
John Ulan

The Promise of Teleglaucoma:

Increasing Outreach, Expanding Access to Care

Can teleglaucoma reach patients whom traditional eye care has missed?

By Annie Stuart, Contributing Writer

First you heard of telemedicine, then teleophthalmology. Thanks to an abundance of technology, the evolution continues. Today it takes many forms. Remote screenings can be done at drugstore kiosks and on personal computers and smartphones. And distance management can happen with home-monitoring devices and apps or in optometry offices via real-time or asynchronous consultation with an ophthalmologist. And the options are only proliferating.

Now a band of glaucoma experts is making the concept their own with teleglaucoma. Chronic, progressive, and largely silent, glaucoma poses challenges for patients and eye care providers alike. Teleglaucoma—the use of electronic technologies to remotely find and enhance management of patients with or at risk of glaucoma—has the potential to help ensure continuity of care and preserve vision in an aging population, said Albert S. Khouri, MD, in Newark, New Jersey.

"The patient-physician relationship in glaucoma is really critical," said Karim F. Damji, MD, in Edmonton, Alberta. "But not every patient needs to be seen for everything, and there are smart ways to leverage technology to improve holistic care."

Benefits

Access to care. Teleglaucoma could increase access to eye care for people in medically underserved areas, said Paula Anne Newman-Casey, MD, in Ann Arbor, Michigan. "This includes impoverished populations and people living in rural or remote areas or countries where they wouldn't otherwise have access to medical expertise."

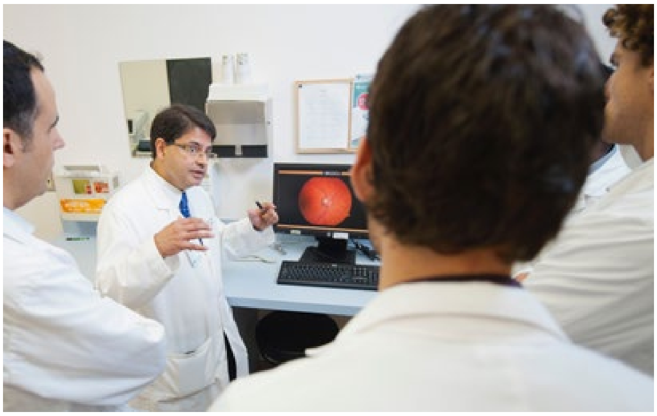
It also offers the potential to shift the paradigm from first-come, first-served to needs based, said Dr. Khouri. "We can develop teleglaucoma standards where patients with more advanced or progressive disease cut the line and are seen first, literally saving the vision of those patients."

Of course, said Dr. Damji, "not all patients are good candidates for teleglaucoma. For example, patients experiencing acute angle-closure glaucoma or those with concomitant mental health issues are better seen in person."

Efficiency and convenience. Patients may appreciate that telemedicine allows them to be seen quickly, rather than waiting months for an appointment in a big eye center, said Dr. Damji. In one northern Alberta program, optometrists work in teleconsultation with a glaucoma specialist to handle ongoing patient management.[1,2]

We can't underestimate the patient's need for convenience, for which some patients may even be willing to pay extra, said Lama A. Al-Aswad, MD, MPH, in New York City. Today, many glaucoma patients must take time off work and spend a couple of hours for testing. "In the future," she said, "home monitoring and ophthalmology kiosks may allow patients greater control over their time."

Cost. As an added benefit, this approach is



TEACHING. *Dr. Damji leverages remote fundus images when he teaches residents and fellows.*

expected to save money. A cost-effectiveness analysis of teleglaucoma screening in Canada demonstrated that implementing teleglaucoma in rural Alberta and targeting an at-risk population was cost-effective when compared with an in-person exam.[3]

Resident education. Teleglaucoma may also have a superb application in resident education, said Dr. Khouri, who is program director of the ophthalmology residency at Rutgers New Jersey Medical School. "For example, it can make it possible for the attending physician to give direct feedback based on objective data—images and readings—through telemedicine, not just a description over the phone."

Implementation Challenges

Telemedicine has come a long way since it was introduced in the 1960s and '70s, yet in today's Internet-enabled world, teleglaucoma still faces challenges.

A complex disease. Diabetic retinopathy (DR) is ideal for a telemedicine-based approach because it requires only a single modality of imaging for diagnosis, said Dr. Newman-Casey. In contrast, "glaucoma requires multiple imaging modalities and ancillary testing to make a good diagnosis." This includes structural assessment of the optic nerve through photographs or optical coherence tomography (OCT), as well as functional assessment through visual field testing. When evaluating a patient's risk of disease progression and deciding on the ideal treatment regimen, ophthalmologists take into account other parameters as well, such as central corneal thickness, intraocular pressure (IOP), and family history, she said.

"Because the diagnosis and management of glaucoma are more complex, it's more difficult to do remotely," said Dr. Newman-Casey. "That being said, it's not impossible."

Validation and standardization. "If you ask doctors to begin using a new technology," said Michael F. Chiang, MD, in Portland, Oregon, "they will often ask, 'Can you prove to me that I'm going to get the right answer?'" The same holds true for teleglaucoma. "You need to demonstrate that you can get the right diagnosis at a distance."

Notably, teleglaucoma needs "models or standards that are validated for image acquisition, transfer, and interpretation as well as tonometry and structure and function testing," said Dr. Khouri. In addition, agreement is needed on questions such as when to refer patients for follow-up, said Dr. Al-Aswad.

Another challenge? "Sometimes the technology evolves so fast that by the time you construct and complete a clinical trial, the technology has evolved, making the data obsolete," said Dr. Khouri, who is currently conducting a clinical trial at Rutgers to compare findings from teleglaucoma evaluations (visual acuity, tonometry, optic nerve, and OCT readings) to a standard clinical exam.[4]

Medical liability. Another need is clear-cut regulation. "There is a range of liability issues in telemedicine, including HIPAA and confidentiality concerns," said Dr. Khouri, "and all of these need to be sorted out for the field to progress." An umbrella license for telemedicine is also urgent, added Dr. Al-Aswad, who cited her inability to read images of New Jersey patients when her mobile eye van crosses into that state from New York, where she has her practice.

Reimbursement. Widespread adoption of teleglaucoma also won't happen without legislation concerning reimbursement, said Dr. Al-Aswad.

"An ongoing challenge of telemedicine in the United States is reimbursement, which has been limited, particularly for the store-and-forward models that are most common in ophthalmology," said Dr. Chiang. Dr. Newman-Casey noted that the reimbursement code used for picture-based store-and-forward screening or diagnosis is not enough to cover the equipment or services provided. "However," she said, "this is now undergoing scrutiny as the patient's burden for monitoring chronic disease becomes more apparent."

To improve reimbursement models for telemedicine, said Dr. Chiang, "we'll need evidence of diagnostic accuracy to demonstrate for providers that these technologies work, evidence of cost-effectiveness to demonstrate for payers that they should be covered, and discussion with policymakers, which the Academy has been involved with. In some diseases like DR and retinopathy

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of prematurity, there is fairly extensive literature demonstrating diagnostic accuracy and cost-effectiveness. For other diseases, there has been far less work."

Reimbursement needs to be carefully thought out, Dr. Newman-Casey pointed out. "We don't want to incentivize patients to not come in to see their provider when it's important that they do so. We want to have some contact with people to make sure they're not having trouble taking their medications—that cost and side effects aren't a barrier and that they know how to put eyedrops in."

Continuity of care. In fact, lack of follow-up and face-to-face contact can be one of the biggest challenges with teleglaucoma, said Dr. Khouri. "Once you identify patients through screening, many may not present back to doctors for continuity of care." However, he said, continued improvements in technology may help remove some of these obstacles. For example, telepresence now allows a remote physician to have access to data in real time. "With synchronous audiovisual communication, you can more comfortably evaluate the patient and make recommendations," he said.

An Array of Teleglaucoma Models

Teleglaucoma has multiple arms, said Dr. Al-Aswad. In addition to synchronous and asynchronous relay of data, a variety of models can be used for screening and management.

Screening. Given that more than 50% of Americans with glaucoma don't know they have the disease,[5] screening may be the lower-hanging fruit for teleglaucoma. "With effective tools, teleglaucoma has the potential to detect the disease early, critically important given that severe damage can occur despite a lack of symptoms," said Felipe A. Medeiros, MD, PhD, in Durham, North Carolina.

One model is consultation-based telehealth. For example, a rural ophthalmologist might remotely collect data to transmit to the nearest glaucoma subspecialist, said Dr. Chiang.

Another model is community-based screening. Dr. Al-Aswad and her team have developed a real-time (synchronous) teleophthalmology program in New York City, where they use a mobile van to screen individuals for the four leading causes of blindness, including glaucoma. This includes video consultation with an eye care provider. (See sidebar, "An Urban Model for Teleophthalmology.") Densely populated areas like this can help facilitate community-based screening, said Dr. Newman-Casey.

Dr. Khouri and his team have also developed and reported on a protocol to detect eye disease in high-risk populations in Newark and other parts of New Jersey.[6,7] "Our teleophthalmology protocols rely on high-resolution imaging and software filters that enhance the detection of vision-threatening diseases," said Dr. Khouri. "Imaging the ganglion cell and nerve fiber layers is important in the early detection of glaucoma. We do screening events at soup kitchens, community centers, churches, temples, and mosques. When we identify patients with pathology, we make recommendations and refer patients to the university hospital for management."

Monitoring. Another strength for telemedicine is monitoring. "As long as we have effective teleglaucoma methods to monitor these patients, they don't need to be coming to the hospital all the time for follow-up," said Dr. Medeiros. An alternative is to have a trained technician conduct tests on glaucoma suspects or patients who are stable, a method that has been piloted in the United Kingdom.[8] "The physician then reviews the data online, reports and signs off, and alternates a virtual visit with an in-person visit," said Dr. Damji.

Home monitoring. "I think the future of teleglaucoma is patients becoming active participants in monitoring their disease," said Dr. Al-Aswad. "I envision that the patient will do home testing—measuring IOP and visual fields, for example—and transmit that data to me. If the patient is stable, I will only see him or her once a year."

Dr. Al-Aswad refers to a study she was involved in using home tonometry to understand disease progression and fluctuation of IOP. Home testing allowed her to spot and treat high IOP in a patient whose test results in the office had all appeared normal.

There are still lots of logistics to work out with home monitoring, said Dr. Chiang. Should patients self refer or be responsible for calling their doctor if their pressure is above a certain cutoff? Or should the data automatically trans-

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GRADING. *Dr. Damji in the process of teleglaucoma grading.*

mit to some central service and flag the system if there is a concern?

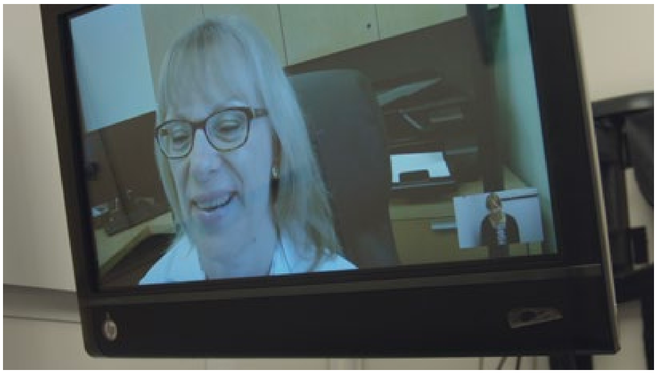
Information overload is another risk with home monitoring. "You can get an overwhelming amount of data with a lot of noise built in," said Dr. Khouri. "But as the technology improves, you will be able to filter out the noise. Or with a product such as iCare HOME, for example, you could ask patients to monitor once a day or customize testing, as needed."

Collaborative care. Shared management, another model, can take several forms.

ODs. In Northern Alberta, we've developed shared-care guidelines,[9] said Dr. Damji. "We collaborate with a large network of optometrists, who manage the patient on the front line. They provide us with structured information, using an asynchronous, store-forward system. We then provide feedback on the particular patient based on the history, exam, and testing, and we advise how soon a patient needs to be seen."

Techs. In Atlanta, April Maa, MD, has created and implemented a collaborative screening program called Technology-Based Eye Care Services, which allows the Veterans Affairs to reach underserved veterans. A trained ophthalmology technician is stationed in a primary care clinic. This person follows a detailed protocol to collect information about the patient's eyes, which is then interpreted remotely. Patients with likely abnormal findings are scheduled for a face-to-face exam in the eye clinic.[10]

Dr. Newman-Casey said she thinks this model works well because screening doesn't take up much space in the family practice office and nonophthalmic staff members aren't expected to capture the ocular data. "If this model were expanded to provide glaucoma monitoring in low-risk patients, the ophthalmic technicians' role could be expanded to provide glaucoma education as well," she said.



CONSULTING. *In Dr. Al-Aswad's mobile unit, a physician at an academic center speaks with a patient.*

SCREENING. *A patient is examined in Dr. Al-Aswad's mobile unit.*

Lama A. Al-Aswad, MD, MPH

Portable Technologies

A variety of types of portable technologies are being developed for remote screening and monitoring of glaucoma. "It's incumbent upon us to test these devices more thoroughly before rolling them out for patient care," said Dr. Newman-Casey. "I would love to see industry take a greater role in validating new instruments in the population in which they'll be used."

Portable cameras. In fact, Dr. Newman-Casey recently conducted an instrument validation study in Nepal to compare the reliability of information that clinicians could obtain from either a traditional tabletop fundus camera or a portable, lightweight, less expensive fundus camera that requires no dilation. The researchers found no clinically significant difference in reliability between the two cameras.[11] "This lays the groundwork for using the portable camera as part of population-based screening for glaucoma," said Dr. Newman-Casey.

Smartphones. Smartphones are another way to visualize the optic nerve. When equipped with special lenses, they can get very good pictures of the back of the eye, said Dr. Medeiros.[12]

"I can foresee the day where patients can obtain a selfie of their own eyes," added Dr. Damji, "and obtain more than just structural information. The device could take photographs of the front and back of the eyes, assist in visual acuity/visual field and eventually other aspects of testing, and provide a template for structured history taking. The patient could then send all this data through a patient electronic portal into an artificial intelligence (AI) filter and then very quickly receive feedback from an eye care professional."

Tablets. "There's also the potential to use the portable camera on a tablet in conjunction with perimetry software, such as the iPad-based Visual Fields Easy App, which is being used in Nepal," said Dr. Newman-Casey. (On the computer, Peristat is a free, web-based visual field test that can be used on monitors 17 inches or larger.)

The iCare HOME tonometer can be connected to a tablet, thus making it possible for that data to be transmitted to your office, something that Dr. Al-Aswad is doing with her patients.

Virtual reality goggles. Taking the next step in technology, Dr. Medeiros' lab has done an initial validation of a portable approach using virtual reality goggles to assess visual field defects. Called the nGoggle, it consists of a brain-computer interface that uses a wireless, dry electroencephalogram, electrooculogram systems, and a head-mounted display.[13] (See "The New World of Virtual Reality," *EyeNet*, October 2018.)

"We have optimized the nGoggle's algorithm for testing and incorporated eye tracking to better detect loss of fixation and ensure testing reliability," said Dr. Medeiros. He hopes to soon begin studies to validate the home-based application.

Artificial Intelligence

Dr. Medeiros is also working with AI. He predicts that AI will be implemented in primary care practices for opportunistic screening of eye diseases within the next five years. "The future is AI and doctors working together to provide better care for our patients," said Dr. Al-Aswad. "It will help us practice at the top of our license, manage disease, and prevent blindness—not replace us."

Optic disc photos. "A model that excites me is the Pegasus system," said Dr. Damji. The retinal analysis decision support system can provide quick grading of the nerve and additional aspects for DR, he said. "Using deep learning, it has the potential to develop a comparable ability in assessing optic disc photographs for glaucoma."

Using OCT to train AI. One challenge in using AI to evaluate fundus photographs for glaucoma, said Dr. Medeiros, is that an AI algorithm—when taught by using human-based grading as reference—will simply replicate the doctors' errors, which are especially common in the early stages of the disease. "We know that ophthalmologists, even glaucoma specialists, tend to perform poorly when trying to detect glaucoma based on a photograph of the optic disc. Therefore, an AI algorithm trained on that is not going to be different," he said.

"An alternative is to use an objective instrument such as OCT, which can give us a much more accurate, precise, and quantifiable assessment of structure," said Dr. Medeiros. "An AI algorithm trained to predict OCT measures from optic disc photographs can give you a quantitative and precise measurement of the amount of nerve damage." Dr. Medeiros and his team have used

An Urban Model for Teleophthalmology

Between 2007 and 2014, Dr. Al-Aswad conducted a screening program in high-risk communities of New York City—and did so without the help of teleglaucoma. "Whether or not they had insurance, 57% had never previously been seen by an eye doctor, which was astonishing to me," she said.

This became the seed for what she and her team ultimately built—telemedicine to screen for leading causes of blindness in high-risk, poor communities in the city. "In 12 months, we've screened close to 1,300 individuals for the four leading causes of blindness," said Dr. Al-Aswad.

MOBILE UNIT. *Dr. Al-Aswad's mobile center brings screening for glaucoma and other blinding conditions to at-risk communities in the New York area.*

It took two to three years to build the program, which included creating the team, acquiring a mobile unit with state-of-the-art equipment for ophthalmology, building a data-capturing system, and ensuring connectivity and security. The free screening includes visual fields, anterior and posterior segment OCT images of the optic nerve, and retina and fundus photographs of the retina.

Recently, Dr. Al-Aswad collaborated with GlobeChek to add the first GlobeChek kiosk to her screening program. "In addition, we screen for comorbidities of eye disease, checking hemoglobin A_{1C}, blood pressure, and body mass index," said Dr. Al-Aswad. "After the technicians complete the screening, the individuals go to a private area in the mobile unit, where they have a videoconference with an ophthalmologist or optometrist to discuss the results."

The eye care physician then gives a recommendation for follow-up. "If it's an emergency, like angle-closure glaucoma, we send them directly to an ER at a safety net hospital," she said. "If it's not an emergency, we send them to the community ophthalmologist or optometrist in their area. This has not only been helpful to the patients, but we're also learning a lot about these eye diseases."

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more than 30,000 pairs of optic disc photos and spectral-domain OCT (SD-OCT) retinal nerve fiber layer retinal (RNFL) scans to train AI to assess the photos and predict the actual estimate of nerve damage.[14] "In a validation study, we found a very strong correlation between the predicted and observed RNFL thickness values—between what the AI algorithm could see in the photo and the SD-OCT result," said Dr. Medeiros.

Although the researchers have not yet implemented this AI approach in a teleglaucoma setting, Dr. Medeiros is optimistic about its potential. An AI algorithm trained this way to assess optic nerve damage from photographs would be much less expensive than an OCT system and, therefore, potentially suitable for large-scale deployment, he added. "Because it provides a quantitative estimate of nerve damage—not just a 'yes' or 'no' diagnosis —it may also be used for monitoring over time," he said, adding that the algorithm has not yet been tested for this kind of follow-up.

More is better? Currently, most AI models rely on either optic nerve head photos or OCTs to determine pathology, said Dr. Khouri. "But, in time, I predict they will integrate both structure and function, and the accuracy of detection will be even better."

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EXTRA **MORE ONLINE.** See this article at aao.org/eyenet for a sidebar on prerequisites for a successful teleglaucoma program.

MEET THE EXPERTS

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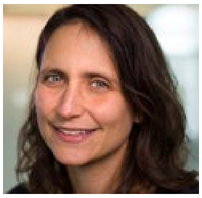

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