Telemedicine utilization in ophthalmology: a review

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ABSTRACT

Telemedicine is gaining the attention of an increasing number of medical researchers. It combines technology and medicine and has ushered in a new era for the prevention, diagnosis, treatment, and monitoring of disease. As ophthalmology relies heavily on visual images, it is not surprising that ophthalmologists have quickly adapted to telemedicine. The aim of this article is to assess the current state of teleophthalmology given the sudden surge in telemedicine demand as a result of the coronavirus disease 2019 (COVID-19) pandemic. A structured review of the literature was carried out from 2000 to 2021. A literature search was conducted through several search engines, but mainly through Google Scholar and Saudi Digital Library, the latter containing hundreds of medical databases, including PubMed, Medline, and Web of Science. The COVID-19 pandemic created a demand for healthcare delivery that limits in-person examination and potential viral exposure. Teleophthalmology allows ophthalmologists to continue caring for their patients while keeping themselves and their patients safe. Although challenges to its full implementation still exist, the pandemic has accelerated its adoption. As a result, teleophthalmology is foreseen to play an integral role in providing efficient and high-quality care in the near future.

Keywords: Telemedicine, teleophthalmology, COVID-19, artificial intelligence, neural networks.

Introduction

The wide access to information technology has enabled such technology to reach all aspects of modern life. It has led to the promotion of more possibilities for progress by improving efficiency, effectiveness, productivity, and innovation. In medicine, technological development has a valuable role: assisting in gaining medical knowledge and targeting distinct facets of health-related issues. Telemedicine, which combines technology and medicine, has ushered in a new era for the prevention, diagnosis, and treatment of health conditions by offering different reliable modes of medical information provision (e.g., texts, sounds, and images/videos) using telecommunication technology (e.g., telephones and computer screens). The World Health Organization defined telemedicine as “the delivery of healthcare services, where distance is a critical factor, by all healthcare professionals using information and communication technologies for the exchange of valid information for diagnosis, treatment, and prevention of disease and injuries, research and evaluation, and for the continuing education of healthcare providers, all in the interests of advancing the health of individuals and their communities” [1]. One of the earliest and most famous uses of telemedicine was in 1959, when a two-way closed-circuit television link was established between Norfolk State Hospital and Nebraska Psychiatric Institute for psychiatric consultations [2].

Telemedicine is beneficial for patients, particularly those in underserved/rural areas or in developing countries without a good health infrastructure. It can also be beneficial between two or more physicians, such as in consultations [3]. Ophthalmology, a visually intensive medical specialty often found at the forefront of technological advances, is also experimenting with telemedicine. As it relies heavily on visual images for screening, diagnosis, treatment, and monitoring of disease, it is not surprising that ophthalmologists have...
adapted quickly to it [4]. The coronavirus disease 2019 (COVID-19) pandemic has forced healthcare systems to adapt rapidly to new ways of coping, which has created a demand for virtual care, and even though the utilization of telemedicine was limited prior to COVID-19, it is becoming the new normal [5,6].

In the study reported herein, a literature review was conducted to explore the impact of the COVID-19 pandemic on telemedicine, particularly teleophthalmology, and the efficacy, benefits to physicians and patients, and advancements of such and the barriers to its implementation.

**Methods**

A structured literature review was conducted from 2000 to 2021. A literature search was first conducted on several search engines, including Google Scholar and Saudi Digital Library, the latter containing hundreds of medical databases, such as PubMed, Medline, and Web of Science. The following keywords were used for the search: teleophthalmology, telemedicine, telehealth, teleconsultation, telescreening, and artificial intelligence (AI). Extension words were also used, such as efficacy, patient outcome, benefits, patient satisfaction, barriers, advancement, impact, and COVID-19. Most of the related papers were included to be able to examine all the publications that meet the search criteria. The exclusion criteria focused on non-peer-reviewed papers (e.g., letters, comments, and opinions), conference abstracts, and working papers. A total of 113 refereed research papers were collected, and 50 of these were considered meeting the set criteria.

**Teleophthalmology efficacy in ophthalmic diseases**

In the United States, despite the evidence-based treatments of people below the age of 60 and the recommendation of annual dilated examinations for them, diabetic retinopathy (DR) remains the leading cause of vision loss in such patients [7]. This may be on account of the fact that only 35%-50% of the patients receive the recommended annual health examination [7,8]. Traditionally, retinal evaluation for DR involves dilated fundus evaluation. The Veterans Affairs Medical Center in the United States has been able to increase its annual retinal exam rate for diabetic patients from 50% to 75% through the use of a digital video retinal imaging device [9]. In India, non-mydriatic fundus cameras have been installed in general hospitals, diabetic clinics, and testing centers [10], and the ocular images obtained therefrom are shared with ophthalmologists. The use of the new technology has decreased the travel time for eye examinations and has allowed screening at younger ages and the screening of more patients [9,10]. In Europe, a multi-center study with a total of 390 diabetic patients was carried out in 4 different countries over a period of 3 months to determine the feasibility of using Tele-Ophthalmological Services Citizen-Centered Applications for detecting DR. The results revealed that 99% of the images were determinable, allowing a retinopathy grade to be given to the patients [11]. In addition, multiple studies have found that teleophthalmology has 62.5%-98.2% sensitivity and 76.6%-98.7% specificity for diagnosing DR compared to the traditional clinical examination [12,13]. DR screening using telemedicine has been determined to be accurate, reliable, sustained, and cost-effective. It also helps in grading the disease in terms of its severity and helps with disease management [12,14-16].

Retinopathy of prematurity (ROP), a disease of the retina that causes abnormal vessel proliferations in preterm and/or low-birth-weight infants, is also being targeted in teleophthalmology. For instance, retinal photography through telemedicine allows pediatric and retinal ophthalmologists to assess and monitor infants remotely, thus allowing expert evaluation while creating an objective record of disease progression [17,18]. The articles reviewed in the present study reported that wide-field digital imaging (WFDI) of premature infant retinas is more competent and time-saving than bedside binocular ophthalmoscopy [19,20]. A 6-year retrospective analysis of a program between multiple children’s hospitals and neonatal intensive care units in the United States has shown 100% sensitivity and specificity [8,21]. Moreover, a systematic review of tele-ROP was conducted by the American Academy of Pediatrics and the American Academy of Ophthalmology, and it was found that tele-ROP was able to detect referral-warranted ROP with 98.2% sensitivity, 80.2% specificity, and 99.6% negative predictive values (NPVs) [22]. In Germany, a multicenter field study was conducted on the 6-year results of the use of WFDI telemedicine designed to reduce the risk of blindness from ROP. It was found that a total of 1,222 premature babies at risk for blindness had been screened with WFDI. The incidence of clinically relevant ROP also appeared to be significantly similar to that reported in other West European countries (27.6%). Furthermore, the sensitivity for detecting suspected treatment-requiring ROP was 100% [21]. In other literature, it is indicated that neonatal intensive care unit nurses used fundus digital photography for premature neonates at risk of developing ROP, and the result was shown to be at the level of that of the conventional binocular indirect ophthalmoscopy used by ophthalmologists [23,24].

Regarding age-related macular degeneration (AMD), there are currently no known active hospital- or clinic-based teleophthalmology screening programs for it. Multiple studies have supported the use of non-mydriatic digital fundus cameras in detecting AMD, and some authors have suggested that incorporating optical coherence tomography images will enhance its reliability [19,25]. ForeseeHome is a home-use device that relies on hyperacuity perimetry to help detect metamorphopsia. The test results are analyzed, and the patient and ophthalmologist are notified if a significant change is detected [26-28]. Notably, comparable results between remote diagnostic imaging and the standard examination...
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Ribeiro et al. [40] conducted a study on the use of teleophthalmology with that obtained via in-person examination by a glaucoma specialist showed a moderate agreement between the two, with a 77.5% positive predictive value (PPV) and an 82.2% NPV [26]. Thomas et al. [31] found low disagreement and misclassification rates between them (3.4% and 1.9%, respectively). Teleophthalmology was also found to be cost-effective in screening glaucoma, with its cost less than 80% of the in-person examination cost [32], and it is possibly a more effective method of diagnosis [25]. A meta-analysis study revealed that tele-glaucoma screening has higher specificity for glaucoma detection than the traditional assessment [31].

A tele-glaucoma screening study with a total of 1,729 patients revealed that 89% of the cases had satisfactory images and that there was an 81% agreement between the hospital and the optometrists in the study about normal and suspected test results. Additionally, 80 patients were newly diagnosed with glaucoma and only 27% screened patients required additional hospital testing [33]. The tele-glaucoma screening study conducted by Keenan et al. [34] involving 1,733 individuals and a 3-year assessment by optometrists at a remote area demonstrated high tele-glaucoma screening efficacy and found that tele-glaucoma screening is a useful glaucoma referral evaluation method that helps reduce false-positive referrals to hospitals. Above all, numerous studies have exhibited a significant agreement between using telemedicine in glaucoma screening and follow-up and using the conventional glaucoma examination. Meanwhile, there is evidence of a high level of true-positive referrals from tele-glaucoma, with a decrease in false-positive referrals [33-36]. A study with 24,257 patients reported that virtual clinics are useful in decreasing the cases of patient misdiagnosis and indicated that telemedicine has 41.3% sensitivity, 89.6% specificity, a 77.58% PPV, and an 82.2% NPV in diagnosing glaucoma [36].

Regarding the use of telemedicine in the emergency department, 95% of 292 administrators and clinicians in 71 hospitals implementing telemedicine agreed that “tele-emergency improves the quality of care at their facility.” Additionally, the use of teleophthalmology has been found to help improve patient care in emergency settings [37]. In the United States, the University of Pittsburgh has established a teleophthalmology program in emergency settings, in which iPhones with an ophthalmoscope adaptor were given to emergency department physicians. As a result, remote ophthalmologists were able to triage patients, and “accurate and safe triage decisions” were made with the method [38]. In Brazil, teleophthalmology examinations were reported to have 74% accuracy compared to face-to-face clinical examinations [39]. Ribeiro et al. [40] conducted a study on the use of teleophthalmology for diagnosing ocular emergencies in remote areas in Brazil and found that the said technology had 92.85% sensitivity, 81.94% specificity, 85% accuracy, 66.66% PPV, and 96.72% NPV in identifying ocular emergencies. In addition, the rate of referrals has decreased as a result of the use of such technology [40].

A recent systematic review of 44 teleophthalmology studies in Europe concluded that teleophthalmology is a reliable method of screening and follow-up and can thus be introduced in ophthalmic care [41]. Many studies have suggested that teleophthalmology is relatively as effective as the traditional face-to-face clinical examination in diagnosing, monitoring, and managing patients with vascular proliferative disease and optic nerve pathologies [19]. In Australia, according to an impact assessment report of teleophthalmology services during a 1-year period, only 3% of the patients needed referral after consultation through telemedicine [42]. In the United States, a retrospective study with 1,935 patients who underwent diabetic telereferal community-based screening was conducted. The aim of the study was to evaluate the accuracy of referrals and final diagnoses via telescreening and to compare this with the accuracy of face-to-face clinical examination. The results showed 90.4% total agreement between telescreening and face-to-face clinical examination, with 73.6% total sensitivity [43]. A scoping review with 62 articles about models of care in teleophthalmology concluded that “teleophthalmology is feasible for consulting, screening, triage and remote supervision applications across a broad range of ophthalmic conditions” [44]. Hong et al. [45] showed 97% ophthalmologist agreement with the referrals based on teleophthalmology screening. The efficacy and reliability of teleophthalmology have thus been proven by many studies.

Benefits to physicians (non-ophtalmologists and ophthamologists)

Benefits to non-ophtalmologists

Non-ophtalmologists can screen patients for certain conditions using teleophthalmology [45]. Furthermore, teleophthalmology has made it possible for physicians to connect with an ophthalmologist from anywhere in the world, thus being able to obtain aid from an ophthalmologist in tricky relevant cases. A physician can effortlessly seek the opinion of an expert via teleophthalmology, which can eventually improve the overall care provided to the patient [46].

Benefits to ophthamologists

The use of teleophthalmology and electronic medical images can make the examination time shorter. Moreover, the use of electronic prescriptions can address the problem of illegible physician handwriting and can greatly minimize mistakes in prescriptions, such as in prescribed drugs and dosages [46].

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Telemonitoring is one of the greatest aspects of teleophthalmology. It gives ophthalmologists opportunities to learn relevant procedures, especially the complex ones, and to have access to these. It can also help them train other ophthalmologists in underserved communities and countries [45].

Benefits to patients

Patients residing in developing countries or in remote areas can benefit much from teleophthalmology as it will allow them to consult a competent physician while saving time, effort, and money. Furthermore, they can easily seek a second opinion if they so desire. Patients with chronic conditions, such as DR, can also have their conditions monitored by their physician even without going to the hospital [46].

Noteworthy savings are made possible by electronic consultations as they cost less than the traditional in-person consultations. Additionally, more costs are cut as unnecessary referrals and tests are avoided [47].

During the COVID-19 pandemic, when patients understandably fear visiting hospitals, teleophthalmology gives them the medical attention and care that they need while protecting them from viral exposure [48].

Barriers

Although teleophthalmology revolutionizes the way healthcare is delivered, there are still numerous barriers to its implementation. One of these relates to the cost of building the ecosystem, including imaging equipment, hardware, and storage. Building a complete and comprehensive ecosystem will require a huge budget to be spent over several years according to the project phases. It is clear from different studies that the hardware will have the lowest cost and that training and expertise building will represent the major part of the cost. Running and maintaining the whole system will also share the cost. Another barrier is physicians’ lack of familiarity with teleophthalmology as a screening method, which has been raised as a concern [49] and is a liability likewise manifested by patients [50]. In addition, in several studies, most of the participating ophthalmologists reported “low confidence” in their ability to make decisions on the basis solely of images. Moreover, as the use of telemedicine continues to rise, cybersecurity and patient privacy are expected to become more crucial concerns for healthcare providers. The success of teleconsultations and the reliability of the decisions to be made in such also rely on the quality and speed of the internet connection. The scarcity of applications in languages other than English also affects the accessibility of such advanced technologies.

Taking these implementation barriers into consideration is important for enhancing the overall use of teleophthalmology. Hence, with improvements in image processing and better integration with electronic medical records, teleophthalmology will likely become a far more accepted and utilized modality.

Advancements and the future of teleophthalmology

The future of teleophthalmology is seen to involve the integration therewith of AI, a branch of computer science that enables computers to function independently in a manner similar to humans [49]. AI encompasses many different fields with a shared purpose of developing systems capable of imitating intelligent behaviors. One of the main principles of AI is machine learning, which allows computers to process input data and make successful predictions or outputs by repeatedly learning the existing representative materials. The applications of AI in ophthalmology are mainly focused on diseases with high incidence, such as DR, AMD, glaucoma, ROP, and age-related or congenital cataract. Promising levels of detection sensitivity and accuracy have been achieved, but they have seldom reached 100% [50]. This may be because AI depends on the availability of clean and high-quality healthcare data and can thus be achieved only with careful execution and liberal funding. AI-assisted screening and diagnosis of high-incidence diseases will enhance medical care and will reduce the excessive burden of healthcare systems.

Results and Conclusion

Technology evolution and advancement are usual consequences of global disasters like the COVID-19 pandemic. The mandatory social distancing protocol during the said pandemic has promoted the use of telemedicine by both patients and physicians [49] as it is the safest interactive method between them. However, 74% of the patients had not heard of telemedicine as an alternative option before the COVID-19 pandemic. Furthermore, newly developed technologies have special requirements and entail high operational costs for effective implementation. However, the screening cost decreases as the number of screened patients increases, and during the current pandemic, several major platforms have reported a 257%-700% increase in visits. Therefore, the major increase in the number of patients screened via telemedicine can result in remarkable cost savings for the healthcare system in the future [50]. To conclude, due to the COVID-19 pandemic, smartphone and camera advancements alongside other technologies may lead to big changes for the future of teleophthalmology. Accessible remotely controlled slit-lamp devices, non-mydriatic fundus cameras, and OCT machines can be developed and used for public places in the future.

List of Abbreviations

AI  Artificial Intelligence
AMD  Age-Related Macular Degeneration
COVID-19  Coronavirus Disease 2019
DR  Diabetic Retinopathy
NPV  Negative Predictive Value
PPV  Positive Predictive Value
Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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References


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