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Teaching Ophthalmoscopy To Medical Students (The TOTeMS Study)

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Abstract

Purpose—To determine medical student preferences for learning the ocular fundus examination and to assess their accuracy using different examination modalities.

Design—Prospective, randomized study of medical student education approaches.

Methods—First-year medical students received training in direct ophthalmoscopy using simulators and human volunteers. Students were randomized to receive vs. not receive specific training on interpreting fundus photographs prior to accuracy assessments. Students' preferences for each of the three methods (direct ophthalmoscopy on simulators or human volunteers, or use of fundus photographs) and recognition of normal and abnormal fundus features were assessed.

Results—Of 138 first year medical students, 119 (86%) completed all required elements. For learning ophthalmoscopy, 85 (71%) preferred humans to simulators. For learning relevant features of the ocular fundus, 92 (77%) preferred photographs to ophthalmoscopy on simulators or humans. Accuracy of answers was better when interpreting fundus photographs than when performing ophthalmoscopy on simulators ($p < 0.001$). Performance improved after specific teaching about assessing fundus photographs before testing ($p = 0.02$). Examination of the ocular fundus was found easier and less frustrating when using photographs than when using ophthalmoscopy on simulators or humans. Eighty-four students (70%) said they would prefer to have fundus photographs instead of using the ophthalmoscope during upcoming clinical rotations.

Conclusions—Students preferred fundus photographs for both learning and examining the ocular fundus. Identification of ocular fundus features was more accurate on photographs compared to examination by direct ophthalmoscopy. In the future, the increasing availability of

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non-mydriatic ocular fundus photography may allow replacement of direct ophthalmoscopy in many clinical settings for non-ophthalmologists.

Keywords

ophthalmoscopy; undergraduate medical education; fundus photography; non-mydriatic retinal camera

INTRODUCTION

Examination of the ocular fundus is critical to the accurate diagnosis of many life- and sight-threatening medical conditions,^{1,2} and there is consensus that all graduating medical students and generalist physicians should be proficient in the fundus examination.³⁻⁵ Standards adopted by the Association of University Professors in Ophthalmology (AUPO) and endorsed by the American Academy of Ophthalmology and International Council of Ophthalmology⁵ specifically require students to be able to visualize the red reflex, the retina, and optic disc, to assess the optic disc for cupping, color, contour, margins, vessels, and edema, and specifically to recognize changes associated with glaucoma and macular degeneration.³ Despite these recommendations the fundus examination is performed infrequently and poorly by students and most non-ophthalmologists.^{1,6,7}

In response to students' lack of proficiency in direct ophthalmoscopy, medical educators have primarily suggested two divergent approaches to the improvement of undergraduate ophthalmology education. Some have attempted intensive, longitudinal ophthalmology training in medical school, but this has failed to produce a meaningful improvement in students' direct ophthalmoscopy skills, and students continued to neglect the fundus examination in their internal medicine clerkships.⁸ As an alternative, others have suggested that students master only basic direct ophthalmoscopy skills and instead focus on learning the signs of clinical ophthalmology emergencies and be aware of other forms of ocular fundus pathology, even those which are not readily detectable by direct ophthalmoscopy.⁹ However, new ocular fundus imaging technologies, such as non-mydriatic ocular fundus cameras provide easy-to-use and reliable alternatives to direct ophthalmoscopy and may allow convergence of these two approaches. By removing the technical challenges of direct ophthalmoscopy, examination of the ocular fundus should be easier and more effective, providing additional time (currently spent on learning how to use the direct ophthalmoscope) to learn key ophthalmologic signs and pathology.

We propose that tomorrow's clinicians may use ocular fundus photography instead of direct ophthalmoscopy for routine ophthalmic screening in appropriate clinical settings, and we sought to explore the integration of digital fundus photography into medical student education.

The aim of our study was to evaluate the capabilities of students to identify major anatomic features of the ocular fundus on eye simulators vs. fundus photographs and to determine student preferences regarding educational techniques (humans vs. eye simulators vs. fundus photographs) and examination methods (direct ophthalmoscopy vs. fundus photography).

METHODS

Study population

This was a prospective, randomized study which was deemed exempt by the Emory University Institutional Review Board. The study was in adherence with the tenets of the Declaration of Helsinki. Participants were all first-year medical students at Emory

University. Inclusion criteria required informed consent, attendance at an introductory eye examination lecture, and a small group skill training session in which students received further eye examination training and practiced direct ophthalmoscopy.

Overview of protocol

First year medical students attended a 45-minute introductory lecture on the eye examination. Subsequent instruction and evaluation was conducted in 2-hour small group sessions. Each group was randomized into one of two training sequences (direct ophthalmoscopy skill training on human volunteers and then on anatomically- and optically-correct eye simulators or vice versa). The groups were then randomized into one of two testing sequences, in which they either received or did not receive specific training on assessing fundus photographs prior to testing their abilities to identify ocular fundus features. Testing and surveys were performed at pre-defined points during the protocol. The protocol is outlined in Figure 1.

Pre-test phase

The introductory lecture for the first year medical school class taught visual pathway anatomy and the screening eye examination, including a short demonstration of direct ophthalmoscopy. Students then completed a 48 item pre-test which collected demographic data and information on prior exposure to ophthalmology; baseline diagnostic skills in interpreting fundus features were also determined by presenting four ocular fundus photographs with questions about the appearance of the optic nerve, retina, and blood vessels (Supplemental Figure 1).

Training sequences

For the remainder of the study, students were assembled in 16 groups of 8–10 students. Each group was taught by an ophthalmology-trained faculty member and training was standardized in each room. Each of the 16 sessions began with five minutes of standardized instruction on how to use the direct ophthalmoscope. Each group was randomized into one of two training sequences (Figure 1). Training sequence 1 consisted of direct ophthalmoscopy skill training on healthy human volunteers (each had one dilated pupil to allow students to practice ophthalmoscopy with and without pupillary dilation) and then on anatomically- and optically-correct eye simulators. Training sequence 2 consisted of direct ophthalmoscopy skill training in the opposite order (eye simulators first, and then volunteers).

Eye simulators were placed in Styrofoam models in the shape of a human head in order to reproduce obstacles to ophthalmoscopy such as the nose and hair (Figure 2). Each eye simulator was constructed with an ocular fundus photograph glued to the inside bottom of a white polyethylene canister (similar to a photograph film canister).¹⁰ A 16-diopter convex lens was inserted in the mouth of the canister in order to reproduce an optically correct eye. A cover with a hole cut for a “pupil” was placed over the lens. Fundus photographs were correctly oriented in the heads to simulate right or left eyes. Each head (including two eye simulators) was accompanied by a printed clinical vignette which presented a short clinical history appropriate to its fundus findings, and included fundus photographs identical to those inside the eye simulators which highlighted important features to identify.

Twenty minutes were allotted for direct ophthalmoscopy training on humans and 20 minutes for the simulators. After each skill training portion, a quality survey was administered. Students were asked to rate, on 10-point Likert scales, ease of viewing the ocular fundus with an ophthalmoscope (10 = easiest), and level of frustration in attempting direct ophthalmoscopy (10 = most frustrated). They were also asked whether lack of time was the

main source of frustration and whether they would spontaneously perform direct ophthalmoscopy routinely during their upcoming clinical clerkships. The quality surveys also included the validated Positive and Negative Affect Schedule (PANAS) consisting of 10 negative and 10 positive mood terms graded on a 5-point Likert response scale to document feelings engendered by the portion of training just completed (Supplemental Figure 2).¹¹ Scores were calculated by a simple sum of the 5-point Likert ratings for each mood term as per the usual method.¹¹ Positive affect scores range from 10–50, with higher scores representing higher levels of positive affect. Negative affect scores also range from 10–50, with lower scores representing lower levels of negative affect.

Testing sequences

The students' small groups were randomized into one of two testing sequences (Figure 1). Testing sequence 1 began with a ten-minute diagnostic training slideshow with instruction on how to determine if a fundus photograph depicted the right or left eye and how to assess basic features of the optic nerve, retina, and blood vessels. Students then completed a simulator post-test and a photograph post-test as well as a quality survey. The simulator post-test consisted of four simulator eyes; for each eye, students were asked if they could visualize anything inside the eye simulator (one of the four eyes was a picture of a vitreous hemorrhage where nothing could be visualized), and were questioned on the appearance of the optic nerve, retina, and blood vessels (Supplemental Figure 3). The photograph post-test consisted of four fundus photographs printed on paper, two of which were identical to fundus photographs in the simulator post-test (Supplemental Figure 4). Fifteen minutes were allotted for each post-test. The post-photograph quality survey asked the same questions as the post-simulator quality survey. In testing sequence 2, students completed the simulator post-test, photograph post-test, and post-photograph quality survey before receiving the diagnostic training slideshow.

Final survey

A final quality survey was administered after all training and testing sequences were complete (Supplemental Figure 5). This quality survey asked which methods students preferred for learning how to use the direct ophthalmoscope (human volunteers vs. eye simulators with clinical vignettes) and for identifying features of the ocular fundus (ophthalmoscopy vs. ocular fundus photographs). It also asked whether they would prefer to use direct ophthalmoscopy or fundus photographs when evaluating a patient during their clinical clerkships, and how often they believed they would attempt to evaluate the ocular fundus over the following year as part of general physical examinations.

Data analysis

Medians and interquartile ranges (IQRs) were reported for continuous data and percentages were reported for categorical data. Statistical analysis was performed using random intercept (for subject, instructor, and day) mixed linear regression models for comparing test scores and one-way analysis of variance with Tukey's post-hoc comparisons for affect scores using R: A Language and Environment for Statistical Computing (R Foundation for Statistical Computing, <http://www.R-project.org>).

RESULTS

Of 138 first year medical students enrolled in the Emory School of Medicine 2016 class, 132 consented to participate in the study and 119 (86%) completed all required elements. Fifty-nine (50%) were women and the median age was 23. Eight students had completed prior courses related to ophthalmology (7 undergraduate and 1 graduate).

Performance accuracy

The pre-test and post-tests (simulator and photograph) each had 48 items. Students answered an average of 28.8 questions correctly on the pre-test (60%). They answered an average of 8.2 additional questions correctly on the simulator post-test (77% correct of 48) and 11.9 additional questions on the photograph post-test (85% correct of 48), both significantly better than the pretest ($p<0.001$). Performance on the post-test was significantly better using fundus photographs compared to simulators ($p<0.001$).

Students who received the diagnostic training slideshow before completing the simulator and photograph post-tests scored an average of 1.7 more responses correctly than students who received the diagnostic training after the post-tests ($p=0.02$). The order of training (human volunteers followed by simulators or vice versa) had no impact on post-test scores (0.38 more questions correct for training on simulators before human volunteers, $p=0.61$).

Student preferences

Student-rated ease and frustration for the different examination modalities (human volunteers, simulators, and photographs) are shown in Figure 3. Limited time was identified as the primary source of frustration in examining human volunteers for 18 students (15%), in examining simulators for 21 students (18%), and on reviewing fundus photographs for one student (1%).

Eighty-five students (71%) preferred human volunteers to simulators for learning to use the direct ophthalmoscope, and 92 (77%) preferred photographs to simulators for learning the features of the ocular fundus. When given the choice between using the direct ophthalmoscope or directly looking at fundus photographs to assess the ocular fundus, 84 (70%) indicated a preference for fundus photographs. Forty-nine percent of students indicated that they would attempt direct ophthalmoscopy forty percent of the time or less as part of a general physical examination during clinical encounters over the next year.

Positive and negative affect

Positive affect scores were highest for training on human volunteers (mean 31.5) compared to 28.9 for simulators and 25.9 for photographs (all $p<0.001$). Higher positive affect scores reflect more pleasurable engagement. Negative affect scores were highest for training on human volunteers (mean 13.8), compared to 13.2 for simulators ($p<0.03$) and 12.1 for photographs ($p<0.001$ vs. human volunteers and $p=0.001$ vs. simulators). Higher negative affect scores reflect negative activation, such as irritability.

DISCUSSION

We found that first year medical students were significantly more accurate at identifying ocular fundus features using fundus photographs than when looking at the ocular fundus of simulators with a direct ophthalmoscope. This better performance was obvious even for the group of students who did not receive specific training in fundus photography. Not surprisingly, specific teaching regarding assessment of fundus photographs resulted in additional improvement in student capability. Additionally, 70% of students indicated a preference for fundus photographs over direct ophthalmoscopy.

Our results suggest that direct ophthalmoscopy may be underutilized primarily because of technical barriers, despite widespread acknowledgement that the ocular fundus examination is a key component of the general physical examination. Numerous studies have documented the underuse of direct ophthalmoscopy. In one study, for example, third-year American medical students attempted direct ophthalmoscopy only 11% of the time a fundus

examination was clinically indicated.¹² In a survey of physicians practicing general and geriatric medicine in a hospital setting, all felt that ophthalmoscopy was important but only three of 72 performed it routinely. Half of these physicians indicated they would perform ophthalmoscopy for patients with diabetes, hypertension, visual impairment, and neurologic symptoms, but on review of 100 case notes, ophthalmoscopy was documented on only three patients; nine with diabetes and 35 with hypertension had no ophthalmoscopy reported.⁷ In a study of pediatric physicians at a university-affiliated hospital, nine of 11 residents and one of five senior physicians responded “one to three times” and the rest said “never” when asked how many times they had examined an ocular fundus during the last year.¹ In a study of the feasibility of nonmydriatic fundus photography in the emergency department (FOTO-ED study), only 14% of patients with conditions for which ophthalmoscopy is considered important, such as headache or acute visual change, had direct ophthalmoscopy performed by emergency room physicians.⁶ In a study asking patients to recall being examined with use of a tendon hammer, ophthalmoscope and stethoscope, nearly half of patients could not recall having ophthalmoscopy performed, while 95.7% recalled being examined with a stethoscope.¹³

These and related studies have not only shown infrequent direct ophthalmoscope use, but also poor performance when the ophthalmoscope is used. Indeed, most primary care interns are unable to perform an adequate screening eye examination at the start of their post-graduate training. In a survey of program directors for 135 American family practice, internal medicine and pediatrics residency programs, nearly 90% of program directors believed that less than 50% of their entering residents met the standard set by the AUPO for a minimal level of competence expected when dealing with ophthalmologic problems.¹⁴ Furthermore, in another study, hospital internists correctly diagnosed ocular fundus abnormalities less than 50% of the time using direct ophthalmoscopy.⁷ In the FOTO-ED study, emergency department physicians failed to recognize relevant ocular fundus abnormalities each time they attempted to use the ophthalmoscope.⁶ Given the limited capabilities of most trainees and physicians with direct ophthalmoscopy, it is not surprising that they also lack self-assurance in performing this skill. In fact, 47% percent of medical student clerks at one Canadian university expressed minimal confidence in their ability to use direct ophthalmoscopy to examine the ocular fundus through an undilated pupil,¹⁵ and 43% of general practitioners surveyed in Great Britain lacked confidence in using the direct ophthalmoscope.¹⁶

Recognizing the poor accuracy and lack of confidence in performing direct ophthalmoscopy, a variety of approaches have been attempted to improve ophthalmoscopy education. A change in the past decade included the creation of the PanOptic ophthalmoscope which provides a wider field of view and may be easier to use than the classic direct ophthalmoscope. However, only a minority of students and practitioners are routinely using this more cumbersome device, and this is why we chose to perform our study with the classic direct ophthalmoscope only. In an assessment of third-year medical student performance of direct ophthalmoscopy, only 32% of students accurately described at least one feature of the optic disc, such as cup, color or margins; this rose to 84% in fourth-year students after ophthalmology retraining.¹² In another study, supplemental formal instruction in ophthalmoscopy resulted in improved performance by medical students compared to their peers and the increased competency persisted when reassessed two months later.¹⁷ However, these types of short term gains were not sustained during a more intensive program, which implemented a longitudinal curriculum for ophthalmic screening examination skills across three years of medical school, with skill retention declining about six months after reinforcement in the curriculum.⁸ In an internet-based assessment of ophthalmoscopy skills, medical students were tested on identifying the optic disc of one of their colleagues from an array of 15 fundus photographs.¹⁸ Another group also attempted to

improve direct ophthalmoscopy by providing their students with an ocular fundus photograph of one of their peers whom they were challenged to identify via direct ophthalmoscopy; this encouraged practice of direct ophthalmoscopy with detailed observation of ocular fundi during their rotation and 84.3% of the students trained in this manner were able to identify a peer's optic nerve photograph vs. only 28.6% of students in the control group.¹⁹ However, no longitudinal follow-up was provided.

In our study, positive affect scores were highest for training on human volunteers, reflecting pleasurable engagement and interest in the activity. Interestingly, negative affect scores were also highest for training on human volunteers compared to use of simulators or fundus photographs, likely a reflection of the higher frustration level and greater perceived difficulty of learning on humans. Overall, however, students preferred human volunteers to simulators for learning how to use the direct ophthalmoscope. The fact that viewing ocular fundus photographs had the lowest scores for both positive and negative affect (with the human-like simulators in the middle) may reflect the paucity of overall emotional response engendered by an inert subject such as simulators.

Although ocular fundus photographs produced little affective change, students in the current study reported that among the examination modalities used, they experienced the greatest ease and least frustration with ocular fundus photographs. The majority of students also preferred fundus photographs for learning features of the ocular fundus and for patient evaluation.

The increasing use of nonmydriatic fundus photography outside of ophthalmology suggests that digital photography may emerge as an alternative diagnostic method to direct ophthalmoscopy. Indeed, the FOTO-ED study showed that non-physician emergency department staff could be trained to obtain high-quality fundus photographs using a commercially available nonmydriatic ocular fundus camera, and that both patients and staff rated the technique as both comfortable and expeditious.²⁰ It also showed, similar to the present study, that providing ocular fundus photographs to emergency department physicians, even without additional training in the interpretation of ocular fundus findings, resulted in substantial improvements in the recognition of ocular fundus findings compared to direct ophthalmoscopy, and in the rate of routine ocular fundus assessment.²¹ However, although ocular fundus photography remains difficult for patients who are unable to cooperate, advances in technology are already beginning to provide opportunities to assess this subset of patients at bedside. Nevertheless, we believe that medical students, our future physicians, would likely be better served if educators were able to incorporate ocular fundus photograph interpretation as an important component of their ophthalmology curriculum.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Study protocol and student flow for teaching ophthalmoscopy to medical students
 Students attended an introductory lecture followed by a pre-test and were then randomized into one of two training sequences and one of two testing sequences. Quality surveys were conducted after each training and testing section. Skill training with human volunteers and simulators required direct ophthalmoscopy.

Figure 2. Patient simulator with optically-correct “eyes” used to teach ophthalmoscopy to medical students

(Left) Styrofoam model in the shape of a human head. (Middle) Ocular fundus photograph at the base of a plastic canister. (Right) Canister for optically-correct eye containing a 16-diopter convex lens capped with a cover containing a hole cut to simulate the pupil.

Figure 3. Student-rated ease and frustration on 10-point Likert scales for different modalities of ocular fundus examination used by medical students

(Left) Median ease (10=easiest) of examination was 5 for human volunteers (interquartile range 3–7), 7 for simulators (5–8) and 9 for photographs (8–10). (Right) Median frustration level (10=most frustrated) was 4 for human volunteers (2–6), 3 for simulators (2–5) and 2.5 for photographs (2–5).