TEACHING TIP

New Direct and Indirect Ophthalmoscopy Teaching Methodology for Veterinary Doctors

Thiago Goncalves dos Santos Martins ■ Paulo Schor ■ José Augusto Stuchi ■ Susan B. Fowler

ABSTRACT

Ophthalmic diseases can reflect the presence of systemic disease in animals. Thus, specialists in veterinary medicine must master the technique of fundus examination. To aid in the acquisition of this skill, we developed a teaching methodology using a low-cost model that students can build themselves and a device that allow for the examination of the animal's retina to teach the techniques of direct and indirect ophthalmoscopy in veterinary medicine.

Key words: optics, ophthalmology, ophthalmoscope, teaching method

RESUMO

As doenças oftalmológicas podem refletir a presença de doenças sistêmicas em animais. Assim, os especialistas em medicina veterinária devem dominar a técnica do exame de fundoscopia. Para auxiliar na aquisição dessa habilidade, desenvolvemos uma metodologia de ensino utilizando um modelo de baixo custo que permite o exame da retina para ensinar as técnicas de oftalmoscopia direta e indireta em medicina veterinária.

Palavras-chave: ótica, oftalmologia, oftalmoscópio, método de Ensino

This translation was provided by the authors. To view the full translated article visit: https://doi.org/10.3138/jvme-2020-0089.pt

INTRODUCTION

Abnormalities found in routine ophthalmic examination may reflect the presence of treatable systemic diseases in animals, leading to early diagnosis and treatment. Because of animals' inability to communicate and the absence of marked ophthalmologic signs in most animals, periodic examinations are important to assess for and detect potential health conditions.[1]

Veterinary ophthalmological examinations aim for the early diagnosis and treatment of ophthalmic and systemic diseases, but they are difficult to perform effectively.[2] Over the years, several studies have shown a high incidence of eye problems in animals, mainly associated with their increased life expectancy.[3] Dogs have one of the highest prevalences of ophthalmic diseases, compared with other species, including cats and livestock species.[4]

Ophthalmoscopy is one of the most difficult routine veterinary procedures.[5] Not all dogs require an eye examination, but it should be performed on all animals that have visual disturbances or systemic disease with ocular involvement.[6] It is important to highlight that, compared with other animals, dogs have a large number of variations in the normal aspect of ophthalmic exams that make it harder to learn how to perform and correctly interpret such examinations.[7–9] For example, in assessing an animal's retina, the veterinarian should observe vascular changes and the size and color of the optic disc, but the variation among dogs makes it difficult to learn about and diagnose ophthalmological changes.[5–10]

Traditionally, two methods are used to examine the fundus: direct ophthalmoscopy and indirect ophthalmoscopy.[6] Indirect ophthalmoscopy provides a wider field of view than direct ophthalmoscopy. In clinical ophthalmology, direct and indirect methods complement one another, making the mastery of both methods important in ophthalmological research.[11]

DIRECT OPHTHALMOSCOPY

The direct ophthalmoscope was developed in 1850 by Hermann von Helmholtz.[12] The invention of the direct ophthalmoscope helped establish an important connection between ophthalmology and other medical specialties. Direct ophthalmoscopy is the modality with which veterinarians are most familiar.[5]

The basic principle of direct ophthalmoscopy is a light source directed to the eye and a viewing hole, with a circular series of convex and concave lenses (in diopters) that serve to focus the retinal image. The device enables the examiner to view the inner surface of the eye at a magnification of 15 times in a restricted field of view of 10°–15°, but it makes it difficult to assess the periphery of the retina.[2] The device has lenses that will correct the refractive error of the animal's eye. The examiner uses only one eye during the examination, which does not allow an evaluation of three dimensions of the retina.[13]

The direct ophthalmoscope is called that because it provides a direct and vertical image of the fundus instead of a virtual and inverted image, such as that provided by the indirect ophthalmoscope.[11] In human patients, direct ophthalmoscopy can provide a good examination of the retina. However, in veterinary medicine, the small field of view often means that areas of the peripheral retina are not usually examined.[6] Ideally, to avoid interference between the examiner and the animal's nose, the examiner's right eye is used to examine the animal's right eye, and vice versa. Examination should be performed as close as possible to the animal's eye to reveal a larger area of the retina. In addition, 10- and 20-diopter lenses can be used to obtain a better view of the lens, cornea, and adnexa.

One of the difficulties inherent in veterinary ophthalmoscopy is the animal's lack of cooperation and constant movement, which frequently causes the image of the fundus to be lost. The quickest method to regain alignment with the animal's pupil is to move back to the initial 25–30 centimeters to locate the retinal reflex. The alignment of the light source is critical because the retina is seen only when the illuminated area and observed retinal area of the fundus coincide. The examination may be hampered by opaque media, such as cataracts, corneal opacity, and vitreous hemorrhages.

INDIRECT OPHTHALMOSCOPY

Indirect ophthalmoscopy uses an appropriate light source and a convex lens (typically 20–30 diopters) placed between the examiner's eye and the animal's eye, with the formation of an inverted virtual image of the ocular fundus.[5] This examination modality provides a magnification of 3.5 times, and because both of the examiner's eyes are being used, depth perception is possible.

Magnification depends on the focal length or dioptric power of the lens. Higher powered lenses provide a wider field of view but a less enlarged image.[6] With the lenses normally used in veterinary medicine, indirect ophthalmoscopy involves a magnification always less than and a field of view larger than that achieved with direct ophthalmoscopy. Therefore, in routine consultation indirect ophthalmoscopy is the preferred method for examining the ocular fundus of the dog or cat because it allows the examination of a larger area of the retina and is thus faster and more complete.[14]

As noted, the image produced by indirect ophthalmoscopy is inverted, which can initially make it harder to precisely locate possible lesions.[15] The lens must be held with the thumb and index finger, leaving the other fingers free to move the animal's eyelid. The convex surface must face the viewer to obtain the best image. The positioning of the lens is the most important part of the technique, and the axis of the lens must be at the same level as the animal's pupil. The lens should be positioned parallel to the iris and without tilting to obtain an image of the retina. The back of the eye appears as a virtual image in front of the lens, and the image appears inverted.[14] To adequately perform indirect ophthalmoscopy, it is important that the room be dark and the pupils well dilated. The procedure may require help from other people who can hold the animal and stabilize its head while the examiner manipulates the lens and light source. For this reason, some veterinarian ophthalmologists consider it important that students be able to perform direct ophthalmoscopy because the direct ophthalmoscope is widely available and easier to use when help to hold the animal is not available.

To avoid an underdiagnosis of ophthalmic diseases, largely as a result of the lack of perception on the part of the animal's owner but also because of veterinarians' lack of observation during routine consultations, we decided to create a study methodology to teach veterinarians about the physical principles of direct and indirect ophthalmoscopy examination, in addition to the use of devices with different degrees of difficulty.

Stage 1: Development of the Teaching Model

Use of a Teaching Model

The use of teaching models began in the Roman era for training military personnel. In the modern era, the use of simulators is very common in training pilots and has been used more and more in the teaching of medicine.[16] There are countless types of simulation, such as mannequins, based on computation and virtual reality. To improve the understanding of the physical aspects of and training in the fundus examination, we encourage the construction of a low-cost model. The use of simulation techniques allows students to acquire varied skills, repeating the diagnostic procedure as many times as necessary until they reach the mastery stage. Instructors can observe the execution of the task so that the necessary corrections are made immediately, and students receive direct assessment of their performance. The simulated reality allows learners to develop skills at their own pace, and it does not restrict the experience to regular class periods, thus allowing students to have greater interaction with the model and each other and actively participate in training. The use of simulators is important not only for teaching veterinary medicine students but also for continuing medical education of currently practicing vets. The use of simulators reduces the risk of complications during visits.[17,18] During simulated training, instructors can define the skills they want students to have knowledge of and students can demonstrate the progress they have made before they train with animals.

The model we developed simulates an eye and can be built by anyone at low cost. It consists of a transparent acrylic sphere, simulating the ocular lenses (cornea and lens), that is placed inside a cardboard box with an opening that simulates the pupil. Photographs placed behind the acrylic sphere simulate retinal lesions. Different images can be placed in the model, and pupil size can also be varied according to need (Figure 1).

The light from the ophthalmoscope that penetrates the model undergoes refraction on an internal face of the acrylic sphere, converging to a single point at which the high-definition (900-dpi) 1-square-centimeter retinal photograph is placed for training. Openings of 3–5 millimeters in the cardboard box are used to simulate different pupil sizes. The small pupillary opening limits the spherical aberration of the model, providing the image of a photograph placed in the focal plane of the sphere to simulate the retina. Acrylic spheres with less transparency can also be used to simulate cataracts and corneal lesions (Figure 2).

Before building and training with the model, students attend a lecture on the anatomy of the eye and the principles of direct and indirect ophthalmoscopy examination. In initial training with the model, the student identifies a six-digit numerical sequence behind the sphere, using pupils of different sizes (3.4 and 5 mm; Figure 3). The teacher asks the student to write down the sequence of numbers, which allows the teacher to ensure that the student is performing the examination correctly. The numerical sequences also showcase that examination performed with the direct ophthalmoscope has no inversion and has a larger increase in the size of images than examination performed with the indirect ophthalmoscope. Consequently, the student understands the main physical principles of the exam, and the teacher is able to provide immediate feedback on learning, correcting the student's difficulties before training with animals.

After this stage, students identify different retinal lesions from photographs placed inside the model. The reduced-size color fundus photographs are obtained from real animals to offer a more realistic learning opportunity. This training methodology prompts students to compare the model with the actual exam they perform with real animals. The student can repeat this procedure on different days to promote the retention of knowledge. During training, the teacher can record and compare the time spent by students and the correctness of numerical sequences and identification of retinal pathologies.

The model allows students to understand the physical principles of examination and to train with increasingly difficult cases. Difficulty levels can be simulated with opacity of different media and pupil sizes. Although there are more sophisticated models of teaching, the goal of the training model is to provide

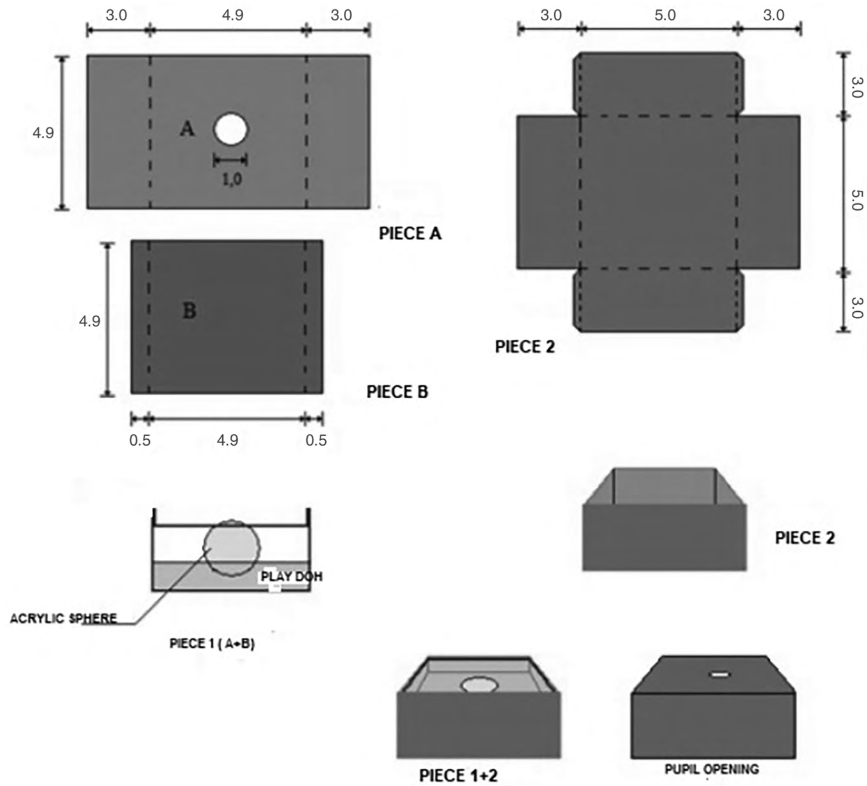

Figure 1: The model, built with cardboard, modeling compound, and an acrylic sphere; the modeling compound is used to hold the acrylic sphere in place

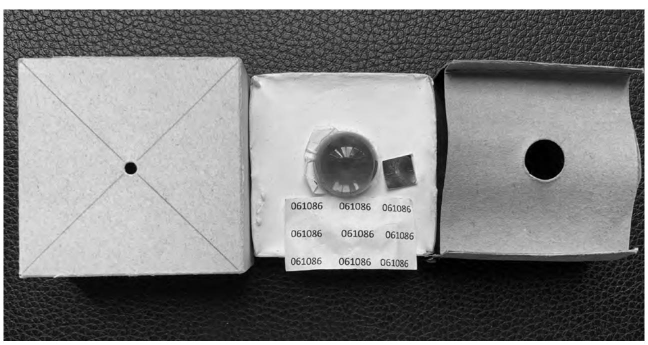

Figure 2: Direct and indirect ophthalmoscopy teaching model; numeric sequences or reduced retinographies from real animals can be placed in the back of the sphere

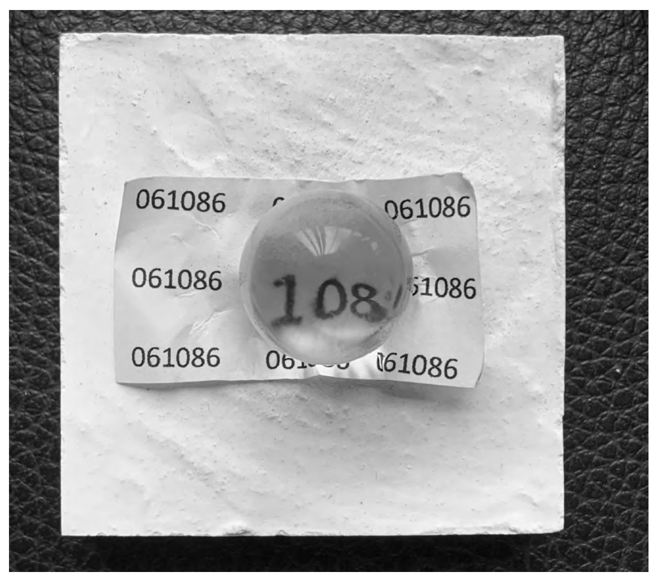

Figure 3: Acrylic sphere and numerical sequence used for learning

a low-cost resource with increasing levels of difficulties before training with animals.

Students should practice and repeat training with the model until they feel safe to proceed to the next stage of training with animals. Training is important to achieve greater sensitivity and specificity in the ophthalmoscopic exam. During this training phase, students have the opportunity to manipulate the direct and indirect ophthalmoscopes and become more familiar with them before training with animals.

One of the important principles of this training phase is that students build the model and train with it. The act of building the model enables the student to understand the physical principles of direct and indirect ophthalmoscopy examination, which is essential for clinical application of the examination. Using a model increases students' participation in the learning process. The use of simulation techniques allows students to acquire varied skills and to repeat the diagnostic procedures as many times as necessary until they reach the mastery stage. This form of training encourages student confidence in group training, and the teacher acts as a facilitator in the formation of knowledge, stimulating students' creativity.

Stage 2: Direct and Indirect Ophthalmoscopy Training With Animals

After completing the training phase with the model, students can begin training for direct and indirect ophthalmoscopy exams with animals. They may return to stage 1 training if they still have difficulty performing the procedure (Figures 4 and 5).

Stage 3: Use of a Portable Retinography Device for Retinal Examination and Diagnostic Confirmation

Students can also confirm that the retinal changes observed in the animal have been correctly identified by performing an examination with a portable fundus camera. This allows the teacher to discuss aspects of the exam with students (Figure 6).[18]

The portable fundus camera allows examination of the animal's retina without the need for pupil dilation, reducing the discomfort of animals used in training. It allows examiners to take photographs with a wide field of view (45°). The device can be coupled with a smartphone, facilitating the sharing of information during training. The data used in the training can be stored in the cloud and accessed outside the students' college environment. The portable fundus camera provides high-quality images that can be printed and reduced for use in training with the model. The use of real images in the model allows them to be compared with real animals during training (see Figure 7).

DISCUSSION

The teaching methodology described demonstrates a progressively increasing level of difficulty to further students' skills before they carry out animal exams. The level of difficulty can be adjusted by simulating pupils of different sizes, simulating media opacity with acrylic spheres with less transparency, and using numerical sequences and images to simulate retinal lesions inside the model.

Constructing their own model is useful in aiding students' understanding of the physical principles of the direct and indirect ophthalmoscopy examinations. In the case of indirect

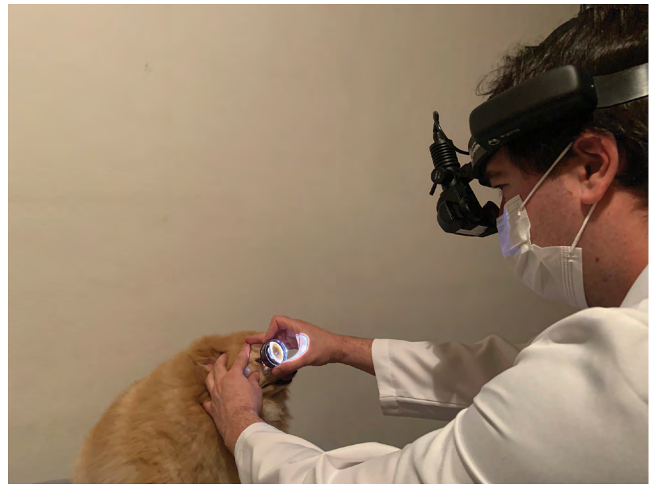

Figure 5: Indirect ophthalmoscopy exam

Figure 6: Portable fundus camera used in training

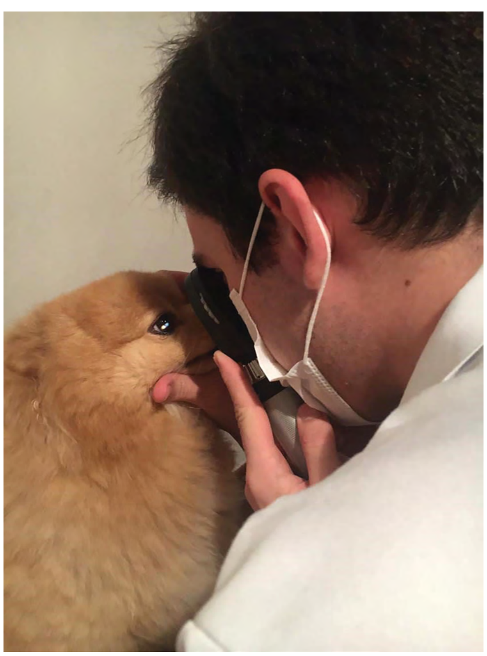

Figure 4: Direct ophthalmoscopy exam

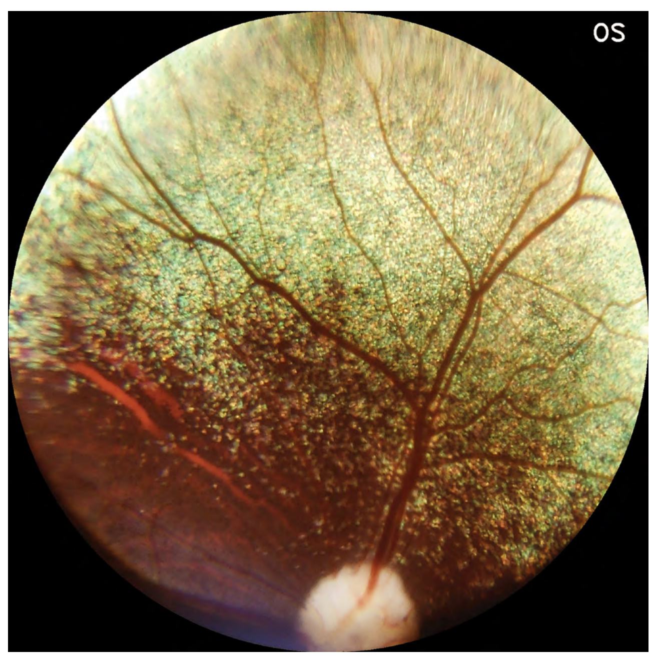

Figure 7: Retinography of a dog captured with the portable device (Phelcom's retinal camera)

ophthalmoscopy examination, it also demonstrates the increase in image size and the inversion of the numerical sequences, which facilitates understanding the exam and the anatomical description of the lesions. Different high-definition (900-dpi) images of the retina can be used in the model to simulate different retinal pathologies. The model can be made more realistic by using reduced-size images from retinography of animals that the student will examine.

The low cost allows students to build and have their own model and to train outside the college environment, thus accelerating and reinforcing learning. The construction of the model increases student interaction with practical learning and allows the instructor to obtain immediate feedback on the student's learning progression. However, training outside the academic environment may be limited if students do not have access to the direct ophthalmoscope.

The use of models is not a substitute for training with animals, but it reduces unnecessary exposure of animals to elementary training. Animals can, therefore, be used by students with more advanced levels of technical knowledge. Knowledge of eye anatomy and the limited field of view during the exam facilitates sequential training on animals with decreased anxiety.

The portable fundus camera gives students a better idea of what they may find when performing an examination with the direct and indirect ophthalmoscopy devices. The portable fundus camera can also be used for telemedicine. The images captured using the device can be discussed by specialists in other locations. Capturing animal images may aid in the development of artificial intelligence algorithms that can be used in the future to assist in the diagnosis and monitoring of eye diseases in dogs. The use of the fundus camera facilitates the acquisition of images that can be used in student training, but it also increases the cost of the training process. However, not every student needs access to a fundus camera. Images can always be printed and made available to students. The use of training models allows for better animal welfare because of reduced errors and unnecessary procedures. The portable fundus camera allows several students to follow the exam at the same time, reducing exposure and stress on the animal.

Strengths and Limitations of the Study

Construction of the low-cost model has been tested by medical school students and has shown good results. The model is easy to construct and provided greater student involvement in the learning process.[13] Most students said that the activity was enjoyable and increased their interest in the subject. Training with the model was important in reducing anxiety and retaining knowledge. Other models for teaching direct ophthalmoscopy to veterinary students have already been described.[19,20,21]

However, the objective of this teaching methodology is the association of a low-cost model with a new portable retinography technology that captures retinal images, allowing for virtual consultations and database building. Constructing the model enabled students to learn the physical principles of direct and indirect ophthalmoscopy. The model's pupil sizes can be varied to create different levels of difficulty. The use of numerical sequences during the training process is a simple way to show students that images are not reversed in direct ophthalmoscopy and are reversed in indirect ophthalmoscopy.

The use of the portable fundus camera during the training allows students to follow the exam in real time on a smartphone screen, and it allows the capture of images of animals' retinas that can be discussed during classes with multiple students.

This teaching methodology stimulates students' active participation throughout the teaching process, from model construction to use of a portable fundus camera that provides immediate feedback. The model's applicability should be tested in clinical studies with veterinary medicine students from different universities. The low cost supports the model's application in several types of medical schools and enables each student to have his or her own training model.

CONCLUSION

Veterinary medicine is a complex field that requires knowledge of ophthalmological health because eye abnormalities can be an indicator of other diseases. The use of a low-cost, easy-to-implement model that facilitates learning about direct and indirect ophthalmoscopy supports the correct and early diagnosis of diseases that can threaten animals' vision and life.

Taking advantage of a teaching method that encompasses practical tutorials oriented by problems and less focus on traditional classes allows for synchronization of course content with students' practical experience, increasing students' ability to learn independently. The use of a portable fundus camera allows students to follow the exam in real time. The images captured can be used in the model, allowing a more realistic simulation. The images can be sent to specialists in other locations, allowing students to use the benefits of telemedicine in learning. Continuous reassessment of the teaching curriculum is essential for efficacious veterinary training. In the future, simulators can be used for certification and accreditation, in addition to ascertaining the knowledge of doctors who want to update their knowledge of ophthalmology.

ACKNOWLEDGMENT

Otaviano Helene and Rufino Silva helped in the study.

FINANCIAL SUPPORT

This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior—Brasil (CAPES), Finance Code 001.

CONFLICT OF INTEREST

José Augusto Stuchi currently works as a managing partner and engineer at Phelcom Technologies.

DISCLOSURE

José Augusto Stuchi currently works as a managing partner and engineer at Phelcom Technologies.

AUTHOR CONTRIBUTION

All authors conceived the study and led the data interpretation. All authors read and approved the final manuscript.

REFERENCES

1 Munger RJ. Veterinary ophthalmology in laboratory animal studies. Vet Ophthalmol. 2002;5(3):167–75. https://doi.org/10.1046/j.1463-5224.2002.00243.x. Medline:12236867
2 Williams DL. Welfare issues in farm animal ophthalmology. Vet Clin North Am Food Anim Pract. 2010;26(3):427–35. https://doi.org/10.1016/j.cvfa.2010.08.005. Medline:21056793
3 Gelatt KN, Gilger BC, Kern TJ. Veterinary ophthalmology. Ames (IA): Wiley; 2013.
4 Westermeyer HD, Druley GE, Royal KD, Mowat FM. Use of a versatile, inexpensive ophthalmoscopy teaching

model in veterinary medical student education increases ophthalmoscopy proficiency. J Vet Med Educ. 2019;46(4):518–22. https://doi.org/10.3138/jvme.1117-157r. Medline:30920947

5 Balicki I, Nestorowicz N, Ofri R. Funduscopic abnormalities and electroretinography in cases of retinopathy in German Shepherd dogs. Vet Ophthalmol. 2013;16(6):397–408. https://doi.org/10.1111/vop.12007. Medline:23240613

6 Bunel M, Chaudieu G, Hamel C, et al. Natural models for retinitis pigmentosa: progressive retinal atrophy in dog breeds. Hum Genet. 2019;138(5):441–53. https://doi.org/10.1007/s00439-019-01999-6. Medline:30904946

7 Heider HJ. Retinadiagnostik bei Hund und Katze [Diagnosis of retinal diseases in dogs and cats]. Tierarztl Prax. 1994;22(5):484–96.

8 Karlstam L, Hertil E, Zeiss C, et al. A slowly progressive retinopathy in the Shetland Sheepdog. Vet Ophthalmol. 2011;14(4):227–38. https://doi.org/10.1111/j.1463-5224.2010.00866.x. Medline:21733063

9 Hertil E, Bergström T, Kell U, Karlstam L, Ekman S, Ekesten B. Retinal degeneration in nine Swedish Jämthund dogs. Vet Ophthalmol. 2010;13(2):110–6. https://doi.org/10.1111/j.1463-5224.2010.00761.x. Medline:20447030

10 Glaze MB. Ophthalmic disease and its management. Vet Clin North Am Small Anim Pract. 1997;27(6):1505–22. https://doi.org/10.1016/S0195-5616(97)50136-7.

11 Stiles J. Veterinary ophthalmology. Preface. Vet Ophthalmol. 2011;14(Suppl 1):1. https://doi.org/10.1111/j.1463-5224.2011.00942.x.

12 Dos Santos Martins TG, Schor P, de Azevedo Costa AL. Teaching ophthalmoscopy to medical students (the TOTeMS Study). Am J Ophthalmol. 2014;157(6):1329–30. https://doi.org/10.1016/j.ajo.2014.02.047. Medline:24881847

13 dos Santos Martins TG. Modelo para o ensino da oftalmoscopia direta. Rev Bras Ensino Fís [Internet]. 2014 [cited 2020 May 26]; 36(2):1–8. Available from: http://www.scielo.br/scielo.php?script=sci_arttext&pid=S1806-11172014000200003&lng=en&nrm=iso>. https://doi.org/10.1590/S1806-11172014000200003.

14 Martins TG, Costa ALF, Helene O, Martins RV, Helene AF, Schor P. Training of direct ophthalmoscopy using models. Clin Teach. 2017;14(6):423–6. https://doi.org/10.1111/tct.12641. Medline:28401735

15 Lantz PE. A simple model for teaching postmortem monocular indirect ophthalmoscopy. J Forensic Sci. 2009;54(3):676–7. https://doi.org/10.1111/j.1556-4029.2009.01030.x. Medline:19432744

16 Rai AS, Rai AS, Mavrikakis E, Lam WC. Teaching binocular indirect ophthalmoscopy to novice residents using an augmented reality simulator. Can J Ophthalmol. 2017;52(5):430–4. https://doi.org/10.1016/j.jcjo.2017.02.015. Medline:28985799

17 Izard SG, Juanes JA, García Peñalvo FJ, Estella JMG, Ledesma MJS, Ruisoto P. Virtual reality as an educational and training tool for medicine. J Med Syst. 2018;42(3):50. https://doi.org/10.1007/s10916-018-0900-2. Medline:29392522

18 Crofts JF, Bartlett C, Ellis D, Hunt LP, Fox R, Draycott TJ. Training for shoulder dystocia: a trial of simulation using low-fidelity and high-fidelity mannequins. Obstet Gynecol. 2006;108(6):1477–85. https://doi.org/10.1097/01.AOG.0000246801.45977.c8. Medline:17138783

19 Pires R, Avila S, Wainer J, Valle E, Abramoff MD, Rocha A. A data-driven approach to referable diabetic retinopathy detection. Artif Intell Med. 2019;96:93–106. https://doi.org/10.1016/j.artmed.2019.03.009. Medline:31164214

20 Williams DL, Wager C, Brearley J. Student attitudes regarding the educational value and welfare implications in the use of model eyes and live dogs in teaching practical fundus examination: evaluation of responses from 40 students. Open Vet J. 2016;6(3):172–7. https://doi.org/10.4314/ovj.v6i3.5. Medline:27822453

21 Nibblett BM, Pereira MM, Williamson JA, Sithole F. Validation of a model for teaching canine fundoscopy. J Vet Med Educ. 2015;42(2):133–9. https://doi.org/10.3138/jvme.1014.100R. Medline:25769909

AUTHOR INFORMATION

Thiago Goncalves dos Santos Martins, MD, is Ophthalmologist, Department of Ophthalmology, Federal University of Sao Paulo, Botucatu Street, 821 Vila Clementino, São Paulo 04023-062, Brazil. Email: thiagogsmartins@yahoo.com.br. His interests include teaching, medical education, ophthalmology, telemedicine, and artificial intelligence.

Paulo Schor, MD, is Ophthalmologist, Department of Ophthalmology, Federal University of Sao Paulo, Botucatu Street, 821 Vila Clementino, São Paulo 04023-062, Brazil. His interests include teaching, medical education, ophthalmology, telemedicine, and artificial intelligence.

José Augusto Stuchi, BS, MS, is Managing Partner and Engineer, Phelcom Technologies, José Missali Street 820, Planalto Paraíso, São Carlos-SP 13562-060, Brazil. He has experience in software and firmware development, signal and image processing, computer vision, machine learning, business management, and marketing.

Susan B. Fowler, PhD, RN, CNRN, FAHA, is Nurse Scientist, Orlando Health, 1335 Sligh Boulevard, Orlando, FL 32806; Editor, *Insight—The Journal of the American Society of Ophthalmic Registered Nurses;* Contributing Faculty, Walden University, Minneapolis, MN; and Mentor, W. Cary Edwards School of Nursing, Thomas Edison State University, Trenton, NJ. Email: njfowlers761@msn.com.