Training for advanced endoscopic imaging in gastrointestinal diseases

Hoogenboom, S.A.; Hooft, J.E. van; Wallace, M.B.

Training for Advanced Endoscopic Imaging in Gastrointestinal Diseases

Sanne A. Hoogenboom, MD,[1,2] Jeanin E. van Hooft, MD, PhD, MBA,[3] and Michael B. Wallace MD, MPH[1]

[1]Department of Gastroenterology and Hepatology, Mayo Clinic, 4500 San Pablo Road, Jacksonville, Florida; [2]Department of Gastroenterology and Hepatology, Amsterdam UMC, Amsterdam Gastroenterology & Metabolism, the Netherlands; and [3]Department of Gastroenterology and Hepatology, Leiden University Medical Center, Leiden, the Netherlands

ABSTRACT

Advanced endoscopic imaging is an emerging field in endoscopy practice, especially in optical diagnosis. Current technologies like virtual chromoendoscopy and small-field technologies allow visualization of subtle changes in mucosal and vascular patterns that are predictive of histology. The limiting factor in broadly utilizing these techniques is training and the need for reliable detection of these subtleties. This review provides the current evidence and limitations of training in advanced endoscopic imaging, and future directions of learning. A literature search was performed on PubMed and Medline through March 2020 with relevant keywords as advanced endoscopic imaging, training, and learning. References of relevant articles were screened for additional literature. Several didactic and web-based education programs are developed for training in virtual chromoendoscopy, autofluorescence imaging, confocal laser endomicroscopy, and volumetric laser endomicroscopy. Studies and post-hoc analysis on learning curves showed relatively steep learning curves after training, and web-based education seems to be as valuable as in-person didactic training for most techniques. However, consistent performance on expert level after training has not yet been demonstrated. Most advanced endoscopic imaging techniques are learned within a reasonable timeframe. Future efforts to enhance training and implementation of these techniques should focus on developing standardized and broadly incorporated training programs. The future role of artificial intelligence-assistance in advanced endoscopy and training has to be elucidated.

Keywords: Advanced endoscopic imaging; Virtual chromoendoscopy; Training; Learning; Education.

1. Introduction

Endoscopy has become a cornerstone in contemporary Gastroenterology practice. After the first gastroscopy performed by Kusmaull in 1868, endoscopy has evolved tremendously.[1] Ergonomically disadvantaged fiberoptic endoscopes were displaced by video endoscopes using charge-coupled devices, making the procedure visible for everyone in the endoscopy room such as fellows, nurses, and students. Various advanced endoscopic imaging modalities have been developed since, improving the visualization of the gastrointestinal mucosa and vasculature and, as a result, allowing fine details and subtle abnormalities to become *visible* to the endoscopist. Improvements in image resolution and software processing have boosted this progress even further. However, the limiting factor nowadays for broadly applying these novel techniques with increased amounts of visual information is the endoscopist, who will need to *recognize* and *classify* these subtleties.[2] The American Society for Gastrointestinal Endoscopy (ASGE) established the "Preservation and Incorporation of Valuable Endoscopic Innovation" (PIVI) statements, which are diagnostic thresholds for optical diagnosis with advanced imaging technologies that need to be met before incorporation in clinical practice. Until now, PIVI thresholds for several advanced endoscopy techniques have been met by experienced users in academic hospitals, yet its benefit in a non-academic setting has not been proven.[3-5] Enhanced imaging techniques provide the endoscopist with more detailed visual information than ever, and training to correctly use and interpret this information is paramount to meet the set thresholds. However, there is no standardized curriculum for advanced endoscopic imaging in the Gastroenterology fellowship, and it is often informally integrated into advanced endoscopy fellowships. In this review, an overview of the current evidence on training in various advanced endoscopic imaging modalities is

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provided, including (virtual) chromoendoscopy, autofluorescence imaging, and confocal- and volumetric laser endoscopy. Furthermore, we aimed to highlight future perspectives on education, including artificial intelligence (AI)-based learning and how it may be implemented.

1.1. Literature Search

A literature search was performed on Pubmed and Medline from January 1976 through March 2020 for relevant articles written in English. Keywords were searched in the title or abstract, or using MESH terms (Supplement 1). All identified articles were screened on title and abstract, and references of selected articles were checked for additional relevant literature. Articles reporting on training in one or more advanced endoscopic imaging techniques were selected for discussion in this review.

2. Results

2.1. Chromoendoscopy

In experienced hands, (magnifying) chromoendoscopy can help visualize and differentiate mucosal lesions during endoscopy for specified indications.[6] For less experienced trainees or consultants, there seems to be no direct benefit in neoplasia detection when using indigo carmine chromoendoscopy (CE) as compared to conventional white light (WL) colonoscopy.[7,8] Although not thoroughly investigated, application and interpretation of chromoendoscopy seem to be learned adequately in a reasonable time frame with a steep learning curve.[7,9] One study investigated a validated training module on diluted acetic acid for the detection of neoplasia in Barrett's Esophagus (BE), including a 3-hour online training and an interactive training day for endoscopists with experience in BE.[10] After training, the endoscopists' performance increased significantly along with their confidence using acetic acid. In addition, diluted acetic acid is easily applicable, and all endoscopists met the ASGE PIVI criteria on imaging in BE after the study.[11] CE with indigo carmine is somewhat more accepted in chronic inflammatory bowel disease and dysplasia surveillance (Figure 1). A study by Picco et al demonstrated that the technique is rapidly learned after a short training session with exemplary images. Although CE is often considered time-consuming, the withdrawal time in this study improved after only 5 cases. By the end of the study, the interobserver agreement between six participating endoscopists was excellent.[12] However, especially in Western countries, CE with indigo carmine has not been widely accepted due to the cumbersome task of dye application.

2.2. Virtual Chromoendoscopy

Virtual chromoendoscopy (VC) applications offer the benefits of CE with a simple "push-of-a-button" technology and without the need for labor-intensive dye application. Commercially available techniques of VC include Narrow-Band Imaging (NBI) (Olympus, Tokyo), i-scan (Pentax, Tokyo), Flexible spectral Imaging Colour Enhancement, and Blue Laser Imaging (Fujifilm, Tokyo). All modalities use digital image pre- or postprocessing techniques to enhance the visualization of mucosa and vascular patterns. Several classification systems have been developed to characterize lesions and mucosa according to their appearance with VC, often including color, epithelial surface pattern, and vascular pattern. The learning curves of VC applications are partially explained by the validity and applicability of these classification systems.

In upper gastrointestinal (GI) endoscopy, learning curves of VC are investigated in various settings, such as the assessment of BE and esophageal and gastric lesions.[13-20] One study investigated the learning curve of BE assessment using magnified NBI (M-NBI) in endoscopists with- and without previous M-NBI experience.[15] Before the onset of the study, the participants underwent a structured learning program and received histological feedback after every assessed video. During the study, 70 M-NBI videos were evaluated by the participants and, again, histological feedback was given after the assessment of each video. Surprisingly, the diagnostic accuracy

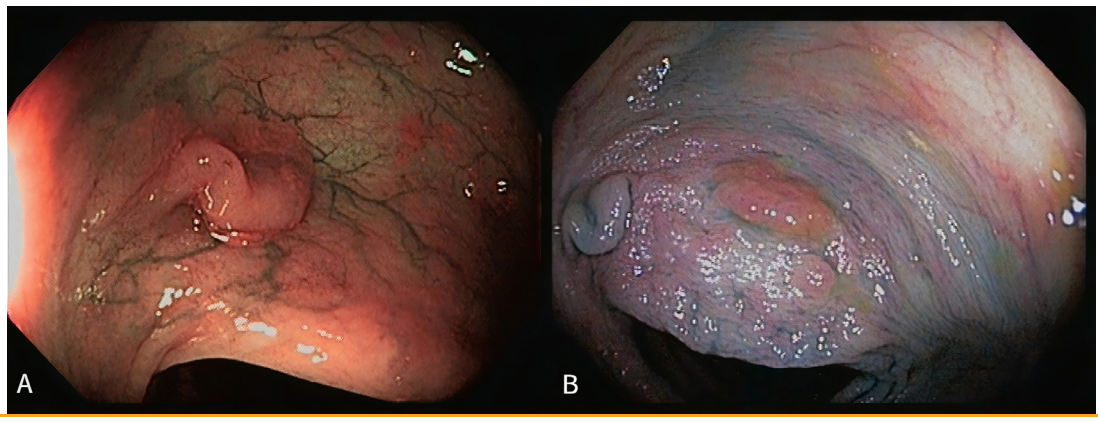

Figure 1. (A) Narrow band imaging view of a very flat, dysplastic lesion (Paris 2b) in ulcerative colitis, adjanced to a pseudopolyp. (B) The same region as A, but with indigo carmine. Note the same pseudopolyp on the left but the poorly circumscribed flat, Paris 2b lesion to the right and below.

for dysplasia did not improve over time; in the first 20 videos, the diagnostic accuracy was 70.0% the experienced group and 76.7% in the inexperienced group. In the last 20 videos, these measures were respectively 70.0% and 63.3%. Likewise, the interobserver agreement did not improve over time, although a decrease in the time needed for evaluation was observed in both groups. The authors attributed the disappointing accuracy to the fact that the evaluation of videos may be more complicated than still images. Another study did not observe a difference after training between medical students and third-year gastroenterology fellows in the diagnostic accuracy for dysplasia in BE.[16] Both groups did not reach the accuracy reported in studies with expert endoscopists using NBI for BE assessment and did not meet PIVI thresholds. A large RCT investigated the effectiveness of an e-learning system, including lectures and practice exercises, in improving the recognition of early gastric cancer lesions with M-NBI. In total, 368 endoscopists were randomized between the e-learning and no e-learning group after they conducted a baseline performance test.[17] The incremental yield of the accuracy after the e-learning was 7% compared to 0% in the no e-learning group. In a secondary analysis of this study, the learning effect was most clearly demonstrated for depressed and small lesions.[20] Dias-Silva et al conducted a study on assessing gastric lesions with NBI. They reported an increasing learning curve in predicting lesion histology after a YouTube-based learning program in both experienced endoscopists (NBI-native) and trainees.[13] Surprisingly, the trainees outperformed the experienced endoscopists in global accuracy. The authors suggested that a greater motivation may cause this outperformance in trainees and because trainees had more time available to study. To conclude, learning curves of VC in upper GI endoscopy are studied, and for the assessment of dysplasia in BE there seems to be a complicated learning curve. Current learning modalities have not yet proven their definite benefit in reaching PIVI thresholds.

In lower GI endoscopy, multiple studies have shown that both experienced endoscopists as trainees have a rapid learning curve for the detection and characterization of colorectal polyps with VC, not only in still images but also in real-time endoscopy[21-29] (Figure 1). Studies assessing the learning curve for optical diagnosis in still images showed impressive curves after a short training session; a diagnostic accuracy of at least 89% was reported in all studies and the durability of this gained competency seems to be at least three months.[23,25-28,30] In contrast, Ladabaum et al evaluated community endoscopists' performance in using NBI for the prediction of colorectal diminutive polyp histology, first in still images after a computerized self-learning program and then during real-time colonoscopy.[3] In total, 91% of participants reached ≥90% accuracy in the *ex vivo* part of the study. In comparison, only 25% reached this accuracy in real-time colonoscopy at the end of the study, after evaluation of 90 independent diminutive polyps. The learning curves of the participating gastroenterologists showed significant variation during the study, without an obvious pattern of early learning in the beginning of the study and stabilization toward the end of the study. Although the ASGE PIVI threshold on the agreement of surveillance intervals for diminutive polyps was not reached (85% agreement), the PIVI threshold for a negative predictive value of at least 90% for adenomatous histology was met in this study.[31] In an academic setting, Rogart et al found that approximately 130 lesions are necessary to reach basic optical diagnosis competency in real-time colonoscopy.[21] Another study, exploring the learning curve of i-scan for optical diagnosis using still images, reported an accuracy of >90% after evaluating 89 still images and a 1-hour online teaching session in gastroenterologist without previous i-scan experience.[32] Interestingly, one study comparing NBI with WL colonoscopy for the prediction of polyp histology in experienced gastroenterologists found not only a learning effect in predicting polyp histology with NBI but also in predicting histology using only WL.[22] These results suggest that NBI may have induced a transferred learning effect for both NBI as WL.

Learning programs commonly utilized in the above-mentioned studies included interactive didactic sessions, training image-sets, self-directed learning, and continuous feedback on endoscopists' performance. Two studies examined the learning curves of self-directed learning and in-classroom education about VC and compared the accuracy and confidence level of polyp characterization between them.[33,34] Both studies demonstrated that there was no benefit for the in-classroom session over self-directed learning. Daly et al found similar results in another study, comparing in-classroom and self-learning in assessing dysplastic changes in BE. However, they reported a significant benefit for the in-classroom group regarding the confidence level of participants about their prediction.[16] Computer-based self-learning offers a relatively inexpensive and resource-low alternative to expert didactic sessions, with the ability to reach a broader audience. Future research should point out if computer-based training can maintain a long-lasting competence in VC, especially for nonacademic gastroenterologists who do not often use VC applications.

2.3. Autofluorescence Imaging

Autofluorescence imaging (AFI) is another advanced imaging method for optical diagnosis, using short-wavelength light that induces tissue to emit autofluorescence light. In a study among inexperienced gastroenterologists using WL, NBI, and AFI for the differentiation of colorectal polyps, it was found that after a short didactic training the application of AFI led to a higher diagnostic accuracy and interobserver agreement than NBI.[35] The authors stated that these findings suggest that novice endoscopists might easier learn AFI with color classification than NBI using Kudo pit pattern classification. However, AFI systems are no longer in routine use in gastrointestinal endoscopy and therefore, their proficiency is not highly relevant.

2.4. Confocal Laser Endomicroscopy

Confocal laser endomicroscopy (CLE) is an endoscopic imaging technology that allows in vivo micron-scale imaging of the gastrointestinal mucosa and is often referred to as "virtual biopsy." Two types of CLE systems are currently available: the endoscope-based CLE (eCLE) with an endomicroscope incorporated in the distal tip of an endoscope and the probe-based CLE (pCLE), which can be passed through the accessory channel of an endoscope.

Gaddam et al evaluated the learning curve of predicting dysplasia in BE with pCLE in 6 gastroenterologists, 3 with prior pCLE experience and 3 without prior experience[36] (Figures 2 and 3). After a 1-hour training session on the application of pCLE and their novel developed pCLE criteria for dysplasia in BE, the inexperienced group was as accurate in detecting dysplasia as the experienced group (79% versus 84%, respectively (P= 0.18). Both groups had an NPV of 85%, still under the PIVI threshold of at least 90%. Besides, no substantial learning effect was found for the accuracy or interobserver agreement during the study, suggesting a short and steep learning curve in the training session. These findings were confirmed in a large RCT assessing the accuracy of novel pCLE users in predicting intestinal metaplasia compared to random biopsies per Seattle protocol.[37] Steep learning curves were also reported in studies using pCLE to detect early-stage esophageal squamous cell cancer and mucosal barrier defects.[38,39] The first study reporting on the learning effect of pCLE in differentiating neoplastic from non-neoplastic colorectal polyps using the Mainz classification demonstrated a significant improvement in accuracy from the beginning (63%) toward the end of the study (86%).[40] All participating endoscopists underwent a 2-hour didactic training before the study and received histological feedback after every evaluated video. In a comparable study applying eCLE for neoplasia prediction in still images, 3 experienced, but eCLE naïve, endoscopists demonstrated a high accuracy (>85%) directly at the initial stage of the study after only a brief training.[41] In-class didactic teaching appears to be more effective for learning pCLE regarding diagnostic accuracy and interobserver agreement than self-directed learning, in contrast with earlier reported findings in VC.[42,43]

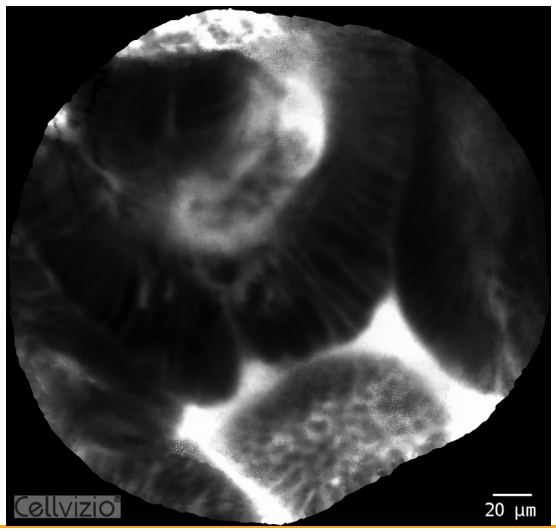

Figure 2. Probe-based Confocal Laser Endomicroscopy (pCLE) image of high grade dysplasia in Barrett's esophagus. Note the dark and thickened cells lining a villiform area of intestinalized epithelium.

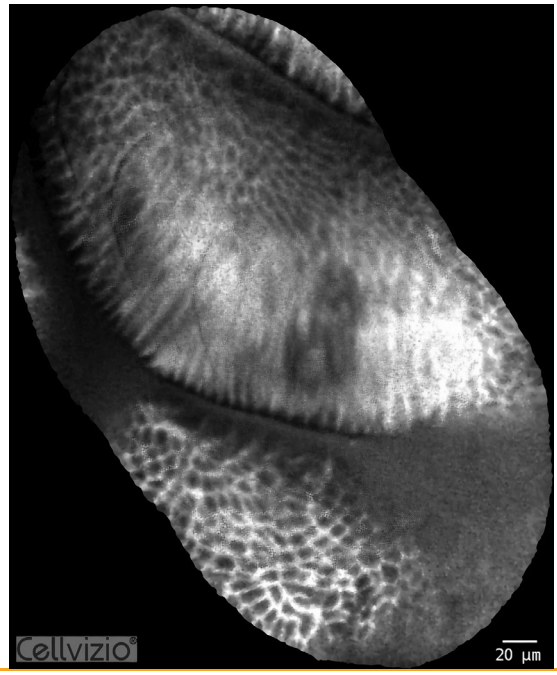

Figure 3. Probe-based Confocal Laser Endomicroscopy (pCLE) image of Barrett's esophagus without dysplasia. The surface epithelium is bright, single cell layered and smooth.

In recent years, needle-based CLE for the assessment of pancreatic cyst has become another area of interest. Preliminary results showed that CLE-naive users were able to assess high-grade dysplasia or worse with a sensitivity and specificity of 93.8% and 100%, after seeing 10 training videos and using predefined criteria for dysplasia.[44] In short, most studies demonstrated a steep learning curve for the interpretation of CLE images and videos, but these results need to be validated in real-time endoscopy studies when both acquisition and interpretation is simultaneously warranted. Furthermore, various criteria for defining dysplasia optically exist, and learning curves are partially explained by the complexity and applicability of these criteria. Endocytoscopy is another probe-based small field technology that captures highly magnified images of the gastrointestinal mucosa. However, no dedicated studies on training programs or learning curves were found.

2.5. Volumetric Laser Endomicroscopy

Volumetric laser endomicroscopy (VLE) is a relatively new advanced imaging technique developed to detect and mark neoplasia in BE. This optical coherence tomography

device can make a cross-sectional (3 mm in depth) and circumferential scan of the esophageal wall (Figure 4). Learning curves on the interpretation of VLE-scans by novice users have been recently investigated in three academic centers.[45] Their study showed that 71% of the participating endoscopists achieved similar competency as experienced VLE-users after a brief online training and reviewing almost 100 VLE-images. However, the learning curve of VLE application and obtaining endoscopic images at the same time has not been investigated. Unfortunately, VLE systems were (temporarily) unavailable at the time this review was written.

2.6. Computer-Aided Diagnosis

Although almost all studies showed that the advanced endoscopic imaging modalities are trainable, these techniques have not yet shown their consistent diagnostic benefit in nonacademic hospitals. Also, interobserver agreement with advanced imaging modalities is often limited, even after training or in experienced users.[3-5] Interestingly, a recent survey among academic and community gastroenterologists in Connecticut reported that approximately 80% of gastroenterologists had ever used VC, but only 11% received formal training.[46] Almost 60% of the respondents used VC in less than 10% of their procedures. The lack of training was commonly reported as the main reason not to use VC, while 76% of the respondents were interested in training. Training in advanced imaging modalities seems poorly implemented in gastroenterology fellowships and is currently determined by the hospital's expertise they are trained at. However, given the continuous innovations in this field, training in advanced mucosal imaging is indispensable and should be standardized.

The sometimes overwhelming amount of visual information captured in an endoscopy image may play an essential role in disappointing accuracy and interobserver variability in nonacademic hospitals. However, promising results have recently been demonstrated by continuing training, monitoring, and auditing in community practice.[47] Moreover, *timely* feedback is considered one of the most critical aspects of effective feedback, preventing trainees from developing misconceptions.[48] Since the histological examination of biopsies and polypectomies requires time, current feedback on endoscopy performance is limited by the time delay between endoscopy and histology. We hypothesize that recent advances in computer-aided diagnosis (CAD) may initiate a complete paradigm shift in future learning by providing real-time feedback on the endoscopists' performance and hereby boosting an immediate learning curve. Novel CAD systems are based on deep learning using multilayered artificial neural networks. Deep learning is characterized by the ability to automatically dissect large amounts of data (eg, endoscopy images) and to recognize and learn multiple features (eg, vascular patterns) fitting to a specific outcome (eg, adenomatous polyp).[49] Highly performing deep learning systems for nearly real-time optical diagnoses are recently developed for early gastric cancer,[50] dysplasia in BE,[51-53] esophageal squamous cell carcinoma,[54] and diminutive colorectal polyps using various advanced mucosal imaging techniques.[55-57] In radiology, similar CAD systems have demonstrated to be particularly useful as an additional reader, overcoming the intra- and interobserver variability often reported in the interpretation of images.[58-61] Future research should point out if these CAD systems will also initiate a learning curve – or the opposite – and enhance the diagnostic accuracy in endoscopists with limited experience in advanced endoscopic imaging. In addition, CAD systems may not only act as a second reader in future educational practice but also target individualized education by automatically pointing out areas of lacking experience and common pitfalls.[62,63]

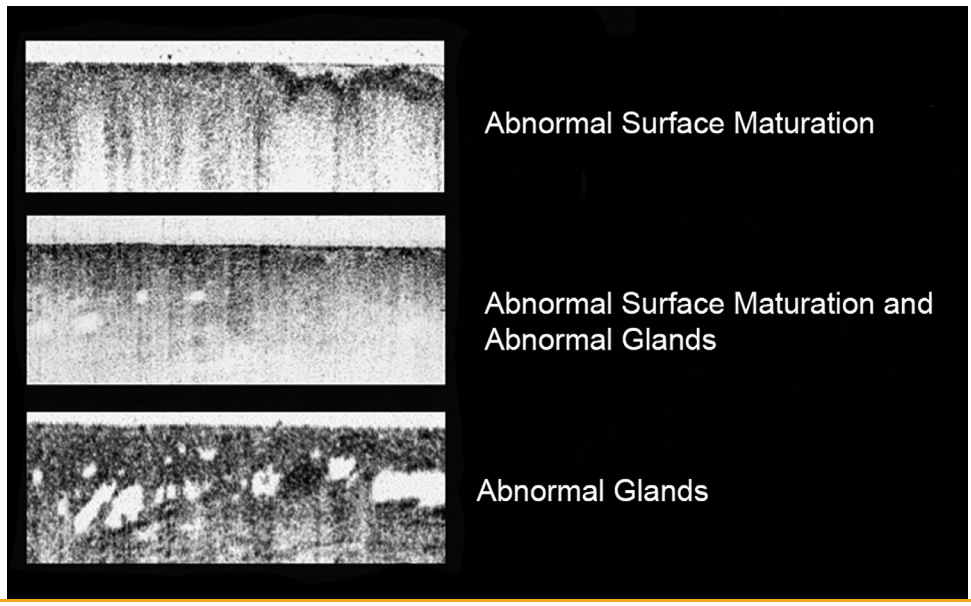

Figure 4. Volumetric laser endomicroscopy (VLE) images of Barrett's esophagus showing features of dysplasia (dark/reflective surface, irregiular glands visible as white areas in subsurface).

As can be learned from the history of endoscopy, innovations in our field arose from close collaborations between physicians and engineers, and future efforts in applying AI in endoscopy might be the next successful example.[64]

3. Conclusion

Advanced endoscopic imaging has evolved tremendously in the last decade, enabling subtle morphological changes to become visible for the endoscopist. Although most of these modalities can be learned within a reasonable timeframe and with acceptable outcomes, broad application in community setting has not yet shown its benefit. Currently, standardized and validated training programs are often lacking and not well implemented in endoscopy fellow programs. The exposure of gastroenterology fellows – or other novice users – to advanced techniques is largely dependent on the expertise of their hospital. Future education should focus on the options of web-based education to reach a broader audience. Furthermore, studies should point out the role of AI-assisted learning, wherein highly performing CAD systems should not only act as a supervising additional reader but also aim to tailor education to the trainees' needs.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.tige.2020.09.001.

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*Corresponding author. e-mail: wallace.michael@mayo.edu

Conflicts of interest

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