



The Future Is Now: Incorporating Telemedicine into Glaucoma Care

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Abstract

Purpose of Review The field of teleglaucoma has expanded rapidly in recent years with several large-scale teleglaucoma screening programs in existence throughout the world. Additionally, teleglaucoma programs for use in disease management are under study. The limited access to care that resulted from the COVID-19 pandemic highlighted the need for expansion of such programs. This article reviews the literature on teleglaucoma for screening and management of glaucoma, discussing considerations for incorporating teleglaucoma into clinical practice.

Recent Findings Teleglaucoma screening reduces the rate of false-positive referrals and can accurately screen at-risk populations with accuracy similar to in-person screening. The use of teleglaucoma for the management of glaucoma shows promise for low-risk patients with early disease. Furthermore, teleglaucoma is cost-effective and reduces travel burden for patients resulting in high patient satisfaction.

Summary Teleglaucoma offers potential for improving access to glaucoma care, reducing the burden on patients and health care systems.

Keywords Telemedicine · Teleglaucoma · Glaucoma screening

Introduction

Glaucoma is the second leading causes of worldwide blindness affecting an estimated 76 million adults in the year 2020 [1]. Since it is a disease that increases in incidence with age, the prevalence of glaucoma will only continue to grow with an aging population. In the USA alone, it is estimated that over 7 million people will carry a diagnosis of primary open angle glaucoma by the year 2050 [2]. Several major clinical trials have demonstrated that with intraocular pressure (IOP) lowering, progression of glaucoma can be slowed [3–5]. However, this requires early detection as well as frequent clinical follow-ups for IOP monitoring, optic nerve imaging, functional visual

field testing, and adjustment of medications. One of the most cited barriers to care by populations at risk for glaucoma is transportation to these clinic appointments [6]. Telemedicine allows physicians to provide care to patients remotely and offers a potential solution to this barrier to care.

The field of telemedicine was first introduced in the USA as early as the 1960s with the development of technology that allowed for two-way communication between patient and physician [7]. Since that time, significant technological advances have allowed the field of telehealth to grow exponentially. While the exciting potential of telehealth to expand health care access to an underserved population has always been apparent, the potential importance of telehealth for routine care became clear over the last year. The COVID-19 pandemic limited access to routine health care services for a significant proportion of the population across the world, uncovering the need for telehealth expansion and incorporation into clinical practices [8]. The medical community quickly recognized this need; a recent PubMed literature search reveals a doubling of publications on the topic of telemedicine in the year 2020. In the last year, many ophthalmologists have incorporated telemedicine into their clinical practice with a recent survey demonstrated that 77.4% of responding eye care providers provided telehealth services during the pandemic, despite most not doing so prior to the COVID-19 outbreak [9].

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Teleglaucoma is defined as the use of telemedicine to provide glaucoma care to patients. The field of teleglaucoma has gained momentum in recent years with wide scale teleglaucoma programs now established in several countries. This article will review the literature on teleglaucoma, discussing its potential applications to augment the diagnosis and management of glaucoma. We will also discuss considerations for incorporation of teleglaucoma into clinical practice.

Types of Telemedicine

There are three primary modalities of delivering telemedicine services: synchronous, asynchronous, and a combination of the two. Synchronous telehealth services involve real-time video conferencing between the provider and the patient [10, 11]. While this allows direct communication, the use of video conferencing to perform a physical examination has limitations. This is especially true in ophthalmology where the majority of the clinical examination is performed under the magnification of a slit lamp.

Asynchronous telehealth services employ a store and forward approach in which data acquisition is performed and then forwarded to the provider for remote assessment [10, 11]. This approach utilizes digital images with potentially improved resolution compared to video conferencing. Furthermore, this method of telehealth allows for the acquisition of diagnostic tests such as slit lamp photos, optical coherence tomography (OCT), and visual field testing. However, there is an intrinsic risk of poor quality, uninterpretable images that limit the ability to accurately assess patients [12].

A third type of telehealth service utilizes a combination of both asynchronous data acquisition and real-time consultation. One can imagine such a clinical scenario: a patient comes in for IOP measurement, OCT, visual field testing, and optic nerve photography [10, 11]. This information is then transmitted to a glaucoma specialist who, after reviewing the data, calls the patient to elicit any further medical history and discuss results in a synchronous format. This most closely mimics the current face to face clinical interactions with which we are most familiar.

Applications for Use

While teleglaucoma has many potential applications, two of the most commonly utilized are triage/screening and disease monitoring [11, 13, 14]. When used for screening, teleglaucoma offers the potential to provide access for patients in remote locations and has the potential to identify at-risk patients in the population who can then be examined by a glaucoma specialist [13]. The efficacy and cost-effectiveness of tele-ophthalmology screening for diabetic retinopathy as a

model of this application has been well-established [15–17, 18]. The use of teleophthalmology for disease management, on the other hand, is less well-established but studies offer promising results [19]. Here we will review the recent literature on these applications.

Teleglaucoma for Screening

Utilizing telemedicine for glaucoma screening has many potential benefits. In developed countries with large numbers of patients and far fewer glaucoma specialists, it can reduce unnecessary subspecialty appointments. Studies investigating the agreement between community-based optometrists and ophthalmologists based on virtual optic nerve head imaging and visual field images support that idea that community-based screening of at-risk glaucoma patients can reduce the false-positive rate of referral to glaucoma specialists [20, 21]. An alternative application of teleglaucoma is large population screening to identify at-risk patients who can then be directed to subspecialty service [22, 23, 24]. Validation of such an approach for correctly screening glaucoma patients has been investigated: a study performed at the Atlanta Veterans Affairs Hospital confirmed a high rate of agreement for glaucoma/glaucoma suspect diagnoses between face-to-face examination and teleglaucoma evaluation in new patients presenting for comprehensive evaluation [22]. The ability of teleglaucoma to identify and escalate care for at-risk patients offers significant public health benefits. Staffieri et al. used telemedicine in the screening of first-degree relatives (FDRs) of patients with advanced glaucoma. Two hundred eleven patients were recruited for examination with 6% of FDRs already carrying a diagnosis of glaucoma, and another 21% of patients were identified who either required prompt referral or received a diagnosis of glaucoma suspect or ocular hypertension [22]. The *Philadelphia Telemedicine Glaucoma Detection and Follow-up Study* utilized trained ophthalmic technicians to obtain IOP measurements, anterior segment, and fundus photographs in a primary care setting. Over 35% of patients who were screened were determined to have suspicious optic nerves or ocular hypertension [24, 25]. In developing countries with high-risk populations, teleglaucoma screening is similarly able to detect high rates of glaucoma and ocular hypertension, identifying patients who need further care to avoid potentially irreversible vision loss [26]. Studies such as these suggest an important role for teleglaucoma screening to identify patients at risk for glaucoma who may otherwise go undetected (Table 1).

Cost-effectiveness analyses of teleglaucoma screening demonstrate tremendous cost savings for the health care system with one study estimating as high as an 80% reduction in cost for teleglaucoma screening compared to in-person examination. Furthermore, it reduces patient travel time

Table 1 Articles on the use of teleglaucoma for triage and screening

Article	Type of teleglaucoma	Number of patients	Design of study	Findings of study
Roberts et al., 2014	Asynchronous	1639 patient identified as at-risk for glaucoma	<ul style="list-style-type: none"> - Initial in person assessment by optometrist (BCVA, SLE, IOP, CCT, HVF, ONH photography) - Notes from initial examination, HVF, and ONH photos then assessed by glaucoma specialists - Primary outcome: accuracy of optometrist assessments compared to glaucoma specialist 	<ul style="list-style-type: none"> - 29.6% of optic nerve head photos were unable to be reviewed due to poor image quality - optometrists had between 47.5–64.6% agreement with glaucoma specialists regarding diagnosis of glaucoma depending on optometrist glaucoma training level <p><i>Community-based optometry screening has acceptable levels of accuracy to keep low-risk patients from seeking unnecessary glaucoma evaluation</i></p>
Kennan et al., 2015	Asynchronous, community--based services	1733 patients identified as glaucoma suspect by outside provider	<ul style="list-style-type: none"> - Remote review of tonometry, pachymetry, disc photos and HVF by optometrist - Validation was performed by glaucoma specialist - Primary outcome: identification of false positive referrals 	<ul style="list-style-type: none"> - 46.6% of patients were discharged without evidence of glaucoma by optometrist initial review - 5.7% more patients were discharged after ophthalmologist review - 3.6% of initially discharged patients were recalled - 91.5% agreement between optometrist and ophthalmologist on clinical decision-making <p><i>Community based glaucoma screening/triage by optometry safely reduces the number of false-positive glaucoma referrals</i></p>
Staffieri et al. 2011	Asynchronous	211 first-degree relatives (FDR) of advanced glaucoma patients	<ul style="list-style-type: none"> - Initial assessment performed by trained registered nurse, optometrist, orthoptist or ophthalmology registrar trainee including BCVA, HVF, IOP, CCT, and ONH photos - Virtual images were then reviewed by a glaucoma specialist - Primary outcome: use of telemedicine to determine incidence of undiagnosed glaucoma in a high-risk population 	<ul style="list-style-type: none"> - 6% of FDRs were already diagnosed with glaucoma - another 5% were identified for prompt referral - 15% of patients were identified as glaucoma suspects - 6% of patients were ocular hypertensives <p><i>Telemedicine is an efficient way to screen high risk populations for glaucoma</i></p>
Maa et al. 2020	Asynchronous versus face to face (FTF)	256 patients with no known ocular disease	<ul style="list-style-type: none"> - Patients scheduled in comprehensive clinic evaluation included BCVA, pupils, IOP, CCT, AC depth, AC photo, and dilated retinal photo - Patients evaluated in person by a comprehensive ophthalmologist - Digital images and clinical history were reviewed by two blinded ophthalmologists - Primary outcome: agreement between evaluations performed virtual versus face-to-face 	<ul style="list-style-type: none"> - 86.3% and 84.0% agreement on the diagnosis of glaucoma or glaucoma suspect between FTF examination and virtual image review for reader 1 and reader 2, respectively - There was 87.5% agreement between reader 1 and reader 2 <p><i>Teleglaucoma screening is accurate compared to face-to-face examination for the diagnosis of glaucoma and glaucoma suspect</i></p>
Hark et al. 2017 and 2018	Asynchronous, community--based services	906 patients without known ocular disease	<ul style="list-style-type: none"> - Trained technicians went to community health centers and obtained testing: VA, IOP, 2 fundus photographs, and 1 anterior segment image - Images were read by a glaucoma specialist and trained retina reader - Primary outcome: the ability to detect glaucoma and other eye diseases in a primary care setting 	<ul style="list-style-type: none"> - 28.5% of patients had suspicious optic nerves - 6.8% of patients had ocular hypertension - 17.1% of images were unreadable <p><i>Teleglaucoma screening was able to identify a large number of patients with concerning optic nerves and ocular hypertension</i></p>
Giorgis et al. 2019	Asynchronous	1002 Ethiopian patients	<ul style="list-style-type: none"> - Patients were screened by a trained ophthalmic nurse and optometrist with VA, IOP, CCT, and optic nerve head photos - A trained glaucoma specialist reviewed the images and clinical data and a glaucoma diagnosis was made based on nerve appearance and IOP - Primary outcome: the prevalence of glaucoma detected through teleglaucoma method 	<ul style="list-style-type: none"> - 13.8% of patients were given a diagnosis of glaucoma suspect - 7.9% of patients were diagnosed with glaucoma - 0.7% of patients were referred to a glaucoma surgeon for further evaluation <p><i>Teleglaucoma screening detected a high prevalence of glaucoma in an Ethiopian population</i></p>

significantly, thereby reducing cost for patients [27•]. Time savings are also seen in reduced appointment times relative to real time face-to-face evaluation by a glaucoma specialist [28].

Teleglaucoma for Disease Management

In addition to screening, teleglaucoma offers the opportunity for remote management of glaucoma. Clarke et al. compared the efficiency of clinical decision-making for the management of glaucoma in patients seen via teleglaucoma to those seen in face-to-face encounters. Of the 204 patients seen, there were only 7 patients identified in whom there was a failure to escalate care with teleglaucoma that was seen during in-person consultation. There was fair interobserver agreement between the five glaucoma specialists reviewing records and the in-person assessment. The authors conclude that given the slow progressive nature of glaucoma and the low rate of adverse disagreement that teleglaucoma is a safe method for certain glaucoma patients [29]. The true advantages of a teleglaucoma system for management are improved access to specialist care and reduced patient burden as evidenced in the study by Arora et al. that showed decreased access time to glaucoma specialists and reduced time spent in the clinic [30]. Furthermore, teleglaucoma can assist with remote management of patients being followed by their local optometrist. Verma et al. used a combined synchronous/asynchronous model of teleglaucoma consultation for disease management. Of the 273 patients seen via teleglaucoma, 171 patients were able to continue care with their local optometrist, with 48% of these patients having follow-up teleglaucoma consultations for disease management. Models such as this demonstrate the potential for glaucoma co-management to improve access to care for patients and reduce the number of in-person visits to a glaucoma specialist (Table 2). [31]

The Use of Teleglaucoma in Education

As an additional consideration, it is hard to ignore the potential utilization of teleglaucoma for educational purposes. The large number of images obtained through a teleglaucoma model can easily be used to expand learning for medical students, residents, and fellows. Studies have shown positive results of incorporating telemedicine into medical education [32, 33]. Large-scale screening programs are likely to acquire images of less commonly detected pathologies generating a library of images for study. Educational opportunities also extend to low-resource countries where teleglaucoma consultation can augment clinical teaching for local ophthalmologists [34]. Atypical patients may produce a digital catalog of images and clinical data can easily be shared between multiple

glaucoma specialists for discussion of difficult management decisions. Serial photographs utilized in teleglaucoma may also allow us to develop a better understanding of the progression of glaucoma [35].

Patient Perceptions of Teleglaucoma

It is important to consider the patient's perspective when thinking about the use of telemedicine. One study demonstrated that just under 75% of patients were amenable to receiving teleglaucoma care. Patient perceptions of telemedicine were influenced by a number of factors, including patient age and education [36]. Despite these predispositions, patients enrolled in teleglaucoma programs show high satisfaction. Of the patients who were examined in a local health clinic with a video slit lamp, nonmydriatic fundus, and videoconferencing with a glaucoma specialist at a university clinic, 96% requested follow-up visit at the local health care clinic over the university clinic. Patients cite decreased travel time, cost savings, and time savings as the most important reasons for preference of telemedicine over in person consultation [37•]. Teleglaucoma visits require significantly less in-office time for patients, reducing the burden on patients [30, 38]. Additionally, patients seen in virtual clinics have a good understanding of their diagnosis with virtual patients demonstrating non-inferior knowledge of their condition compared to in-person clinics [39].

Considerations for Incorporating Teleglaucoma into a Clinical Practice

The recent COVID-19 pandemic forced a majority of glaucoma providers to incorporate some aspect of telemedicine into their clinical practice [9, 40]. For many providers, this trend has reversed with the reduced case numbers and increased number of vaccinated patients. However, about 50% of glaucoma providers plan to continue using telemedicine to provide care for glaucoma patients after the pandemic [9]. For these providers, it is important to consider which requirements are necessary for successful teleglaucoma implementation, including trained personnel to perform diagnostic testing, videoconferencing and data storage equipment, tools for clinical evaluation, and diagnostic equipment, to name a few [18•].

Personnel

A key component to any teleglaucoma program is the personnel acquiring relevant history and performing clinical and diagnostic testing [11•]. This can include ophthalmic technicians, nurses, or optometrists. Well-trained personnel obtaining images can attenuate high numbers of uninterpretable images that would require return visits for

Table 2 Articles on the use of teleglaucoma for disease management

Article	Type of teleglaucoma	Number of patients	Design of study	Findings of study
Verma et al. 2014	Combined asynchronous/synchronous	273 patients	<ul style="list-style-type: none"> - Included patients were followed by optometrist - Technician performed history, examination, VF testing, fundus photos ± OCT - Glaucoma specialists reviewed testing and called patient to discuss findings and management 	<ul style="list-style-type: none"> - 31% of patients were diagnosed with glaucoma, 87% of these had treatment initiated remotely - 171 patients continued to be followed by optometrist with 48% of these having repeat teleconsultation - 20 patients started on therapy with follow-up via teleglaucoma, 13 continued teleglaucoma follow-up for third visit, 5 recommended for in-person follow-up, and 2 discharged to optometry care <p><i>Teleglaucoma reduces in-person glaucoma specialist visits and allows for distance collaborations of care for glaucoma patients</i></p>
Arora et al. 2014	Asynchronous	71 patients seen via telehealth versus 63 patients seen in-person	<ul style="list-style-type: none"> - Patients were referred from optometrists for glaucoma evaluation - Technician performed interview, slit lamp examination, anterior segment imaging to assess angles, stereo nerve photos, and OCT - Glaucoma specialist reviewed testing and generated letter with referral or recommendations, patients were called by program manager <p>Primary goal: to assess access time and clinical efficiency</p>	<ul style="list-style-type: none"> - Mean access time for patients seen through teleglaucoma was 45±22 days versus 87 ±47 days for in-person examination. - Patients seen for teleglaucoma also spent significantly less time in the waiting room <p><i>Teleglaucoma allows for improved access time and improved clinical efficiency compared to in-person assessment</i></p>
Clarke et al. 2017	Asynchronous versus face-to-face	204 patients	<ul style="list-style-type: none"> - Technicians performed VA, visual field testing, optic disc photos and scanning laser ophthalmoscopy, slit lamp examination, and IOP measurement - Patients were then evaluated by a consultant or glaucoma fellow - Virtual images were sent to five glaucoma specialists who reviewed the images - Clinical decision-making was compared between teleglaucoma and in-person <p>Primary goal: to compare clinical decisions made using teleglaucoma to in-person consultation</p>	<ul style="list-style-type: none"> - 7 patients had adverse disagreement where teleglaucoma consultation failed to appropriately escalate care - There was fair agreement between the teleglaucoma reviewers and in-person consultants <p><i>Teleglaucoma has a low rate of adverse disagreement compared to in-person consultation with fair agreement between in-person and teleglaucoma clinical decision-making</i></p>

patients. After images have been obtained, they should be reviewed by a trained glaucoma specialist in a timely manner [27]. The results of the review must then be communicated to the patient either by a trained member of the teleglaucoma team or by the physician directly. This team member must be prepared to counsel and educate the patient on their diagnosis and/or management decisions. Several studies demonstrated the benefit of coordinating care with local optometrists who can perform a large portion of these tasks [20, 21, 31].

Equipment

Unlike TeleRetina screening programs, which require only fundus photography, teleglaucoma screening requires measurement of IOP as well as structure and function testing of the optic nerve [41, 42]. The more diagnostic testing obtained in a teleglaucoma visit, the better the diagnostic decision-making of the specialist reviewing the data. Fortunately, advances in glaucoma diagnostics have made acquisition of such data easier with many tests providing digital read outs or digital images that can be compiled for review. Here we will discuss the various aspects of the examination and the necessary equipment to obtain these measurements.

IOP measurement is essential for both the diagnosis and management of glaucoma. While applanation tonometry remains the gold standard, newer methods such as rebound tonometry allow for quick IOP measurement without positioning in a slit lamp or topical anesthetic and can be easily incorporated into a telehealth visit. The iCare HOME also allows for accurate home measurement of IOP and provides useful information on diurnal IOP curves improving remote decision-making for glaucoma providers [43, 44]. While such systems exist, they do require in-person training and manual download of measurements. Furthermore, these systems are expensive and readings depend on accurate patient administration which can be challenging for visually impaired patients. This is potentially a large barrier to more wide-spread use of teleglaucoma monitoring. CCT also offers important information in the diagnosis and management of glaucoma. Pachymetry can be performed easily by a trained technician using a number of different devices: ultrasound pachymeter, optical low-coherence reflectometry, Pentacam Scheimpflug imaging, and noncontact specular microscopy. Several portable pachymeter devices exist that can be easily transported [45, 46]. Visual field testing with standard automated perimetry is critical to teleglaucoma and is commonly obtained with either the Humphrey Field Analyzer (Carl Zeiss Meditec, Jena, Germany) or the Octopus Perimeter (Haag-Streit, Koniz, Switzerland). These tests require patients to present to an office setting and should be performed by trained ophthalmic technicians [42, 47]. There are currently a handful of tablet and virtual reality testing systems under development which may improve remote monitoring of visual fields in glaucoma patients [48–50]. Optic nerve assessment involves both optic disc photography for qualitative evaluation of

the nerve and quantitative structural analysis with OCT. Standard equipment for acquiring optic nerve photos and OCTs are bulky and require in-person visits for images to be obtained. Portable fundus cameras and OCT machines are under evaluation for clinical use and show promise for the tele-evaluation of glaucoma patients [51, 52]. There is certainly a trend toward portable diagnostic tools, several of which interface with smart phones that will likely enhance the future use of teleglaucoma both for patient monitoring and for expanding the scope of tele-screening in glaucoma but this is still an area that needs improvement [53, 54]. To truly expand the use of teleglaucoma and ensure it is a reliable, accurate, and efficient method of delivering care to patients, we need more dependable, cost effective, and ideally portable methods with which to obtain these images and clinical data.

Other Considerations

Legal considerations are another crucial aspect of teleglaucoma incorporation into clinical practice. The first of these is informed consent, which is required from the patient for teleglaucoma participation. Patients must understand the nature of the services provided by teleglaucoma as well as their limitations. It is of utmost importance that patients recognize that refusal of teleglaucoma services does not preclude them from in-person care. The potential of patient images to be used for research also requires patient consent [55]. Previous regulatory issues required that the physician participating in telehealth reviews must be licensed in the state where the patient is located which certainly limited patient access to virtual subspecialty care. The COVID-19 pandemic required rapid expansion of telehealth services and such licensing policies were amended; however, it is unclear how long this regulatory pause will be effective [55, 56]. Additionally, physician liability is a concern. It starts with the understanding that tele-consultation constitutes a patient-physician relationship and mandates HIPAA compliance. Any consultation with other physicians requires patient consent. Review of clinical data and communication with the patient is also the legal responsibility of the physician, and any technician-interpreted clinical data requires physician oversight [11]. As the use of telemedicine continues to expand, it is likely that many of these legal considerations will be addressed by state and federal regulations.

Conclusions

Glaucoma is one of the most common causes of blindness worldwide. Teleglaucoma programs can be used in a number of ways to augment current clinical practices, allowing for improved access to screening in high-risk populations and in resource-limited areas. It can also reduce unnecessary specialist appointments and improve co-management programs in remote locations. This results in cost and time savings for the health care system and patients alike, thus reducing the

burden of disease. However, implementing a full-scale teleglaucoma program requires trained personnel and sufficient equipment in order to allow for the most accurate and effective clinical decision-making. Many new advances in diagnostic imaging allow for remote, in-home monitoring of patients allowing for expansion of teleglaucoma programs, but there is still work to be done.

Declarations

Conflict of interest The authors declare no competing interests.

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- Of importance
- Of major importance

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