Mastering Diagnostic Skills: Enhancing Proficiency in Otitis Media, a Model for Diagnostic Skills Training

WHAT'S KNOWN ON THIS SUBJECT: Accurate otoscopic diagnosis (ie, distinguishing between AOM and OME) in infants and young children often is difficult. In training programs, opportunities to compare TM findings across cases and to receive feedback regarding accuracy are limited.

WHAT THIS STUDY ADDS: Our interactive online curriculum includes images illustrating various otoscopic findings, mnemonic guides, and discrimination sessions that include feedback and assessments of diagnostic skills. *e*PROM aims to enhance learners' abilities to detect the presence and type of otitis media accurately.

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KEY WORDS
otitis media, proficiency, diagnostic skills, training

ABBREVIATIONS
TM—tympanic membrane
AOM—acute otitis media
OME—otitis media with effusion
DxEAR—Diagnostic Ear Assessment Resource
UPMC—University of Pittsburgh Medical Center
PGY1—postgraduate year 1
PGY2—postgraduate year 2
*e*PROM—Enhancing Proficiency in Otitis Media

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abstract

OBJECTIVE: We developed a program for training in the diagnosis of otitis media that included images illustrating various otoscopic findings, mnemonic guides to recollection, and discrimination sessions that included feedback and assessments of diagnostic skills.

METHODS: We prepared a computerized, interactive curriculum, Enhancing Proficiency in Otitis Media (*e*PROM), that was centered around assemblages of clinically diverse, still and video images of tympanic membranes (TMs). To assess curriculum effectiveness, we constructed a test, the Diagnostic Ear Assessment Resource, that consisted of 50 video TM images. We administered the test to 84 residents in pediatrics or family practice who had not been exposed to *e*PROM and, varying the order in which the images were presented, to another group of 102 residents in the same programs both before and after exposure to *e*PROM.

RESULTS: Mean proportions of correct diagnoses in the Diagnostic Ear Assessment Resource were larger among residents who had been exposed to ePROM than among residents at comparable levels of training who had not been exposed (67% vs 62%; $P = .007$). Among residents exposed to *e*PROM, mean proportions of correct diagnoses were larger after exposure than before (67% vs 55%; $P < .001$).

CONCLUSION: A structured, computerized curriculum to supplement standard clinical training can enhance residents' abilities to interpret still and video images of TMs and may improve their skills in diagnosing otitis media. *Pediatrics* 2009;124:e714–e720

Otoscopic diagnosis in infants and young children often is difficult. More than with most other physical findings in children, learning to perceive and to interpret tympanic membrane (TM) findings accurately entails repeated practice under expert supervision.

Assessment of the status of the middle ear requires rapid assimilation and synthesis of detailed and often subtle visual findings gained from brief observation of the TM. Clinicians often find it difficult to distinguish between normal and pathologic findings and between acute otitis media (AOM) and otitis media with effusion (OME), conditions that have differing management approaches. Because otitis media is the most commonly diagnosed illness in US children next to the common cold, the potential for inappropriate use of antimicrobial agents when the condition is overdiagnosed or misdiagnosed is high.[1,2]

In training programs, opportunities to compare TM findings across cases and to receive feedback regarding accuracy are limited for a number of reasons, that is, trainees may not be exposed to sufficient numbers of illustrative cases, trainee and teacher may not experience findings identically even when they perform sequential examinations of patients, and repeated examinations of young children may cause the children physical or emotional discomfort. Adjunctive enrichment of training in otoscopy outside clinical settings through focused educational modules might address these limitations effectively.

We have developed a program that includes images illustrating various otoscopic findings, mnemonic guides to guide perceptions, and discrimination sessions that include feedback and assessments of diagnostic skills. Our interactive, online curriculum, Enhancing Proficiency in Otitis Media (*e*PROM) (available at http://PedsEd.pitt.edu), aims to enhance learners' ability to detect accurately the presence and type of otitis media. We describe the results of a study to assess the program's effectiveness in a cohort of residents training in pediatrics or family medicine in 5 teaching hospitals in the United States. We hypothesized that (1) a group of trainees tested for diagnostic accuracy would perform significantly better in equivalent testing after receiving standard teaching plus exposure to *e*PROM and (2) the performance of trainees who received standard teaching plus exposure to *e*PROM would be significantly better than the performance of comparable trainees at a similar level who received standard teaching alone. The study was approved by the respective institutional review boards, and participants gave written consent.

METHODS

Development of the *e*PROM Curriculum

*e*PROM centers primarily around assemblages of clinically diverse, high-quality, still and video TM images collected, with parental consent, from patients at Children's Hospital of Pittsburgh of the University of Pittsburgh Medical Center (UPMC). We incorporated images, informational text, clinical tips, practice sessions, and references into a group of six 30-minute, Internet-accessible, interactive, self-study modules. The modules concerned (1) equipment and techniques used in pneumatic otoscopy; (2) diagnosis of OME; (3) diagnosis of AOM; (4) tympanometry and acoustic reflectometry; (5) epidemiological, pathophysiologic, and microbiologic features of otitis media; and (6) counseling of parents regarding diagnostic tympanocentesis.

The modules incorporated a number of features considered important for promoting effective self-instruction,[3] including introduction of concepts in small steps; structured opportunities for active learner responses; immediate feedback on learner trials, demonstrating the acquisition of knowledge and skills; and learner control of the pace of the educational experience. Modules included premodule and postmodule quizzes to assess short-term changes in learner knowledge and comprehension. We organized module content for posting on the Internet by using the Navigator Learning Management System designed by the UPMC Laboratory for Educational Technology. The UPMC Laboratory for Educational Technology hosted the modules on its medical education Web site. We pilot-tested the modules with groups of residents before implementing the current study.

Development of an Outcome Measure Proficiency Test

To assess residents' proficiency in middle-ear diagnosis, we constructed a test, the Diagnostic Ear Assessment Resource (DxEAR), that consisted of 50 video images of TMs (other than those used in the *e*PROM curriculum) selected by a panel of 3 validated otoscopists from a previously published image set.[4] Only videos that the panel considered readily interpretable and for whose diagnosis the panel reached consensus were included. Of the 50 images, 20 depicted AOM, 20 depicted OME, and 10 depicted no effusion. The test required that, for each video, the viewer commit to 1 of those 3 middle-ear diagnoses. In a preliminary validation study using the DxEAR, the degree of agreement among a group of 17 expert otoscopists ranged from moderate ($\kappa = 0.50$) to very good ($\kappa = 0.91$). For all except 9 (18%) of the 50 TM images, experts concurred independently regarding the diagnosis $\geq$82% of the time. To test residents before and after they interacted with *e*PROM, we prepared 2 versions of the test (Dx-

EAR_1 and $DxEAR_2$), which differed only in the order in which the same 50 video images were presented. The test was hosted on a unique Web site, and access to it was controlled by the project's data manager (Ms Colborn).

Definitions of AOM and OME

Throughout the *e*PROM curriculum and in the DxEAR, we diagnosed AOM and OME on the basis of observation of the TM alone; the presence of bulging was considered indicative of AOM.[2] Information regarding symptoms was not provided. Our intent was to train residents to recognize the visual findings consistent with the diagnoses of AOM, OME, and no effusion.

Participants and Procedures

In 2004, we enrolled a reference group of 84 residents early in postgraduate year 2 (PGY2) from 6 US residency programs. Five of the programs, namely, those at Children's Hospital of Pittsburgh of UPMC, Nationwide Children's Hospital (formerly, Columbus [Ohio] Children's Hospital), Greenville (South Carolina) Hospital System, West Virginia University Health Sciences Center, and University of Rochester Medical Center, were in pediatrics and 1, that at UPMC St Margaret, was in family practice. These residents in PGY2 underwent proctored testing with $DxEAR_1$ without having received previous targeted instruction regarding the diagnosis of otitis media.

In 2005, we enrolled an experimental group of 102 residents early in postgraduate year 1 (PGY1) in all except 1 (University of Rochester Medical Center) of the 6 aforementioned programs. These residents in PGY1 underwent proctored testing with $DxEAR_1$ without having received previous targeted instruction. After the completion of $DxEAR_1$ testing, residents were informed of their scores and provided with elective, online access to the *e*PROM modules. We encouraged the residents to access *e*PROM but imposed no requirements to do so. Therefore, accession by residents was inconsistent; 20 of the 102 residents did not access *e*PROM at all. Two months before the end of the academic year, the modules were closed and then residents were tested with $DxEAR_2$.

In each program, 1 or 2 faculty members implemented resident enrollment and served as on-site project training directors. Before implementation of the curriculum, we discussed with these faculty members approaches to testing and teaching residents with the curriculum, and we reviewed interpretations of selected still and video images of a range of TM findings.

All DxEAR testing was arranged and proctored by the on-site training directors or their designees. After scores were recorded electronically, access to the test was terminated. The numbers of residents who underwent DxEAR testing are shown in Fig 1.

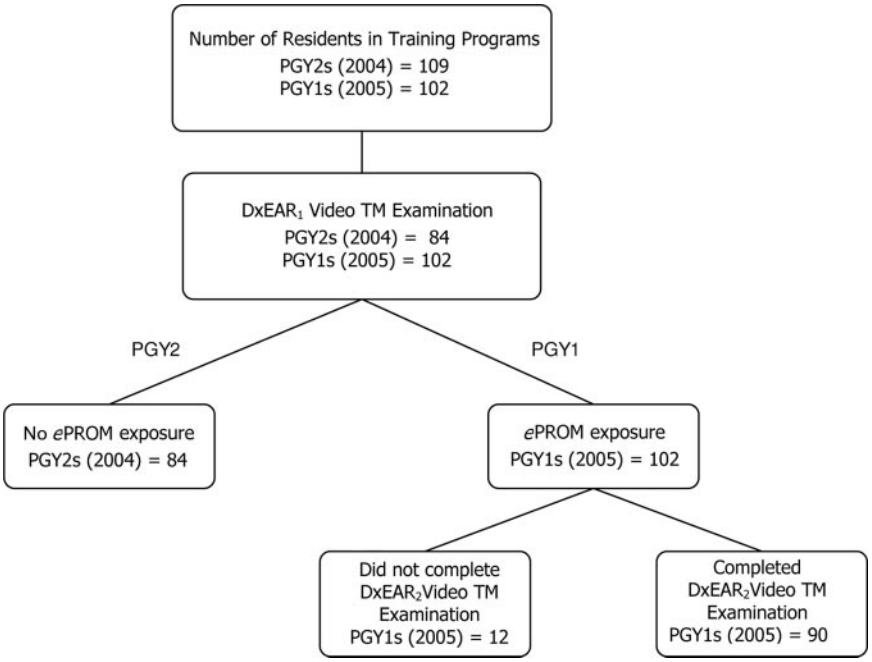

FIGURE 1
Numbers of residents who underwent DxEAR testing.

Statistical Analyses

We analyzed the data according to the principle of intention to treat; therefore, the results for all residents were included in the analyses regardless of whether, and the extent to which, they accessed the *e*PROM curriculum. We used χ^2 tests to test for differences between proportions, *t* tests to assess differences between mean proportions of ear images diagnosed correctly, and paired *t* tests to compare proportions of ear images diagnosed correctly before and after *e*PROM use among residents in PGY1 exposed to the *e*PROM curriculum. In comparing mean proportions, we first applied an arcsine transformation. All statistical tests were 2-tailed, and we set statistical significance at $P < .05$.

RESULTS

Study Sites and Enrollment

The distribution of the participating residents according to training institution is shown in Table 1. Of the residents in PGY2, 70% were in the cate-

TABLE 1 Distribution of Participating Residents According to Residency Programs

Residency Programs	*n* (%)	
	Residents in PGY2, 2004 ($N = 84$)	Residents in PGY1, 2005 ($N = 102$)
Children's Hospital of Pittsburgh of UPMC	22 (26)	30 (29)
Nationwide Children's Hospital	17 (20)	37 (36)
Greenville (South Carolina) Hospital System	12 (14)	13 (13)
UPMC St Margaret Hospital	11 (13)	13 (13)
West Virginia University Health Sciences Center	7 (8)	9 (9)
University of Rochester Medical Center	15 (18)	NA

Because of rounding, percentages may not sum to 100%. NA indicates not applicable.

gorical pediatrics track, 14% in medicine-pediatrics, 2% in pediatrics-psychiatry-child and adolescent psychiatry, and 13% in family medicine. Corresponding values for the residents in PGY1 were 62%, 24%, 2%, and 13%.

Residents' DxEAR Scores

Of the 84 residents in PGY2, all completed $DxEAR_1$. Of the 102 residents in PGY1, 90 (88%) completed both $DxEAR_1$ and $DxEAR_2$, and 12 (12%) completed $DxEAR_1$ only. The mean $DxEAR_1$ scores of these 12 residents did not differ significantly from those of the 90 residents who completed both $DxEAR_1$ and $DxEAR_2$. All results for all tests completed in each training program are included in the present analyses. Figure 2 shows the proportions of individual TM images diagnosed correctly by the residents in PGY2 and PGY1 in $DxEAR_1$ and by the residents in PGY1 in $DxEAR_2$. Values are shown separately for all diagnoses combined and for AOM, OME, and no effusion.

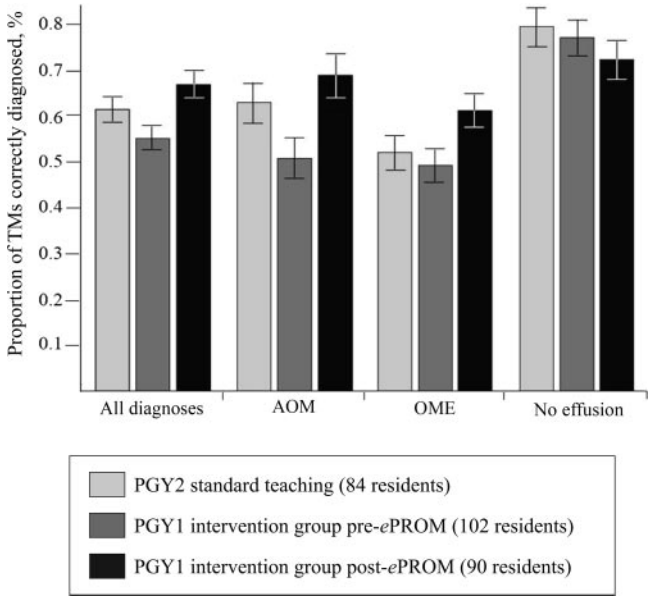

FIGURE 2
Proportions of TM images in $DxEAR_1$ and $DxEAR_2$ diagnosed correctly by residents before and after exposure to *e*PROM, with 95% confidence intervals. Mean proportions of correct diagnoses for residents in PGY1 after and before exposure to *e*PROM were 67% and 55%, respectively ($P < .001$). Mean proportions of correct diagnoses for *e*PROM-exposed residents and nonexposed residents at comparable levels of training were 67% and 62%, respectively ($P = .007$). All remaining comparisons were significant ($P < .05$) except for PGY2 versus PGY1 before *e*PROM for OME ($P = .29$) and no effusion ($P = .52$) and PGY1 after *e*PROM versus PGY2 for AOM ($P = .07$). Light gray bars indicate PGY2 standard teaching (84 residents); dark gray bars, PGY1 intervention group, before *e*PROM (102 residents); black bars, PGY1 intervention group, after *e*PROM (90 residents).

Except for the diagnosis of no effusion, the mean proportions of correct diagnoses were lowest among the residents in PGY1 for $DxEAR_1$, intermediate among the residents in PGY2 for $DxEAR_1$, and highest among the residents in PGY1 for DxEAR2. Among residents exposed to *e*PROM, mean proportions of correct diagnoses were larger after exposure than before (67% vs 55%; $P < .001$). In addition, mean proportions of correct diagnoses in DxEAR testing were higher among residents who had been exposed to *e*PROM than among residents at comparable levels of training who had not been exposed (67% vs 62%; $P = .007$).

Of the residents who took the $DxEAR_2$ posttest, the mean change in the proportion of TMs diagnosed correctly ($DxEAR_2$ versus $DxEAR_1$) did not differ significantly ($P = .10$) between the 32 residents (completers) who completed both the AOM and OME module quizzes (13.6% difference) and the 15 residents (noncompleters) who had no documented exposure to any module (6.7% difference). This trend suggests greater improvement for resident completers, compared with noncompleters.

In contrast to Fig 2, which shows proportions of individual TM images diagnosed correctly, Table 2 shows the proportions of residents in the 3 test modes whose diagnoses were correct for ≥70% and ≥80% of the images on the DxEAR. We selected these cutoff points because they seemed clinically meaningful. The relationships parallel those shown in Fig 2. Most of these differences were statistically significant.

We also analyzed the distribution of residents in PGY1 according to changes in the proportions of correct diagnoses from $DxEAR_1$ to $DxEAR_2$. The proportion correct for all diagnoses combined was greater for 69 (77%) of the 90 residents in PGY1, unchanged for 7 (8%), and lower for 14 (16%). The

TABLE 2 Distribution of Residents According to the Proportions of Their DxEAR Diagnoses That Were Correct

Diagnosis	Resident Group and *e*PROM Exposure	*n* (%)	
		≥70% of Diagnoses Correct	≥80% of Diagnoses Correct
All combined	PGY2, no *e*PROM	24 (28.6)	6 (7.1)
	PGY1, before *e*PROM	11 (10.8)	3 (2.9)
	PGY1, after *e*PROM	46 (51.1)	18 (20.0)
AOM	PGY2, no *e*PROM	39 (46.4)	22 (26.2)
	PGY1, before *e*PROM	28 (27.5)	13 (12.7)
	PGY1, after *e*PROM	52 (57.8)	43 (47.8)
OME	PGY2, no *e*PROM	18 (21.4)	7 (8.3)
	PGY1, before *e*PROM	18 (17.6)	7 (6.9)
	PGY1, after *e*PROM	37 (41.1)	21 (23.3)
No effusion	PGY2, no *e*PROM	67 (79.8)	54 (64.3)
	PGY1, before *e*PROM	76 (74.5)	58 (56.9)
	PGY1, after *e*PROM	61 (67.8)	45 (50.0)

corresponding values for AOM were 65 (72%), 7 (8%), and 18 (20%); for OME, 63 (70%), 5 (6%), and 22 (24%); for no effusion, 31 (34%), 11 (12%), and 48 (53%).

Table 3 shows the distribution of diagnoses by PGY1 residents in $DxEAR_1$ and $DxEAR_2$ in relation to the correct diagnosis. As noted earlier, there was general improvement from $DxEAR_1$ to $DxEAR_2$ except regarding the diagnosis of no effusion. In both tests, the patterns of misdiagnosis were the same; of the misdiagnosed images depicting AOM, more were diagnosed as OME than as no effusion; of the misdiagnosed images depicting OME, approximately equal proportions were diagnosed as AOM and as no effusion; of the misdiagnosed images depicting no effusion, more were diagnosed as OME than as AOM.

DISCUSSION

Our findings suggest that exposure to a structured training program such as the *e*PROM curriculum may serve as an effective supplement to conventional clinical training in improving trainees' overall skills in correctly diagnosing otitis media. Our findings seem analogous to those of Kerfoot et al,[5] who found that Internet-based teaching as an adjuvant to clinical experiences significantly and durably enhanced medical students' learning of urology and improved their learning efficiency.

The desirability of a training program on diagnosing otitis media derives from a set of circumstances. First, otitis media is highly prevalent in young children and constitutes the main indication for children's receipt of antimicrobial drugs. Second, the diagnosis of otitis media depends exclusively or mainly on TM findings, as viewed otoscopically, and these findings in young children often are subtle and difficult to interpret.[6,7] Third, a number of studies of both trainees and practitioners showed their otoscopic diagnostic skills to be limited. Pichichero,[8] in a test using 9 videotaped, otoendoscopically obtained examinations (of which 1 depicted AOM) projected onto a large screen, reported mean correct scores of only 41% among 383 pediatric residents and 51% among 2190 practicing pediatricians, and Steinbach et al[9] found only slight to moderate correlations between the clinical diagnostic findings of 27 pediatric residents and those of 2 pediatric otolaryngologists and between the residents' findings and the results of tympanometry. In addition, variability in otoscopic diagnostic acumen does not seem to be limited to the United States.[10,11]

Residency training is a most appropriate venue for focusing on the acquisition of otoscopic diagnostic skills. Varrasso[12] asserted that enhancement of current training in otitis media is an "absolute necessity." Steinbach and Sectish[13] reported, however, that only approximately one half of responding pediatric residency program directors reported offering formal educational programs on this topic. In a cross-sectional study of 141 pediatric residents who were asked to identify only the presence or absence of middle-ear effusion on videotaped ear examinations, Jones et al[4] found no significant differences among the mean total scores of the resident groups (PGY1, PGY2, or postgraduate year 3). This raises questions regarding the optimal timing, ideal frequency, and most advantageous methods of training on otitis media during residency. On the basis of these data, one educational approach could be to implement such training during the first year of resi-

TABLE 3 Distribution of $DxEAR_1$ and $DxEAR_2$ Diagnoses by Residents in PGY1 in Relation to Correct Diagnoses

Correct Diagnosis	Misdiagnosis	Misdiagnosed Images, *n* (%)	
		$DxEAR_1$	$DxEAR_2$
AOM (1800 images)	OME	695 (38.6)	391 (21.7)
	No effusion	180 (10.0)	161 (8.9)
	Total misdiagnosed	875 (48.6)	552 (30.7)
OME (1800 images)	AOM	412 (22.9)	387 (21.5)
	No effusion	493 (27.4)	304 (16.9)
	Total misdiagnosed	905 (50.3)	691 (38.4)
No effusion (900 images)	AOM	84 (9.3)	54 (6.0)
	OME	120 (13.3)	196 (21.8)
	Total misdiagnosed	204 (22.7)	250 (27.8)

dency and include a subsequent "booster dose." Alternatively, assessment of maintenance of skills could be considered in the second (or possibly early in the third) year of residency.

In the present study, in a group of residents early in PGY2 who had received their institution's standard teaching during PGY1, only 62% of the otoscopic diagnoses were correct. This value was somewhat higher than the 55% scored by a group of residents in PGY1 early in their first training year but was somewhat less favorable than the 67% scored by the same group of residents in PGY1 after they had been exposed to *e*PROM. However results were measured, that is, comparisons of overall proportions of correct diagnoses (Fig 2), distribution of residents according to the proportions of their diagnoses that were correct (Table 2), or proportions of residents in PGY1 who improved their scores from $DxEAR_1$ to $DxEAR_2$ (Table 3), *e*PROM seemed to have had a favorable effect in enabling the residents in PGY1 to identify AOM and OME correctly. However, the degree of improvement was limited, and there was no improvement in abilities to identify no effusion correctly. As experience indicates and as is shown in Table 3, differentiating between AOM and OME and between OME and no effusion is inherently more difficult than differentiating between AOM and no effusion. Contributing to limitations in the degree of improvement may be limitations in the extent to which recorded images can faithfully convey the subtleties of color and translucency discernible in actual examinations. Different monitors, as well as individual viewers' perceptions of colors, may lead to visualizations that vary from the true TM color. Variations in perceived color of the TM, however, did not impair the accuracy of final diagnoses made by a group of expert otoscopists who viewed TM images on the same computer monitor (N. S., unpublished data, 2009). Discrimination of subtle differences also may require more practice and feedback than our relatively brief, adjunctive *e*PROM curriculum provided. Finally, it may be speculated that the degree of improvement might have been greater if all of the residents in PGY1 had uniformly taken full advantage of the *e*PROM program, which was designed to facilitate and to complement hands-on teaching in the clinical setting.

The *e*PROM curriculum addresses common limitations of standard training by incorporating an online teaching tool that includes discrimination practice sessions with feedback and associated assessments of diagnostic skills. The curriculum seems applicable not only to trainees and clinical practitioners but also to investigators, by helping to standardize otitis media diagnosis. Freestanding programs such as *e*PROM have a number of advantages. They can be available at all hours and in many locations to fit individual schedules, can provide standardized content of material taught, can provide opportunities for repeated practice, and can reinforce faculty teaching. The educational model represented by *e*PROM also has potential for improving diagnostic skills for other conditions that require repetitive examinations and focused visual or auditory discrimination training (eg, in ophthalmology, dermatology, or cardiology).

The present study has a number of limitations. First, it rests on the assumptions that (1) the conventional training and clinical exposure to otitis media for the residents in PGY2 and the residents in PGY1 during their respective PGY1 terms were comparable; (2) the residents in PGY2 were comparable to the residents in PGY1 in inherent diagnostic skills; and (3) no factors other than conventional training or participation in the *e*PROM program (eg, levels of resident interest or competitiveness) affected the residents' test scores. Second, we had data for resident premodule and postmodule quiz completion but not for actual viewing of the corresponding modules. Because residents could have taken the quizzes without viewing the relevant modules, we could not report on correlations between the number of times and which modules were actually accessed by residents and residents' DxEAR scores. Third, demonstration of the ability to identify findings correctly on an Internet-based test does not guarantee that that ability will be transferred to the clinical setting. Specifically, our Internet-based educational modules prepare learners for what to look for, but how to implement the knowledge gained must be mastered through hands-on instruction and direct clinical experience. Further study could focus on the impact of the training modules in improving clinical competence with actual patients. Finally, because the transmission of high-quality still images and videos requires a high-speed Internet connection and media-playing software, access to the *e*PROM curriculum from all settings may not be possible. DVDs of the training modules, with accompanying proficiency tests, might be used to circumvent this latter limitation.

CONCLUSION

A structured computerized curriculum to supplement standard clinical training can enhance residents' abilities to interpret still and video images of TMs and may improve their skills in diagnosing otitis media.

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