialty on score changes, separately. Analyses were performed using paired *t* test for comparing pre- and postcourse scores (paired columns, gray = precourse score, black = postcourse score). Data were presented as mean and standard deviation for each column. ** $p < 0.01$ and *** $p < 0.001$.

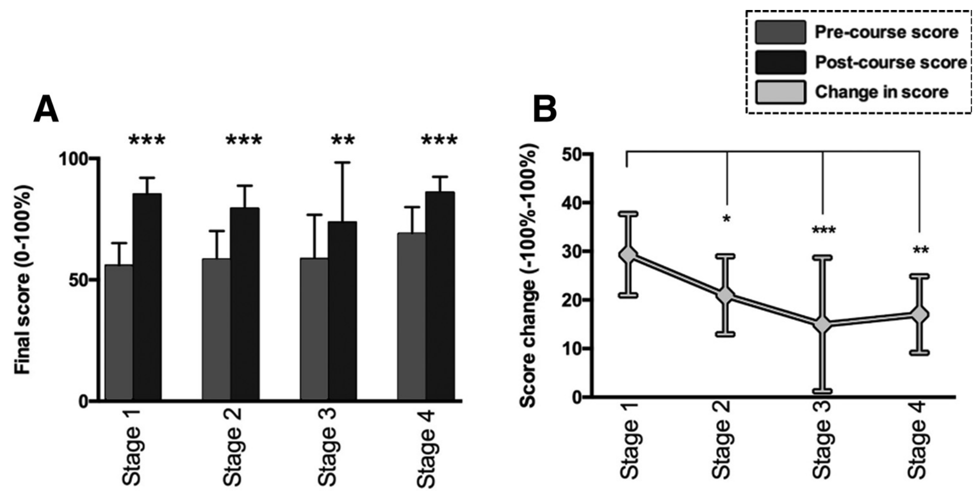

Figure 4. Comparing the magnitude of knowledge improvement between different stages of training: **(a)** Effect of online lectures (previously recorded) on score change was evaluated in each stage of training (stages 1−4), separately. Analysis was performed using paired *t* test or paired Wilcoxon signed rank test for comparing pre- and postcourse scores (paired columns, gray = precourse score, black = post course score). Data were presented as mean and standard deviation. **(b)** Comparisons of score change (post- minus precourse scores) between different stages of training. Data were compared using analysis of variance followed by Tukey's posthoc test; all stages were compared with stage 1) Data were presented as mean and 95% confidence interval. * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

radiology education (22,23). Several online training resources such as RISE, STATdx, and Radiopaedia, provide in-depth computer-based learning modules that lack interactive didactic one-on-one training (24). Another such effort to create a subspecialty web-based pediatric radiology training tool is by Reid et al. (25). Their web-based program is based on ACGME standards and includes learning modules and self-assessments and has the potential to supplement sub-specialty training across the globe (25).

We designed our web-based radiology subspecialty training program by considering all components of learning materials including **(I)** content development, **(II)** information management and delivery, and **(III)** standardization (26). **(I)** The program content was designed by the lead trainers of JHU based on the radiology subspecialty training syllabus at JHU incorporated with ABR and ACGME standards (13,14). We aimed to design a program which is representative of JHU subspecialty training by covering all topics and providing similar quality of training. **(II)** For information management and delivery, we built up our training program by combining all successful learning methods (22). Our program combines several key components of learning including online lectures, online interactive case reviews as virtual learning (trainees have interaction with the trainer using video conference software), consolidating a repertoire of online radiology training material, books and articles as offline materials, and traditional hands-on learning provided as an observership at our institution (27). Altogether, our web-based subspecialty training program can be labeled as a hybrid learning method which is defined as a combination of traditional and modern methods (28).

(III) For program evaluation and content standardization, we used quantitative before and after analysis. The results show that all stages of training resulted in significant knowledge improvement. We observed that the degree of score change decreased with each successive stage of training. This plateau in learning is likely due to the ceiling effect of knowledge improvement and increased precourse scores in subsequent stages. Because of the significant impact of stage four (last stage), we cannot suggest reducing the duration of training in future attempts.

We have also performed causal-comparative research to determine whether trainees' characteristics were related to the magnitude of score change. Regression analyses revealed that the score improvement was not associated with age and number of years after completion of residency training or obtaining medical diploma. Therefore, it can be concluded that web-based subspecialty training may be effective years after completing residency training.

We acknowledge several limitations of our study. We included a small sample size of 10 radiologists. Future research involving a greater number of trainees from multiple institutions is needed. The effectiveness of the program was determined based on immediate recall with postcourse questions and without long-term assessment of learning retention over time. No control group (received no training, or traditional training, or in-person training with the same educational material) was included in our study. However, we do rely on the results of prior studies conducted to compare the effectiveness of web-based and traditional learning methods that showed web-based methods to be a useful adjunct with improved test scores compared with traditional methods (29,30). Future studies conducted may help compare the effectiveness of web-based with traditional radiology subspecialty training. Although we created all pre- and postcourse exams based on the validated protocols, the reliability, and accuracy of exams were not evaluated. Despite the fact that web-based training might be a cost-effective method in comparison with traditional methods or traveling for training, no cost-effectiveness analysis was conducted. Finally, we only focused on four subspecialties and future studies on all radiology subspecialties such as breast imaging, pediatric radiology, etc. are recommended.

In conclusion, web-based radiology subspecialty training program results in improved knowledge of radiologists. Implementation of such a program could be an effective and feasible method for institutions without subspecialty faculty and training programs and may serve as a useful adjunct to traditional subspecialty training in radiology.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.acra.2019.02.025.