

Telemedical Strategies for Glaucoma

Advances in technology are helping ophthalmologists expand their diagnostic and therapeutic boundaries.

BY LOUIS R. PASQUALE, MD

Teleglaucoma is an emerging branch of teleophthalmology, which in turn is a subdivision of telemedicine. The Greek prefix *tele* in all of these terms means distance. Teleglaucoma therefore broadly encompasses the evaluation and treatment of IOP-related diseases of the optic nerve among patients in remote locations. This subspecialty care might include screening, diagnostic testing, the monitoring of IOP, and strategies for managing glaucoma (ie, the possible delivery of medical and surgical care). In addition, teleglaucoma facilitates collaborative research.

Rapid advances in technology are allowing glaucoma specialists to deliver, in real time or in a store-and-forward fashion, services and care that were previously available only through face-to-face interactions.

EVOLVING TECHNOLOGY

More than a decade ago, when I lectured primary care providers about general ophthalmology, I advised them never to diagnose or treat a red eye over the phone. I explained that the differential diagnosis for a red eye is sufficiently broad that an exclusively oral historical review would not provide the information they needed to deliver effective care.

Times have certainly changed. We now have access to versatile computers, digital imaging systems, postprocessing software, and sophisticated telecommunications technology that allow us to evaluate information transmitted from remote locations in the context of a preexisting electronic medical record (EMR). This technology has transformed a phone line into a veritable goldmine of medical information by enhancing our ability to render ophthalmic diagnoses and recommend a course of action from remote locations.

We are all familiar with catchy phrases like *film is cheap* and *a picture is worth a thousand words*. Today, however, a digital image of an optic nerve is literally

worth about 1 MB. When one considers Moore's law, which states that the number of transistors that can be readily placed on an integrated circuit doubles every 2 years, 1 MB does not take up a lot of space on a computer's hard drive. Although Gordon E. Moore, the cofounder of Intel Corporation (Santa Clara, CA), first described his law in 1965, his observation holds true today, and the trend is expected to continue through 2010 and beyond.

Through dedicated planning and the management of resources, ophthalmologists have used telemedicine to enhance eye care. Most successfully, retina specialists have created screening programs for diabetic retinopathy¹ and retinopathy of prematurity.²

TECHNICAL NECESSITIES

To get the field of teleglaucoma off the ground, ophthalmologists need telemedical technologies that provide stereopsis for assessing the excavation of the neuroretinal rim, red-free filters to detect dropout in the retinal nerve fiber layer (RNFL), and online tools to measure/grade glaucomatous cupping of the optic disc. Several imaging devices are currently available, including the ARIS (Automated Retinal Imaging System; Visual Pathways, Prescott AZ). This fundus camera's automated eye-tracking technology acquires nearly simultaneous stereoscopic images of the retina via a fixed-displacement stereo base. Readers can enhance the view of the RNFL by applying red-free filters to the fundus photographs during postprocessing. Another device, the Nidek AFC-230/210 nonmydriatic autofocus camera (Nidek Co., Ltd., Gamagori, Japan), uses a fixed stereo base to capture simultaneous stereophotographic retinal images.

Physicians at remote teleretinal reading stations use prismatic viewers, red-green anaglyph spectacles, or liquid crystal display shutter glasses to evaluate stereoscopic photographs transmitted from imaging sites. These

postprocessing strategies help readers comprehensively review and study the appearance of the optic nerve.

To achieve optimal stereopsis, physicians should obtain fundus photographs through pupils that are least 4 mm in diameter. Most currently available technology adequately captures structural information about the optic nerve through smaller pupils, but no nonmydriatic digital imaging format has yet been validated for widespread screening and clinical use.

An efficient teleglaucoma program also requires diagnostic and telecommunications equipment that complies with the DICOM (Digital Imaging and Communications in Medicine) standards set forth by the Medical Imaging and Technology Alliance.³ DICOM standards identify discrete objects (ie, images) associated with a nomenclature and regulate the transmission of data from an imaging gateway to a server, thus fostering compatibility across different health care environments.

The ideal DICOM-compliant imaging platform for teleglaucoma would obtain images through undilated

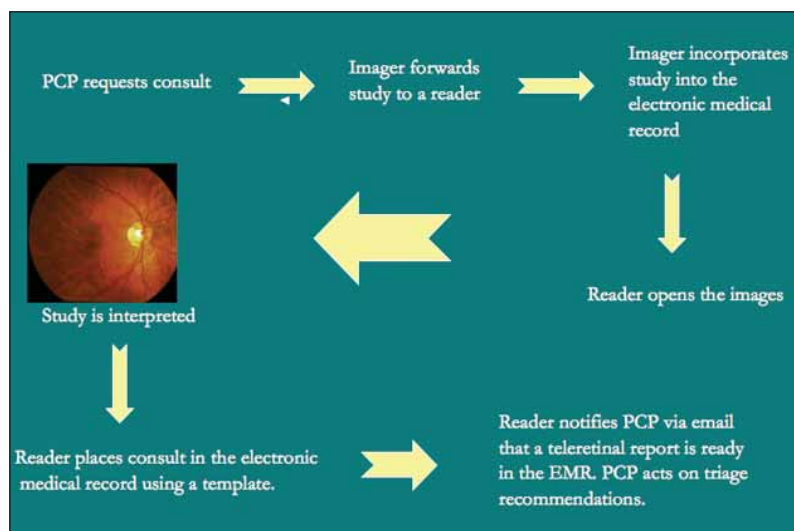


Figure 1. Schematic of the Massachusetts Eye and Ear Infirmary's diabetes teleretinal program. PCP = primary care provider.

pupils, provide high-quality digital information, and accomplish these objectives at reasonable costs. Finally, the designers of teleglaucoma systems must decide how they will incorporate factors such as tonometry,⁴ digital slit-lamp biomicroscopy, and telemedicine-friendly psychophysical testing into their protocols.

CREATING THE IDEAL REFERENCE RESOURCE

Imagine a world in which we could construct a database containing retinal images from everyone who applied for a driver's license. Technicians at the registry of motor vehicles would not have to dilate applicants' eyes pharmacologically to obtain these images. Instead, they could use an infrared nonmydriatic camera to take advantage of the pupil's physiologic response to low levels of light. Such a program would generate a huge archive of fundus images that investigators could retrieve for medical and research endeavors at a later date.

For example, if a 50-year-old patient presented to an ophthalmologist with a suspicious optic disc, his physician could compare the images he or she obtained in the office with the fundus photograph on record at the Department of Motor Vehicles. Such information could help the physician formulate a plan for the patient's man-

agement. Prior knowledge of the appearance of patients' optic nerves would be particularly helpful if the observed changes in the disc were accompanied by unreliable visual field tests.

Unfortunately, the absence of a sustainable infrastructure and a lack of regulations about sharing data, legal liability, and privacy currently prevent this sort of a database from becoming a reality. These barriers can be broken, however, as demonstrated by the National Institutes of Health's database of Genotypes and Phenotypes. The data composing this resource have been stripped of any information that could identify individuals and thus allow researchers to access genetic information about thousands of patients without violating anyone's privacy. A similar system could control access to the archived retinal images of young adults who apply for a driver's license.

ROLE MODEL

Teleretinal Imaging Program

In March 2006, the US Veterans Administration (VA) deployed a nationwide teleretinal imaging program to screen patients for diabetic retinopathy. Six million US veterans, 20% of whom have diabetes, are currently served by a limited number of eye care providers. The VA's teleretinal screening program was designed to meet the American Diabetes Association's objective of annually evaluating the retinas of diabetic veterans.

The three-field imaging protocol with which the VA obtains digital photographs reportedly detects treatable diabetic retinopathy through undilated pupils as effectively as a face-to-face dilated examination.⁵ In addition, data suggest that teleretinal imaging improves patients' adherence with annual diabetic eye examinations⁶ and that participants are highly satisfied with this form of evaluation.⁷

The diabetic teleretinal imaging program at the Massachusetts Eye and Ear Infirmary is modeled after the system developed by the Veterans Administration Healthcare System (Figure 1).

Primary care practitioners initiate the screening process by referring a patient to a facility that is properly equipped to obtain stereoscopic photographs. The footprint for data acquisition is small and consists of the patient, an imaging device/acquisition system, and a computer. The patient's images are then incorporated into his or her EMR and forwarded to a teleretinal reading center. There, a reader reviews the data in the context of the patient's EMR, creates an impression, and formulates a treatment plan. The reader deposits the findings in the patient's EMR and emails the primary care provider who requested the consultation to notify him or her that the results are available for review.

Unpublished data from the VA's screening program indicate that fewer than 5% of the participating patients have diabetic retinopathy that warrants immediate treatment. The program thus spares highly skilled retinal surgeons from screening a large number of patients who do not have clinically significant retinopathy.

Implications for Glaucoma

By reviewing the objective of the VA's teleretinal imaging program and studying its configuration, we may be able to create a comparable system that will transform teleglaucoma from a novelty into a firmly rooted institutional service. Such a program could allow patients who are eligible for Medicare's glaucoma screening benefit to receive care in areas where there are not enough ophthalmologists. In this scenario, the teleglaucoma providers could receive a technical fee for acquiring images, and certified readers could collect a professional fee for interpreting images.

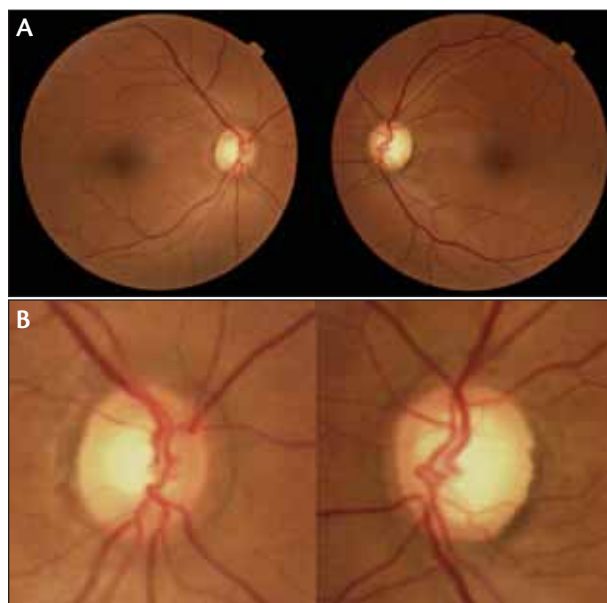


Figure 2. Fundus photographs obtained from a 52-year-old Hispanic female with a 4-year history of type 2 diabetes were negative for diabetic retinopathy bilaterally (A). The images were collected with a nonmydriatic camera as part of a teleretinal screening program. Careful inspection of the 30° images centered on the macula revealed suspicious thinning of the superior and inferior neuroretinal rim in her left eye (B).

Several studies have shown that diabetes is an independent risk factor for glaucoma.⁸⁻¹⁴ Images collected for diabetes teleretinal programs often include discs that appear to have glaucomatous changes (Figure 2).

My colleagues at the Ocular TeleHealth Center at the Boston VA Hospital and I investigated if images previously screened for diabetic retinopathy could also be used to identify optic discs that were suspicious for glaucoma. We found that readers who retrospectively analyzed images obtained through the Boston VA teleretinal program rarely missed discs that showed glaucomatous changes.^{15,16} In fact, they tended to overestimate the number of glaucomatous discs. These data suggest that, with some modifications, we may be able to develop a teleglaucoma program that effectively detects manifest glaucoma with visual field loss.

CONCLUSION

The technology we need to implement a remote screening system for glaucoma is currently available. The advent of noninvasive measurement techniques such as rebound and noncontact tonometry allows almost anyone to measure IOP. Furthermore, the emergence of point-and-autofocus devices has made it possible for technicians to acquire images of the optic nerve

without receiving specialized training in ophthalmic photography. In addition, the ease with which patients can perform frequency-doubling perimetry suggests that visual field testing may play a role in teleglaucoma.

The next step in building a teleglaucoma program involves sketching out and validating a streamlined protocol that detects glaucoma with maximal sensitivity and specificity. A successful teleglaucoma screening program must also be able to sustain itself and ensure that patients suspected of having glaucoma receive a comprehensive ophthalmic examination. Ultimately, the hope is to deploy such a program among populations that have a high risk of glaucoma. □

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1. Conlin PR, Fisch BM, Orcutt JC, et al. Framework for a national teleretinal imaging program to screen for diabetic retinopathy in Veterans Health Administration patients. *J Rehabil Res Dev*. 2006;43(6):741-748.
2. Photographic Screening for Retinopathy of Prematurity (Photo-ROP) Cooperative Group. The photographic screening for retinopathy of prematurity study (photo-ROP). Primary outcomes. *Retina*. 2008;28(3 suppl):S47-54.
3. Khouri AS, Szirth BC, Salti HI, Fechtner RD. DICOM transmission of simultaneous stereoscopic images of the optic nerve in patients with glaucoma. *J Telemed Telecare*. 2007;13(7):337-340.
4. Kumar S, Middlemiss C, Bulsara M, et al. Telemedicine-friendly, portable tonometers: an evaluation for intraocular pressure screening. *Clin Experiment Ophthalmol*. 2006;34(7):666-670.
5. Chow S, Aiello L, Cavallerano J, et al. Comparison of nonmydriatic digital retinal imaging versus dilated ophthalmic examination for nondiabetic eye disease in persons with diabetes. *Ophthalmology*. 2006;113:833-840.
6. Conlin P, Fisch B, Cavallerano A, et al. Nonmydriatic teleretinal imaging improves adherence to annual eye examinations in patients with diabetes. *J Rehab Res Dev*. 2006;43:733-740.
7. Paul P, Raman R, Rani R, et al. Patient satisfaction levels during teleophthalmology consultation in rural south India. *Telemedicine and e-Health*. 2006;12(5):571-578.
8. Klein BE, Klein R, Jensen SC. Open-angle glaucoma and older-onset diabetes. The Beaver Dam Eye Study. *Ophthalmology*. 1994;101(7):1173-1177.
9. Dielemans I, de Jong PT, Stolk R, et al. Primary open-angle glaucoma, intraocular pressure, and diabetes mellitus in the general elderly population. The Rotterdam Study. *Ophthalmology*. 1996;103(8):1271-1275.
10. Mitchell P, Smith W, Chey T, Healey PR. Open-angle glaucoma and diabetes: the Blue Mountains Eye Study, Australia. *Ophthalmology*. 1997;104(4):712-718.
11. Katz J, Sommer A. Risk factors for primary open angle glaucoma. *Am J Prev Med*. 1988;4(2):110-114.
12. Uhm KB, Shin DH. Glaucoma risk factors in primary open-angle glaucoma patients compared to ocular hypertensives and control subjects. *Korean J Ophthalmol*. 1992;6(2):91-99.
13. Pasquale LR, Kang JH, Manson JE, et al. Prospective study of type 2 diabetes mellitus and risk of primary open-angle glaucoma in women. *Ophthalmology*. 2006;113(7):1081-1086.
14. Chopra V, Varma R, Francis BA, et al. Type 2 diabetes mellitus and the risk of open-angle glaucoma: the Los Angeles Latino Eye Study. *Ophthalmology*. 2008;115(2):227-232.
15. Pasquale LR, Asefzadeh B, Dunphy RW, et al. Detection of glaucoma-like optic discs in a diabetes teleretinal program. *Optometry*. 2007;78(12):657-663.
16. Asefzadeh B, Pasquale LR. Detection of glaucoma-like optic discs in a diabetes teleretinal program. *Optometry*. 2008;79(10):560.

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