Teleophthalmology: where are we now?

Teleoftalmologia: onde estamos?

Ana Beatriz D. Grisolia[1], Maria Fernanda Abalem[1,2], Yan Lu[3], Lisia Aoki[2], Suzana Matayoshi[2]

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

RESUMO

A tecnologia da informação alcança diversos aspectos da vida moderna, incluindo a medicina. Com o objetivo de aprimorar o ensino, pesquisa e assitência médica, seja por motivos geográficos ou econômicos, a telemedicina é uma tendência em ascenção. A teleoftalmologia é possivelmente uma das aplicações mais desafiadoras da telemedicina, uma vez que requer imagens digitais de alta resolução. Entretanto, avanços tecnológicos estão continuamente melhorando a transmissão de informações e expandindo o potencial da teleoftalmologia. Um revisão da literatura foi realizada para investigar a evolução e o status atual da teleoftalmologia, descrevendo e explorando sua aplicação em diferentes subespecialidades. Apesar de não representar uma substituição para a assistência oftalmológica tradicional, e, embora ainda existam desafios frente a uma implementação adequada, a teleoftalmologia é um método efetivo de assistência, facilitando a distribuição de atendimento, especialmente em regiões remotas e/ou menos desenvolvidas.

Descritores: *Telemedicina; Teleconsulta; Consulta remota, videoconferência; Saúde ocular; Oftalmologia*

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 1970s[(1)]. 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 underserved[(2)]. 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 1960s[(2,3)]. 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 period[(4)]. 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 telemedicine[(3)]. This objective would be accomplished by decreasing travel distance and, in turn, care delay, enabling tertiary and primary care independent of the patient location[(3,5)]. 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

Submitted for publication: July 6, 2017
Accepted for publication: September 2, 2017

[1] Department of Ophthalmology and Visual Sciences, Kellogg Eye Center, University of Michigan Medical School, Ann Arbor, MI, USA.
[2] Division of Clinical Ophthalmology, Universidade de São Paulo, São Paulo, SP, Brazil.
[3] Department of Ophthalmology, Jinling Hospital, School of Medicine, Nanjing University, Nanjing, Jiangsu Province, China.

Funding: No specific financial support was available for this study.

Disclosure of potential conflicts of interest: None of the authors have any potential conflict of interest to disclose.

Corresponding author: Suzana Matayoshi. Av. Dr. Enéas Carvalho de Aguiar, 255 - 6º andar - São Paulo - SP - 05403-000 - Brazil - E-mail: suzana.matayoshi@gmail.com

http://dx.doi.org/10.5935/0004-2749.20170099

care delivery. Moreover, electronic consultations have been shown to cost less than face-to-face consultations[6], representing significant savings[7]. Comprehensive patient information available at the evaluation also may minimize the need for exam or tests replication, reducing extra cost and time to establish diagnosis and management, and avoiding unnecessary referrals[5], representing a time-effective advantage.

As in other medical fields, telemedicine has been introduced in ophthalmology care and has been applied and absorbed differently by the diverse subspecialties, as an ascending trend[8]. Here, a review of the literature was made to explore the evolution, current situation, and perspectives of teleophthalmology.

METHODS

We reviewed articles on telemedicine-related ophthalmology care identified in a PubMed search. Search terms included "telemedicine" AND "ophthalmology," "telehealth", "teleconsultation," and "teleophthalmology." Articles were initially evaluated based on their abstracts. The full text was retrieved when abstracts indicated relevance in exploring telemedicine and teleophthalmology development and application. Some articles mentioned in the references section of the retrieved articles were reviewed and included. A book, also cited in one reference, has been used as a source of research, as it assessed the earliest visions and expectations of telemedicine, especially with the space race, after the 1960s.

RESULTS

A total of 99 articles were retrieved using the descriptors. All articles were in English, except for one published in Portuguese. Articles without full text or abstract available, published in other languages, or that did not assess remote consultation or screening were excluded. A total of 72 articles were included in this review.

DISCUSSION

Telemedicine and ophthalmology

As telemedicine was introduced gradually, it was evaluated simply with descriptive studies and only by the end of the 1990s did teleophthalmology application begin to be assessed through analytic studies[9]. Teleophthalmology might be one of the most challenging applications of telemedicine given its level of detailed elements and need for refined imaging. Financial planning is essential for sustainability of teleophthalmology, as it may require more sophisticated and numerous equipment, which can be compared to teledermatology[10]. In addition to telecommunication features, such as high image resolution, audio clarity, and signal reception, specific protocols are required to provide ophthalmic clinical data[9,11]. Even though limitations remain regarding the available telecommunication equipment, technology has advanced rapidly since the first attempts at teleophthalmology application, vexing the past incredulity in its ability to provide adequate examinations.

In teleophthalmology care, proper evaluation for diagnosis, screening, and management are expected to be executed from distant sites, and demand equipment able to provide high digital image quality with high resolution and color fidelity. This last feature is especially relevant for optic nerve[12] and retinal evaluation[13,14].

Retina and tele-evaluation

The majority of early and recent studies assessed the application of teleophthalmology in retinal diseases and investigated the reliability of the image quality to be used for evaluation. Currently, digital imaging (DI) has been considered at least as accurate (and more accurate by some studies) than ophthalmoscopy performed by eye care professionals in detection of diabetic retinopathy (DR)[15]. Of note, DI may be useful for documentation purposes, including patient follow-up, medical teaching, and legal issues.

The current major use of teleophthalmology is related to diabetes[8], 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[16,17], different accurate, reliable, and cost-effective teleophthalmology screening imaging tools are currently available[18]. Although controversial regarding the aptness of adequate information collection by mydriatic and nonmydriatic digital cameras[19], both were reported to be efficient in detecting and grading retinopathy[20-22]. 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[23]. 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[24].

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[25]. 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[26]. 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[27]. Apart from effective screening of DR, teleophthalmology has been shown to be highly cost-effective, with potential extensive cost-savings[28,29]. Teleophthalmology enabled the increase of DR screening examination, reducing the referral to eye specialists during a period of five years[18]. 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%)[18].

Teleophthalmology also has been valuable in screening and in providing timely appropriate care for retinopathy of prematurity (ROP)[30] and other pediatric retinal diseases[31]. Although binocular indirect ophthalmoscopy is accepted as the current gold standard method for ROP screening[32], several studies have reported good reliability and better performance using wide-field digital imaging compared to traditional bedside binocular ophthalmoscopy[33-37]. It is also valuable to compare DIs between examinations and, thus, identify disease progression[38]. 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[39]. 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[40]. 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 telemedicine for ROP screening, the initial investment and maintenance costs were returned within half of the period of the project execution[30].

The use of teleophthalmology was also identified in other conditions such as AMD, cytomegalovirus retinitis, and choroidal nevi[28,29,41,42]. In AMD, teleophthalmology has been described for screening and follow-up. For screening, good sensitivity and specificity were demonstrated in identifying referable and nonreferable 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[22]. 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 nevi 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 benefitted 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-ophthalmology, 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 kbits/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[51,53]. 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[54] and also a sensitive method for diagnosis of neurologic diseases[53].

While investigating the impact of teleophthalmology on retinal evaluation, other pathologies could be identified, including suspicious nerve cupping[28,29,41,42]. Contrasting with earlier studies, in which discrepancies of image quality among referral services were observed[55], glaucoma care currently seems to be viable in virtual clinics[56]. 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[57,58] and possibly a more effective method of diagnosis[57].

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[59]. "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 ophthalmology, image-based triage has been observed to reduce face-to-face appointments by 16% to 48%[5], 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[47], when compared to face-to-face consultation in diagnosing chronic blurred vision causes[60]. 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[61].

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[62,63]. 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[63]. 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[64]. Long-distance interaction has helped in gathering information of rare diseases such as Wegener's granulomatosis of the orbit and ocular adnexa[65], and even successfully assisted in an orbital tumor surgery by tele-mentoring[61] 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 22%[13,14]. Poor imaging itself is responsible for the large majority (86%) of referrals[14]. This issue may result from inadequate equipment and/or insufficient training[22]. 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 teleophthalmology[28]. 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 transmission[67]. 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 DR[68]. In regard to cost-effectiveness, larger populations in emerging countries may benefit from simplified imaging tools without financial burden in the case of DR screening[69]. 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 cases[64].

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 telehealth[70].

As the internet has become part of the routine care delivery at a faster pace than previously anticipated[64], 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 facet that deserves to be addressed attentively in the face of teleophthalmology development is the doctor-patient relationship[72]. 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 technologic 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.

REFERENCES

1. Alexander AD. Impacts of telemation on modern society. On theory and practice of robots and manipulators. Berlin, Heidelberg: Springer Berlin Heidelberg; 1972. p.121-36.
2. Dunn EV, Conrath DW, Bloor WG, Tranquada B. An evaluation of four telemedicine systems for primary care. Health Serv Res. 1977;12(1):19-29.
3. Bashshur RL. Telemedicine/telehealth: an international perspective. Telemedicine and health care. Telemed J E Health. 2002;8(1):5-12.
4. Staub FJ. OR consultation by telemedicine. AORN J. 1977;25(6):1169-78.
5. Caffery LJ, Farjian M, Smith AC. Telehealth interventions for reducing waiting lists and waiting times for specialist outpatient services: A scoping review. J Telemed Telecare. 2016;22(8):504-12.
6. Liddy C, Rowan MS, Afkham A, Maranger J, Keely E. Building access to specialist care through e-consultation. Open Med. 2013;7(1):e1-8.
7. Kirsh S, Carey E, Aron DC, Cardenas O, Graham G, Jain R, et al. Impact of a national specialty e-consultation implementation project on access. Am J Manag Care. 2015; 21(12):e648-54.
8. Wilson LS, Maeder AJ. Recent directions in telemedicine: review of trends in research and practice. Healthc Inform Res. 2015;21(4):213-22.
9. Flowers CW, Jr., Baker RS, Khanna S, Ali B, March GA, Scott C, et al. Teleophthalmology: rationale, current issues, future directions. Telemed J. 1997;3(1):43-52.
10. Vidmar DA. Plea for standardization in teledermatology: a worm's eye view. Telemed J. 1997;3(2):173-8.
11. Perednia DA, Gaines JA, Butruille TW. Comparison of the clinical informativeness of photographs and digital imaging media with multiple-choice receiver operating characteristic analysis. Arch Dermatol. 1995;131(3):292-7.
12. Li HK. Telemedicine and ophthalmology. Surv Ophthalmol. 1999;44(1):61-72.
13. Gupta A, Cavallerano J, Sun JK, Silva PS. Evidence for telemedicine for diabetic retinal disease. Semin Ophthalmol. 2017;32(1):22-8.
14. Mansberger SL, Gleitsmann K, Gardiner S, Sheppler C, Demirel S, Wooten K, et al. Comparing the effectiveness of telemedicine and traditional surveillance in providing diabetic retinopathy screening examinations: a randomized controlled trial. Telemed J E-Health. 2013;19(12):942-8.
15. Whited JD. Accuracy and reliability of teleophthalmology for diagnosing diabetic retinopathy and macular edema: a review of the literature. Diabetes Technol Ther. 2006;8(1):102-11.
16. Silva PS, Cavallerano JD, Sun JK, Noble J, Aiello LM, Aiello LP. Nonmydriatic ultrawide field retinal imaging compared with dilated standard 7-field 35-mm photography and retinal specialist examination for evaluation of diabetic retinopathy. Am J Ophthalmol. 2012;154(3):549-59. e2.
17. Talks SJ, Manjunath V, Steel DH, Peto T, Taylor R. New vessels detected on wide-field imaging compared to two-field and seven-field imaging: implications for diabetic retinopathy screening image analysis. Br J Ophthalmol. 2015;99(12):1606-9.
18. Mansberger SL, Sheppler C, Barker G, Gardiner SK, Demirel S, Wooten K, Becker TM. Long-term comparative effectiveness of telemedicine in providing diabetic retinopathy screening examinations: A randomized clinical trial. JAMA Ophthalmol. 2015; 133(5):518-25.
19. Malerbi FK, Morales PH, Farah ME, Drummond KR, Mattos TC, Pinheiro AA, Mallmann F, Perez RV, Leal FS, Gomes MB, Dib SA; Brazilian Type 1 Diabetes Study Group. Comparison between binocular indirect ophthalmoscopy and digital retinography for diabetic

retinopathy screening: the multicenter Brazilian Type 1 Diabetes Study. Diabetol Metab Syndr. 2015;7:116.
20. Gomez-Ulla F, Fernandez MI, Gonzalez F, Rey P, Rodriguez M, Rodriguez-Cid MJ, et al. Digital retinal images and teleophthalmology for detecting and grading diabetic retinopathy. Diabetes Care. 2002;25(8):1384-9.
21. Surendran TS, Raman R. Teleophthalmology in diabetic retinopathy. J Diabetes Sci Technol. 2014;8(2):262-66.
22. Li Z, Wu C, Olayiwola JN, Hilaire DS, Huang JJ. Telemedicine-based digital retinal imaging vs standard ophthalmologic evaluation for the assessment of diabetic retinopathy. Conn Med. 2012;76(2):85-90.
23. Park DW, Mansberger SL. eye disease in patients with diabetes screened with telemedicine. Telemed J E Health. 2017;23(2):113-8.
24. Li HK, Horton M, Bursell SE, Cavallerano J, Zimmer-Galler I, Tennant M, Abramoff M, Chaum E, Debuc DC, Leonard-Martin T, Winchester M, American Telemedicine Association Diabetic Retinopathy Telehealth Practice Recommendations Working Group, Lawrence MG, Bauman W, Gardner WK, Hildebran L, Federman J. Telehealth practice recommendations for diabetic retinopathy, second edition. Telemed J E Health. 2011;17(10):814-37.
25. Rudnisky CJ, Tennant MT, Weis E, Ting A, Hinz BJ, Greve MD. Web-based grading of compressed stereoscopic digital photography versus standard slide film photography for the diagnosis of diabetic retinopathy. Ophthalmology. 2007;114(9):1748-54.
26. Wang YT, Tadarati M, Wolfson Y, Bressler SB, Bressler NM. Comparison of prevalence of diabetic macular edema based on monocular fundus photography vs optical coherence tomography. JAMA Ophthalmol. 2016;134(2):222-8.
27. Kozak I, Payne JF, Schatz P, Al-Kahtani E, Winkler M. Teleophthalmology image-based navigated retinal laser therapy for diabetic macular edema: a concept of retinal telephotocoagulation. Graefes Arch Clin Exp Ophthalmol. 255(8):1509-13.
28. Kanjee R, Dookeran RI, Mathen MK, Stockl FA, Leicht R. Six-year prevalence and incidence of diabetic retinopathy and cost-effectiveness of tele-ophthalmology in Manitoba. Can J Ophthalmol. 2016;51(6):467-70.
29. Jeganathan VS, Hall HN, Sanders R. Electronic referrals and digital imaging systems in ophthalmology: A global perspective. Asia Pac J Ophthalmol (Phila). 2017;6(1):3-7.
30. Kovacs G, Somogyvari Z, Maka E, Nagyjanosi L. Bedside ROP screening and telemedicine interpretation integrated to a neonatal transport system: Economic aspects and return on investment analysis. Early Hum Dev. 2017;106-107:1-5.
31. Pathipati AS, Moshfeghi DM. Telemedicine applications in pediatric retinal disease. J Clin Med. 2017;6(4). pii: E36.
32. Sekeroglu MA, Hekimoglu E, Sekeroglu HT, Arslan U. Alternative methods for the screening of retinopathy of prematurity: binocular indirect ophthalmoscopy vs wide-field digital retinal imaging. Eye (Lond). 2013;27(9):1053-7.
33. Richter GM, Williams SL, Starren J, Flynn JT, Chiang MF. Telemedicine for retinopathy of prematurity diagnosis: evaluation and challenges. Surv Ophthalmol. 2009;54(6):671-85.
34. Weaver DT. Telemedicine for retinopathy of prematurity. Curr Opin Ophthalmol. 2013; 24(5):425-31.
35. Kandasamy Y, Smith R, Wright I, Hartley L. Use of digital retinal imaging in screening for retinopathy of prematurity. J Paediatr Child Health. 2013;49(1):E1-5.
36. Sreelatha OK, Ramesh SV. Teleophthalmology: improving patient outcomes? Clin Ophthalmol. 2016;10:285-95.
37. Vinekar A, Mangalesh S, Jayadev C, Gilbert C, Dogra M, Shetty B. Impact of expansion of telemedicine screening for retinopathy of prematurity in India. Indian J Ophthalmol. 2017;65(5):390-95.
38. Myung JS, Gelman R, Aaker GD, Radcliffe NM, Chan RV, Chiang MF. Evaluation of vascular disease progression in retinopathy of prematurity using static and dynamic retinal images. Am J Ophthalmol. 2012;153(3):544-51 e2.
39. Quinn GE, Ells A, Capone A, Jr., Hubbard GB, Daniel E, Hildebrand PL, et al. Analysis of discrepancy between diagnostic clinical examination findings and corresponding evaluation of digital images in the telemedicine approaches to evaluating acute-phase retinopathy of prematurity study. JAMA Ophthalmol. 2016;134(11):1263-70.
40. Morrison D, Bothun ED, Ying GS, Daniel E, Baumritter A, Quinn G. Impact of number and quality of retinal images in a telemedicine screening program for ROP: results from the e-ROP study. J AAPOS. 2016;20(6):481-85.
41. Owsley C, McGwin G, Jr., Lee DJ, Lam BL, Friedman DS, Gower EW, et al. Diabetes eye screening in urban settings serving minority populations: detection of diabetic retinopathy and other ocular findings using telemedicine. JAMA Ophthalmol. 2015; 133(2):174-81.
42. Chasan JE, Delaune B, Maa AY, Lynch MG. Effect of a teleretinal screening program on eye care use and resources. JAMA Ophthalmol. 2014;132(9):1045-51.
43. Duchin KS, Asefzadeh B, Poulaki V, Rett D, Marescalchi P, Cavallerano A. Teleretinal imaging for detection of referable macular degeneration. Optom Vis Sci. 2015;92(6): 714-8.
44. Chew EY, Clemons TE, Harrington M, Bressler SB, Elman MJ, Kim JE, et al. Effectiveness of different monitoring modalities in the detection of neovascular age-related macular degeneration: The home study, report number 3. Retina. 2016;36(8):1542-7.
45. Sim DA, Mitry D, Alexander P, Goverdhan S, Aslam T, Tufail A, et al. The evolution of teleophthalmology programs in the united kingdom: beyond diabetic retinopathy screening. J Diabetes Sci Technol. 2016;10(2):308-17.
46. Cameron JR, Ahmed S, Curry P, Forrest G, Sanders R. Impact of direct electronic optometric referral with ocular imaging to a hospital eye service. Eye (Lond). 2009;23(5): 1134-40.
47. Bar-Sela SM, Glovinsky Y. A feasibility study of an Internet-based telemedicine system for consultation in an ophthalmic emergency room. J Telemed Telecare. 2007;13(3): 119-24.
48. Kumar S, Yogesan K, Hudson B, Tay-Kearney ML, Constable IJ. Emergency eye care in rural Australia: role of internet. Eye (Lond). 2006;20(12):1342-4.
49. Ribeiro AG, Rodrigues RA, Guerreiro AM, Regatieri CV. A teleophthalmology system for the diagnosis of ocular urgency in remote areas of Brazil. Arq Bras Oftalmol. 2014; 77(4):214-8.
50. Wedekind L, Sainani K, Pershing S. Supply and perceived demand for teleophthalmology in triage and consultations in California emergency departments. JAMA Ophthalmol. 2016. doi: 10.1001/jamaophthalmol.2016.0316.
51. Perez MA, Bruce BB, Newman NJ, Biousse V. The use of retinal photography in nonophthalmic settings and its potential for neurology. Neurologist. 2012;18(6):350-5.
52. Bremner F, Kennedy C, Rees A, Acheson J, Murdoch I. Usefulness of teleconsultations in neuro-ophthalmology. J Telemed Telecare. 2002;8(5):305-6.
53. Bruce BB, Newman NJ, Perez MA, Biousse V. Non-mydriatic ocular fundus photography and telemedicine: past, present, and future. Neuroophthalmology. 2013;37(2). doi: 10.3109/01658107.2013.773451.
54. Bruce BB. Nonmydriatic ocular fundus photography in the emergency department: How it can benefit neurologists. Semin Neurol. 2015;35(5):491-5.
55. Tuulonen A, Ohinmaa T, Alanko HI, Hyytinen P, Juutinen A, Toppinen E. The application of teleophthalmology in examining patients with glaucoma: a pilot study. J Glaucoma. 1999;8(6):367-73.
56. Clarke J, Puertas R, Kotecha A, Foster PJ, Barton K. Virtual clinics in glaucoma care: face-to-face versus remote decision-making. Br J Ophthalmol. 2016;101(7):892-5.
57. Thomas SM, Jeyaraman MM, Hodge WG, Hutnik C, Costella J, Malvankar-Mehta MS. The effectiveness of teleglaucoma versus in-patient examination for glaucoma screening: a systematic review and meta-analysis. PLoS One. 2014;9(12):e113779.
58. Thomas S, Hodge W, Malvankar-Mehta M. The Cost-Effectiveness Analysis of Teleglaucoma Screening Device. PLoS One. 2015;10(9):e0137913.
59. Finamor LP, Martins MC, Muccioli C, Singulem D, Lopes PR, Belfort R, Jr. [Teleophthalmology as an auxiliary approach for the diagnosis of infectious and inflammatory ocular diseases: evaluation of an asynchronous method of consultation]. Rev Assoc Med Bras. (1992) 2005;51(5):279-84. Portuguese.
60. Tan JC, Poh EW, Srinivasan S, Lim TH. A pilot trial of tele-ophthalmology for diagnosis of chronic blurred vision. J Telemed Telecare. 2013;19(2):65-9.
61. Host BK, Turner AW, Muir J. Real-time teleophthalmology video consultation: an analysis of patient satisfaction in rural Western Australia. Clin Exp Optom. 2017;Apr 23.
62. Threlkeld AB, Fahd T, Camp M, Johnson MH. Telemedical evaluation of ocular adnexa and anterior segment. Am J Ophthalmol. 1999;127(4):464-6.
63. Rayner S, Beaconsfield M, Kennedy C, Collin R, Taylor P, Murdoch I. Subspecialty adnexal ophthalmological examination using telemedicine. J Telemed Telecare. 2001;7 Suppl 1:29-31.
64. Verma M, Raman R, Mohan RE. Application of tele-ophthalmology in remote diagnosis and management of adnexal and orbital diseases. Indian J Ophthalmol. 2009; 57(5):381-4.
65. Woo TL, Francis IC, Wilcsek GA, Coroneo MT, McNab AA, Sullivan TJ. Australasian orbital and adnexal Wegener's granulomatosis. Ophthalmology. 2001;108(9):1535-43.
66. Camara JG, Zabala RR, Henson RD, Senft SH. Teleophthalmology: the use of real-time telementoring to remove an orbital tumor. Ophthalmology. 2000;107(8):1468-71.
67. Tan IJ, Dobson LP, Bartnik S, Muir J, Turner AW. Real-time teleophthalmology versus face-to-face consultation: A systematic review. J Telemed Telecare. 2017;23(7):629-38.
68. Gulshan V, Peng L, Coram M, Stumpe MC, Wu D, Narayanaswamy A, et al. Development and validation of a deep learning algorithm for detection of diabetic retinopathy in retinal fundus photographs. JAMA. 2016;316(22):2402-10.
69. Sharma A. Emerging simplified retinal imaging. Dev Ophthalmol. 2017;600:56-62.
70. Scott RE, Mars M. The same language speak we do - consensus terminology for telehealth. Stud Health Technol Inform. 2016;231:99-109.
71. Siwicki B. Applying the Internet in health care. Health Data Manag. 1998;6(3):38-40, 42-5, 47-8.
72. Stanberry B. Telemedicine: barriers and opportunities in the 21st century. J Intern Med. 2000;247(6):615-28.