Teleophthalmology: where are we now?

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ABSTRACT

Information and communication technology has rapidly reached diverse aspects of modern life, including medicine and health-related matters. Aiming to improve teaching, research, and health care delivery for geographic or economic reasons, telemedicine is an ascending trend. Teleophthalmology might be one of the most challenging applications of telemedicine given its need for standardized and high definition digital images. However, technological advances are enhancing information transmission continuously and expanding the potential of teleophthalmology. In this review, we investigate the evolution and current status of teleophthalmology, describe its use in different areas, and explore its applicability. Although teleophthalmology is not a replacement for traditional eye care and still faces challenges for adequate implementation, it represents an effective care delivery method, facilitating appropriate and timely distribution of service especially in remote and/or underdeveloped regions.

Keywords: Telemedicine, Teleconsultation, Remote consultation, Telehealth; Eye health; Ophthalmology

INTRODUCTION

The continuous development of information technology has reached all aspects of modern life. Its wide access promotes more possibilities for progress by improving effectiveness, efficiency, productivity, and innovation. In medicine, development of technology has a valuable role, assisting in medical knowledge and distinct facets of health-related issues.

The concept of telemedicine has been applied long before the earliest substantial investments and effort in implementing long-distance medicine. For example, the concept was used in the development of astronaut crew monitoring for space exploration in the 1970s11. In theory, telemedicine was possible ever since the simplest long-distance communication equipment could be used, which allowed a case discussion over the telephone or even through letters. However, comprehensive telemedical care requires extensive information and clear communication, which demands proper support, equipment, and trained personnel. Continuous advances in communication technology have conquered modern society. A parallel progress has been reached in the medical field; however, problems related to increasing cost and unequal access to quality health care remain. Therefore, many areas remain medically underserved15. In addition, a huge gap remains with delivery of medical care between and within countries, particularly in remote, sparsely-populated, and/or emerging sites.

Combining technology and medicine, telemedicine has risen to offer new possibilities to favor medical education, research, communication, and delivery of health care. Telemedicine has increasingly become more popular since the late 1960s16,17. During that time, telecommunications offered high-priced systems unable to combine audio and visual data properly. As a result, there was a low recognition and acceptance in the face of conventional medicine, compromising the opportunity of more significant development during that period18. In the 1980s, the emerging digital era was marked by digitalization and computer advances. The integration of these technologies enabled simultaneous transmission of voice, video, and biometrics data, representing an important development incentive. The continuous improvement and growth of communication technology reached the internet era, producing an inexpensive global network of widespread technology. In addition, the possibility to store extensive image, audio, and text information, with the ability to provide services, has been explored more, enabling robust advances in telemedicine in a short period.

Health care accessibility is considered the cornerstone of telemedicine19. This objective would be accomplished by decreasing travel distance and, in turn, care delay, enabling tertiary and primary care independent of the patient location20. Patient care delivered in local health facilities promotes cost reduction by diminishing the need for transportation to tertiary care centers or for specialists to travel for health
The current major use of teleophthalmology is related to diabetes, specially focused on the screening and referral of DR. Even though Early Treatment Diabetic Retinopathy Study (ETDRS) photographs remain the most well-established method of detecting and assessing severity for DR, different accurate, reliable, and cost-effective teleophthalmology screening imaging tools are currently available. Although controversial regarding the aptness of adequate information collection by mydriatic and nonmydriatic digital cameras, both were reported to be efficient in detecting and grading retinopathy. Recently, it was shown that when nonmydriatic cameras were used for DR screening, different eye diseases such as glaucoma and age-related macular degeneration (AMD) were detected with this modality. Of note, the American Telemedicine Association classifies tele-screening approaches using different levels of validations. Category 1 includes patients who have minimal or no DR and more than minimal DR, category 2 includes patients either with or without sight-threatening DR, category 3 allows patients to be treated based on clinical retinal examination through dilated pupils, and category 4 allows a program to replace ETDRS photographs.

Teleophthalmology is also useful for detecting diabetic macular edema (DME). Although the presence of hard exudates is a surrogate for the presence of DME, stereoscopic fundus photography has also been used and seems to have high specificity (92.9%) in detecting DME. On the other hand, the use of fundus photography may be less accurate when compared to optical coherence tomography (OCT). It has been demonstrated that eyes diagnosed with DME on fundus photographs had no DME based on OCT, while many eyes diagnosed without DME on fundus photographs showed DME on OCT. More recently, the concept of telephotocoagulation was described for the treatment of DME. In this strategy, one site provides the retinal imaging, including fluorescein angiography, and another site creates an image-based treatment plan. Apart from effective screening of DR, teleophthalmology has been shown to be highly cost-effective, with potential extensive cost-savings.

Teleophthalmology enabled the increase of DR screening examination, reducing the referral to eye specialists during a period of five years. When compared to the traditional surveillance, teleophthalmology screened patients were more likely to be examined during a six-month period or less (94.6% vs. 43.9%).

Teleophthalmology also has been valuable in screening and in providing timely appropriate care for retinopathy of prematurity (ROP) and other pediatric retinal diseases. Although binocular indirect ophthalmoscopy is accepted as the current gold standard method for ROP screening, several studies have reported good reliability and better performance using wide-field digital imaging compared to traditional bedside binocular ophthalmoscopy. It is also valuable to compare DIs between examinations and, thus, identify disease progression. However, although imaging evaluation may provide better delimitation of zone I (the retina region in which most severe diseases occur), it failed to detect subtleties of the clinical findings that still required insights by experienced specialists. The investigators noted the need to establish improved grading protocols to determine location of the retinopathy and to describe clearly which image sets are ungradable or essential for telemedicine-based ROP evaluation performance. In addition, acceptable image quality aligned with a full set of retinal images is crucial for the detection of ROP. Therefore, standardized examination with protocols are also needed to promote adequate approaches and accommodate the rapid expansion of telemedicine in pediatric retinal diseases. Although controversial when considering DIs as a reliable screening method, teleophthalmology provides examination for infants whose fragile condition limits dislocation for evaluation (and, therefore, delaying intervention and negatively impacting long-term vision) and provides care by a specialist. In addition, when analyzing the financial aspect of a 10-year project using teledermatology for ROP screening, the initial investment and maintenance costs were returned within half of the period of the project execution.
The use of teleophthalmology was also identified in other conditions such as AMD, cytomegalovirus retinitis, and choroidal neovascularization[28,34,41,42]. In AMD, teleophthalmology has been described for screening and follow-up. For screening, good sensitivity and specificity were demonstrated in identifying referable and nonreferred AMD with a device used previously for DR screening[43]. For follow-up, teleophthalmology may be useful to decrease the inconveniences associated with frequent patient visits and also in early detection of neovascularization[44]. The Home study report number three[44] showed a higher detection rate for neovascular AMD and vision loss in the group that used the home-monitoring device compared to the prescheduled office visits group. In contrast, one study showed that the use of teleophthalmology for monitoring neovascular AMD recurrence resulted in longer waiting periods to initiate treatment, though no differences in visual outcomes were found[45]. Teleophthalmology has also been described in the screening of cytomegalovirus retinitis by ophthalmologists and nonophthalmologists. Although the imaging quality and personnel training were considered limitations, patients benefited from early diagnosis and, hence, early treatment with better visual outcomes. Another described applicability of teleophthalmology is in choroidal monitoring. Teleophthalmology represents a beneficial method for these cases, reducing the need for patient and/or specialist dislocation when appropriate routine exam documentation is provided[45,46].

**OPHTHALMOLOGY EMERGENCY TELECONSULTATION**

Besides retinal diseases, teleophthalmology has been used more progressively in other areas such as emergency medicine. The feasibility of an internet-based emergency consultation has been investigated[47]. In this study, 49 patients (98 eyes) had slit-lamp ocular images taken, processed, and transmitted by e-mail to a senior ophthalmologist, who re-examined the patients on the following day. The diagnosis agreement achieved 100% between internet-based and on-site consultations, with a high rate of patient acceptance (98% of the patients would prefer telemedicine urgent care). In a different context, it was observed that eye care in rural areas benefited greatly with telemedicine, as it enabled proper management of patients for adequate care and with a less expensive care delivery compared to that of patient referral and transportation[48]. The diagnosis of an urgent eye condition was proven to be accurate using mobile phone camera pictures, with high specificity (81.94%) and sensitivity (92.85%)[49]. In this study, the investigators concluded that mobile phone cameras could be viable for underprivileged areas, where specialized care is scarce. On the other hand, a recent study indicated that DIs and videos of a traumatized eye might not be as reliable for proper evaluation, which was mentioned most as a disadvantage by the nurses and physicians[50]. Nevertheless, the same study noted that emergency teleophthalmology was highly rated and considered as a potential triage method by physicians. However, it was noted that rural sites can count on significantly less emergency coverage than nonrural sites (48.6% vs. 74.7%), possibly reflecting the higher positive rating for teleophthalmology by the first group.

**NEURO-OPTHALMOLOGY, GLAUCOMA, UVEITIS, AND TELEOPHTHALMOLOGY**

The use of teleophthalmology in neuro-ophthalmology has also been described. Ocular fundus imaging with retinal photography has been considered a helpful tool for diagnosis of neuro-ophthalmologic disorders in the emergency department[51]. However, in cases evaluated through real-time video transmission[52] for discussions requiring dynamic clinical signs or subtle posterior segment abnormalities, the equipment used (384 kbit/s videoconferencing) failed to prove effectiveness, while signs that could be detected by slit-lamp imaging were communicated effectively through videoconference. Albeit controversial, the use of nonmydriatic fundus photography in neuro-ophthalmology has been evaluated positively[53,54]. A higher sensitivity of nonmydriatic fundus photography has been observed compared to direct ophthalmoscopy. As a result, the use of nonmydriatic fundus photography represents a promising diagnosis method for emergency neurology[55] and also a sensitive method for diagnosis of neurologic diseases[56].

While investigating the impact of teleophthalmology on retinal evaluation, other pathologies could be identified, including suspicious nerve cupping[57,58]. Contrasting with earlier studies, in which discrepancies of image quality among referral services were observed[59], glaucoma care currently seems to be viable in virtual clinics[60]. When face-to-face examination is compared to remote decision-making for glaucoma patients, low disagreement and misclassification rates (3.4% and 1.9%, respectively) were observed. This observation approach was considered cost-effective in screening the disease, representing 80% less than in-person examination cost[61,62] and possibly a more effective method of diagnosis[63].

The use of teleophthalmology in uveitis has also been studied. Asynchronous analysis of uveitis cases using retinography or biomicroscopy photographs showed 73.4% agreement between two specialists in establishing diagnosis and further management[64]. "Lack of clinical data" and "low quality of images" were the main reasons related to diagnosis difficulty.

**TELEOPHTHALMOLOGY IN GENERAL OPHTHALMOLOGY AND OCULAR ADNEXA CONDITIONS**

In comprehensive teleophthalmology, image-based triage has been observed to reduce face-to-face appointments by 16% to 48%, avoiding unnecessary appointments, shortening waiting lists, and improving the coordination of specialist services. In addition, teleophthalmology has been considered comparably effective or superior in providing accurate diagnosis[65], when compared to face-to-face consultation in diagnosing chronic blurred vision causes[66]. Regarding satisfaction with remote consultation, due to the immersion in technology and as a cost- and time-saving modality, teleophthalmology showed high acceptance, regardless of patient age[67].

The perception of the ability of teleophthalmology in guiding diagnosis and management for ocular adnexa (eyelid and orbit) conditions has also evolved from when it had once been considered limited in providing proper evaluation[68,69]. When an initial examination was performed from long-distance followed by a face-to-face consultation, ptosis cases were assessed accurately by teleconsultation, but conditions such as enucleation follow-up or other orbital socket issues were better evaluated by face-to-face consultation. This indicated that teleophthalmology could be used only in selected cases[70]. With image quality improvement, it has been possible to transmit more accurate information, either by imaging or live interaction, enabling teleophthalmology to provide preliminary diagnosis for orbital, adnexa, and lid diseases[71]. Long-distance interaction has helped in gathering information of rare diseases such as Wegener’s granulomatosis of the orbit and ocular adnexa[72], and even successfully assisted in an orbital tumor surgery by tele-monitoring[73], allowing reduction of consultant and patient travelling costs, and a more efficient use of treatment time and skills transfer.

**LIMITATIONS AND PERSPECTIVES**

Despite innovations and advances, telemedicine remains challenged by the usual obstacles faced by technology in matters of access, communication process, service quality, and security. For research purposes, telemedicine represents an extremely useful means of facilitating and expanding multicentric trials and consolidating new models of medical education, as it enables access to skills-transfer methods and medical advancement updates. The technology used in teleophthalmology is expected to be able to process, analyze, compress, store, and visualize large data, and these aspects have been enhanced continuously. However, although there is significant improvement in imaging technologies, poor quality images are still mentioned as a critical cause for retina-specialist referral, with rates...
of approximately 3% to 229%13,14. Poor imaging itself is responsible for the large majority (86%) of referrals14. This issue may result from inadequate equipment and/or insufficient training14,15. In addition, a learning curve associated with proper use of the apparatus involved in the capture of images must be overcome. With progressive technology advance, inadequate imaging (either in its quality or transmission) is expected to represent a minor issue for real-time teleophthalmology20. In addition, the integration between live interactive consultation and image collection for posterior analysis appears to surpass isolated methods, transcending the limitations of inadequate information transmission67. For instance, technology advances may allow automated screening with fast result reports. In the case of diabetes, the use of automated algorithms based on machine learning has shown high sensitivity and high specificity for detecting DR68. In regard to cost-effectiveness, larger populations in emerging countries may benefit from simplified imaging tools without financial burden in the case of DR screening69. The applicability of these devices in external diseases has not been investigated extensively to our knowledge as they have been for DR evaluation; however, it is expected that they will be similarly useful in these cases64.

Technology access itself is a persisting issue in many regions, hindering telemedicine’s concretization, particularly where underdeveloped economy impairs quality services. In general, regions deprived of quality health service might face more significant difficulties to have proper access to advanced communication technology and, hence, to telemedicine. The differences in territory size and economic aspects influence differently the cost-effectiveness of teleophthalmology in each scenario due to the amount of investments required for telehealth implementation. Emerging and developed countries may present with different needs for specialized care, reflecting different main causes of disparities in care delivery such as geographic, economic, or combined reasons.

The traditional instruments used for a face-to-face consultation remain indispensable for proper patient evaluation. In the meantime, the quality of tele-consultations is related directly to remote specialists’ expertise and their ability to explore digital diagnostic apparatus. In addition to medical knowledge, specific personnel training and standardized and intelligible communication are fundamental for adequate information transmission and interpretation. In addition to trained and/or experienced personnel, clear nomenclature is necessary for proper application and practice of telehealth21. As the internet has become part of the routine care delivery at a faster pace than previously anticipated64, the challenge of assuring data security remains a concern. Network maximal protection and constant surveillance are mandatory to assure confidentiality and integrity of patient information. As it becomes possible for teleophthalmology to be practiced nationally and internationally, regulations related to licensing, medical practice boundaries, responsibilities, and remuneration remain a major challenge. Therefore, the different aspects of teleconsultation regulation deserve cautious planning and require the elaboration of protocols involving norms of conduct for teleophthalmology liability.

Another relevant fact that deserves to be addressed attentively in the face of teleophthalmology development is the doctor-patient relationship22. High technology and telehealth are able to supplement health care; however, they do not substitute for personal human interaction. Although the main objective of telemedicine is to promote and assure access to medical care, humanizing healthcare and empathy must be some of the essential guides for present and future medicine.

CONCLUSION

The studies cited in this review were performed at different locations that might differ in medical teaching and practice methodologies, regulations, technology access, and health service investments. However, they agree in the positive aspect of the possibilities for diagnosis, treatment, health education, epidemiology, research, and logistics improvement that can be achieved with teleophthalmology. All of these factors may justify the exponential growing interest in implementing programs that use internet-based features, reflected by the increasing number of studies assessing this type of medical practice.

Although teleophthalmology still faces obstacles such as security, nomenclature standardization, specialized personnel, regulations, and ethics, it has been shown to be an additional and efficient tool for care delivery in the different areas of ophthalmology. Teleophthalmology is not meant to substitute face-to-face eye examination; it is rather meant to facilitate and provide appropriate and timely distribution of ophthalmology assistance, prioritizing the demand for ophthalmology care, especially in underserved areas. The initial experiences with telemedicine and teleophthalmology application demonstrated modest numbers regarding reliability in providing proper diagnosis; however, with potential. With technological advancement and imaging equipment quality increase, the precision of photographs and new devices to detect ophthalmic diseases and transmit data are in continuous ascension, making teleophthalmology expansion more attainable.

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