REVIEW

sciendo

10.2478/AMB-2023-0012

TELEMEDICINE IN OPHTHALMOLOGY: LESSONS FROM THE COVID-19 ERA AND BEYOND

S. Uzunova[1,2], K. Kilova[3]

[1]Faculty of Public Health, Medical University of Plovdiv – Bulgaria
[2]Clinic of Ophthalmology "Dr. Uzunova", Plovdiv – Bulgaria
[3]Department of Medical Informatics, Biostatistics and e-Learning, Faculty of Public Health, Medical University of Plovdiv – Bulgaria

Abstract. *The progress of information and communication technologies in the era of COVID-19 created an unprecedented opportunity for medicine to adapt to new models of care. Telemedicine and telehealth have enabled medical care at a distance in various fields, including ophthalmology.* ***The aim*** *of this article is to review the current state and the opportunities for telemedicine in ophthalmology.* ***Materials and methods:*** *PubMed, ScienceDirect Database, Google Scholar databases, as well as official sites of various governmental and non-governmental institutions were explored. The search was conducted between May 1, 2022 and July 31, 2022 using as key words "teleophthalmology"; "telemedicine/telehealth and ophthalmology"; "ophthalmology and COVID-19".* ***Results:*** *87 primary sources were reviewed. An exploratory analysis of the current state and application of telemedicine in ophthalmology was made.* ***Conclusion:*** *A great number of innovations have created an environment allowing for teleophthalmology to flourish, whereas the COVID-19 epidemic has accelerated the development and adoption of these digital technologies. Telemedicine has become an extremely valuable tool during a pandemic, and even if it would never fully replace in the person-to-person patient visits, it certainly has an important role in our dynamic and high-tech world.*

Key words: *teleophthalmology, telemedicine, telehealth, COVID-19, information and communication technologies, healthcare*

Corresponding author: *Kristina Kilova, PhD, Department of Medical Informatics, Biostatistics and e-Learning, Faculty of Public Health, Medical University of Plovdiv, Bulgaria; e-mail: k_kilova@yahoo.com*

Received: *26 September 2022;* ***Accepted:*** *6 November 2023*

INTRODUCTION

The COVID-19 pandemic, announced by the World Health Organization in March 2020, fundamentally changed the practice of medicine. Doctors had to live in a new reality. They had daily to apply incredible, often creative, and innovative methods in increasingly complex conditions. The situation unfolded in real time and the push was to make smart decisions that would keep the public body safe while providing the best possible medical care. Its safe, timely and efficient provision was becoming an increasing challenge. Necessary but non-urgent examinations and operations were postponed, often indefinitely. At the same time, efforts to limit the spread of the virus placed patients in a situation where they had to choose between receiving medical care and risking exposure to the coronavirus infection (COVID-19).

COVID-19 had left no aspect of modern life untouched; its impact was unprecedented and long-lasting. In addition to unexpected consequences for patients with existing eye problems and difficult access to medical care, there were also consequences for everyone else – increased prevalence of dry eye syndrome for computer workers, development of myopia in children. Remote work and learning inevitably lead to increased screen time – a change that had a significant impact on eye health. Studies showed that the average number of blinks dropped from about 18 per minute under normal conditions to three or four per minute while looking at a screen. These flashes were not as strong or complete as those made under normal conditions. Low humidity and restricted indoor air flow had been suggested to induce or exacerbate eye conditions [1].

There are good reasons why progressive myopia has become a global epidemic in the last two or three decades: children are spending much less time outdoors than they used to, at the expense of close viewing at devices such as smartphones and tablets [2].

During the pandemic, especially during the weeks of strict isolation, distance learning became a reality for many children and young people. As a result, they spent even longer hours indoors in front of computer and tablet screens, neglecting both outdoor time and time spent looking at distant points like the classroom blackboard. Meanwhile, studies showed that one hour of active outdoor activity reduced significantly the risk of progressive myopia – by as much as 45% [3]. Children who used electronic devices for longer than six hours a day and had less than three hours of outdoor activity per week had twice the risk of developing near-sightedness. All this led to the increase in incidence of myopia.

Social distancing, quarantine and lockdown periods prevented many patients from receiving regular eye exams, limiting their access to treatment. They were reluctant to leave their homes, and routine examinations were cancelled or postponed. At the same time, planned operations were suspended. Shortages of medical professionals due to illness or quarantine further limited the ability to follow up and monitor patients. Chronic eye conditions such as diabetic retinopathy (DR), age-related macular degeneration (AMD) and glaucoma need routine periodic outpatient screening and monitoring, regular follow-up tests, perimetry exams and optical coherence tomography (OCT). Common eye emergencies such as retinal detachment and acute angle-closure glaucoma, which require timely diagnosis and specialist intervention, were cumbersome and difficult to manage in this setting. Quarantine and stay-at-home prescriptions could lead to adverse psychological consequences, whereby patients may refuse to seek immediate medical care and may limit their access to appropriate eye care [4].

Eye examinations are extremely difficult to perform in compliance with safety protocols. The use of portable diagnostic equipment such as a handheld tonometer or bio-microscope reduces the accuracy compared to gold standards in eye diseases. Preliminary data suggested that nearly one-third of patients with COVID-19 might have nonspecific ocular manifestations consistent with conjunctivitis, such as epiphora, conjunctival hyperemia, and chemosis. Although these manifestations usually occur in patients with a more severe course, those with conjunctivitis as a first symptom were identified [5].

Significant advances in information and communication technologies allow the application of remote medical care in various fields, including ophthalmology. Telemedicine is defined as the use of digital means and information exchange to provide health care with remote access [6]. The presence of powerful hardware, advanced software and fast communication enable doctors to diagnose and treat various emergency and chronic eye conditions remotely. The use of telemedicine in ophthalmology presents a unique challenge. The pandemic has dramatically changed the practice in ophthalmology, and home tele-diagnosis solutions allow to remotely monitor the patients, becoming invaluable tools for many practices.

The simultaneous progress of multiple information and communication technologies in 2020 created an unprecedented opportunity for ophthalmology to adapt to new models of care using telehealth supported by digital innovation. These digital innovations include artificial intelligence (AI), 5th generation telecommunication networks (5G) and the Internet of Things (IoT), creating an interdependent digital ecosystem offering opportunities for developing new models of eye care that address the challenges of COVID-19 [7]. Ophthalmology is advancing in these fields in part because of the many imaging-based studies. Telehealth and AI provide synchronous solutions to challenges faced by ophthalmologists and healthcare providers worldwide [8].

The aim of this article was to review and analyse the current state and the opportunities for the application of telemedicine in ophthalmology.

MATERIALS AND METHODS

PubMed, ScienceDirect Database, Google Scholar databases, as well as official sites of various governmental and non-governmental institutions were explored. The search was conducted in the period May 1, 2022 – July 31, 2022 using key words and phrases

such as “tele-ophthalmology”; “telemedicine/telehealth and ophthalmology”; “ophthalmology and COVID-19”.

RESULTS

In response to the COVID-19 pandemic, the American Academy of Ophthalmology (AAO) published guidelines on March 18, 2020, advising the discontinuation of any non-urgent or urgent care [9]. At the Vanderbilt Eye Institute, daily workloads in April 2020 were reduced by approximately 70%. This coincided with an initiative for patient service while minimizing exposure. A contract was signed with Zoom® (Zoom Video Communications, San Jose, CA) for a virtual meeting on the Epic Electronic Medical Record (EMR) platform, and access for each physician and patient was established through a “my health” link. Within four weeks, telemedicine visits increased to account for 18.5% of all visits performed at the Vanderbilt Eye Institute. During the 12-week period following implementation of the telemedicine platform, pediatric and postoperative visits accounted for the largest share (35.7%) of all telemedicine visits, followed by neuro-ophthalmology (22.4%) and oculoplastics (22.4%). The mean age for the follow-up cohort was 36.5 years. On the other hand, regarding retinal diseases, the overwhelming majority of in-person visits (70%) were for intravitreal injections of anti-vascular endothelial factors in AMD [10]. Patients with early visits in their postoperative course following intraocular surgery represented also a significant part of the examinations, given the inability to assess intraocular inflammation and view of the posterior segment using modern telemedicine technologies. Despite these limitations, every ophthalmology subspecialty can successfully use the new telemedicine format although partially.

Physical eye examination, including visual acuity and intraocular pressure, may be difficult or impossible to perform at home. Remote visual acuity testing is available through various apps, but these are not validated and are incompatible with Snellen visual acuity measurements. However, in a study done at the Moorfield Eye Hospital, London UK, involving 350 patients who used the Home Vision Monitor app, 70% of the pilot group felt reassured knowing their vision was being monitored during a pandemic. Approximately 93% of participants thought the app was easy to use, while 85% used it at least once or twice a week. The technology was designed specifically for patients with macular diseases, including neo-vascular age-related macular degeneration (AMD) and diabetes [11].

Remote measurement of intraocular pressure poses similar challenges. The iCare Home Tonometer (iCare Finland Oy) facilitates measurements, but not all patients have such a device. Home technology for optical coherence tomography has been developed for conditions such as age-related macular degeneration (AMD), but access to such a device is difficult in most cases. There are also major gaps in the use of these remote methods and further research is needed, concerning their validation, to allow their use for routine tele-ophthalmic care. In addition to the challenges inherent in ophthalmology itself, any medical center or clinic wishing to offer telemedicine services must also anticipate staff challenges. Considerable preparation work and training are required to ensure these e-visits run smoothly.

The ForeseeHome® AMD Monitoring program was designed by Notal Vision as a monitoring device that can be prescribed to AMD patients as part of a remote diagnostic service provided by the Notal Vision Diagnostic Clinic. Using automated AI-based alert generation, ForeseeHome helps detecting AMD at an earlier stage, allowing early treatment, minimizing the risk of irreversible visual acuity loss. The AREDS2-HOME study, sponsored by the National Eye Institute (NEI), demonstrated that 94% of patients, whose wet AMD had been detected with the ForeseeHome, preserved better vision, compared to 62% of patients whose clinicians used only standard methods for detection such as the Amsler Grid [12]. Patients were instructed to test their eyes daily and the results were automatically transmitted to the clinic at the end of each test. An AI-based classifier identified changes in visual distortions that might indicate a dry-to-wet AMD conversion, and when a statistically significant change in test patterns was detected, an app alerted the treating physician so they can determine the best way to action. The patient’s test data can be accessed by the doctor through a secure portal at any time.

Caffery et al. described 62 discrete tele-ophthalmic models of care ranging from eye disease screening, various consultation services, triage, remote monitoring, educational purposes, and emergency services [13]. Most tele-ophthalmology services relied on digital images captured by primary care physicians or trained technicians with various modalities for capturing the anterior and/or posterior segment of the eye. Images were transmitted electronically for evaluation to an ophthalmologist. Ophthalmology is a high-volume specialty and telemedicine has the potential to offer a cost-effective alternative to a live consultation. This concept plays an important role in rural and remote areas where medical care is not available. In addition, the use of telemedicine may be useful in other special circumstances where access to medical care is limited, such as during natural disasters or when social distancing is necessary, as in the COVID-19 pandemic.

Telemedicine is a convenient way to reduce face-to-face meetings during times of social distancing and self-isolation. Major advantages of telemedicine during the COVID-19 pandemic are lised below:

1. Virtual triage

This technique allows sorting patients out for treatment before they go on site to the health facility. Any reduction in face-to-face consultations improves the protection of patients, doctors and the wider community. The utility of triage will increase with the growing need for social distancing and self-isolation. The key to its successful implementation is a good risk determination strategy based on a minimal data set. In ophthalmology, this may include elements of medical history, objective measurements (visual acuity, intraocular pressure) and imaging tests (photographs, OCT, visual fields). Triage protocols can be optimized through automated intelligent decision trees guiding the collection of structured data. An example of such a platform is the Big Picture Medical, connecting opticians with ophthalmologists from Moorfelds Eye Hospital, London, UK [14]. There is huge potential for this technology to ease the pressure on eye clinics at times of greatest stress.

2. Bio-microscope examination

Advanced imaging and diagnostic techniques raise the question of whether a bio-microscope examination is necessary in all cases. This examination requires the doctor and patient to sit facing each other at a distance of less than one meter. The barrier shields placed on the split lamps since 2020 could reduce, but cannot eliminate the risk of cross-infection. The evaluation of the benefits and risks of this specific exam is critical today, especially since other equipment can also be used to view eye structures.

3. Eye video consultation

This type of consultation is particularly suitable for minor emergencies, oculoplastics and strabismus, for example. Following in the footsteps of tele-dermatology, platforms such as Consultant Connect [15] and Attend Anywhere [16] are being increasingly used in the National Health Service (NHS) in Great Britain. Patients get more convenient and often earlier access to specialized care. For instance, a virtual waiting room can imitate an eye clinic.

A collaboration between the NHS Forth Valley and Moorfelds Eye Hospital has recently demonstrated the world's first tele-examination of an eye in 4K resolution using 5G broadband, where video of a bio-microscope examination was transmitted live between London and a conference in Edinburgh. This was a turning point in tele-ophthalmology as detailed real-time video was successfully provided using readily available equipment. In this way, a remote examination by an on-call ophthalmologist is possible.

4. Communication

Instant messaging applications allow easier communication [17], making the patient's condition more stable – especially when individual team members unexpectedly need to go into isolation. There is an option to take images using your own device and to send them for immediate review by a specialist. This technology provides a "rough and ready" storage and transmission solution at a time when it is physically impossible to visit a clinic. Communication failure is a known key factor and can cause patient anxiety and stress [18, 19].

5. Remote control systems

During a crisis like the COVID-19 pandemic, it is inevitable that hospitals will rush to implement remote management systems that allow them to provide some care for patients who are unable or unwilling to visit the clinic. However, as the crisis passes, we see many of the innovations designed to meet short-term needs becoming long-term solutions. These new systems must be subject to constant control to ensure their quality, their meeting standards, and future developments.

Despite numerous attempts to find a solution and more and more new and innovative devices and apparatus, common criteria, as well as concise guidelines in tele-ophthalmology have not yet been created. A major obstacle to the diagnosis and treatment of eye diseases through telemedicine is the need for a detailed examination, which requires measurement of visual acuity, intraocular pressure, examination of the anterior and posterior eye segments. Although some diagnoses may require the use of specialized equipment, patients feel better if they share their concerns via phone or video call. Often a red or irritated eye turns out to be a subconjunctival hemorrhage or halation. By allowing us to diagnose these conditions remotely, tele-ophthalmology minimizes any potential exposure to COVID-19 for patients and staff while providing medical care.

The establishment of specialized ophthalmic clinics equipped with remote monitoring devices that are self-managed or that can be operated by minimally trained personnel can overcome the gap in the treatment for periods of prolonged quarantine and isolation for patients with COVID-19. For medical staff, remote care is also a safer alternative to in-person screening, allowing more patients to be tested for a given period of time. Advanced imaging techniques such as ultra-wide-field, artificial intelligence-based algorithms, and automated robotic systems have the potential to accelerate the implementation of tele-ophthalmology and to increase its utility. Nevertheless, telemedicine relies heavily on network and Internet capabilities, integration with current electronic medical

records (EMR) and image quality. Existing barriers in the legal, financial, bureaucratic system, as well as conservatism will have to be reviewed on a country-by-country basis. Technological barriers are still a prerequisite for slow large-scale adoption. With improvements in image processing as well as better integration with EMRs, teleophthalmology is likely to become a far more accepted and utilized modality even more so in circumstances where social distancing is required.

Countless innovations have created an environment ripe for telemedicine in ophthalmology, and COVID-19 has accelerated the development and adoption of these digital technologies. Emerging artificial intelligence systems and telecommunication technologies can potentially transform globally the data-rich and image-dependent specialty of ophthalmology. 5G, IoT and AI are gradually introduced in ophthalmology, but the potential for reliably connected machines such as optical coherence tomography (OCT) and fundus cameras and algorithms transforming the delivery of ophthalmic services is significant. Such technolgy is likely to become more prevalent with the increase of the 5G network coverages, enabling better IoT. These technologies may be able to make a key contribution to providing quality, sustainable eye care to all patients. The experience of the pandemic has revealed the utility of telemedicine even in densely populated and well-resourced places. Challenges to the implementation of these technologies remain, including validation, patient acceptance, and end-user education about these technologies [8].

CONCLUSION

The “new normal” for medicine after this pandemic will include telehealth. Although the technology for remote ophthalmic monitoring is not quite ready, patients are willing to accept this approach. This crisis will urge innovation. In ophthalmology, this may mean home testing. Remotely controlled optical coherence tomography devices, mobile applications, and non-mydriatic eye cameras may become more widely available in public places. Telemedicine has become an extremely valuable tool in the current situation, and while it will never completely replace in-person visits, it certainly has a place in today’s dynamic and high-tech world. This pandemic has urged medical professionals to adapt their practices and protocols in creative ways – certainly for the better. These new lessons and tools need to be put forward into the future so that we can evolve and offer our patients the best possible treatment and care methods.

Acknowledgments: *This article is financed under the NGO “Electronic Health in Bulgaria” (e-health), under an agreement with the Ministry of Education and Culture D-01-200/16.11.2018.*

Disclosure Summary: *The authors have nothing to disclose.*

REFERENCES

1. Patel S, Henderson R, Bradley L et al. Effect of visual display unit use on blink rate and tear stability. Optom Vis Sci. 1991;68(11):888-892.
2. Hansen MH, Laigaard PP, Olsen EM, et al. Low physical activity and higher use of screen devices are associated with myopia at the age of 16-17 years in the CCC2000 Eye Study. Acta Ophthalmol. 2020;98(3):315-321.
3. Lingham G, Mackey DA, Lucas R, Yazar S. How does spending time outdoors protect against myopia? A review. Br J Ophthalmol. 2020;104(5):593-599.
4. Brooks SK, Webster RK, Smith LE, et al. The psychological impact of quarantine and how to reduce it: rapid review of the evidence. Lancet. 2020;395(10227):912-920.
5. Wu P, Duan F, Luo C, et al. Characteristics of Ocular Findings of Patients with Coronavirus Disease 2019 (COVID-19) in Hubei Province, China. JAMA Ophthalmol. 2020;138(5):575-578.
6. Lurie N, Carr BG. The Role of Telehealth in the Medical Response to Disasters. JAMA Intern Med. 2018;178(6):745-746.
7. Ting DSW, Carin L, Dzau V, et al. Digital technology and COVID-19. Nat. Med. 2020;26:459-461.
8. Li JO, Liu H, Ting DSJ, et al. Digital technology, tele-medicine and artificial intelligence in ophthalmology: A global perspective. Prog Retin Eye Res. 2021;82:100900.
9. American Academy of Ophthalmology. Important coronavirus updates for ophthalmologists. Available from: https://www.aao.org/h eadline/alert-important-coronavirus-context
10. Williams AM, Kalra G, Commiskey PW, et al. Ophthalmology Practice During the Coronavirus Disease 2019 Pandemic: The University of Pittsburgh Experience in Promoting Clinic Safety and Embracing Video Visits. Ophthalmol Ther. 2020;9(3):1-9.
11. Powell S. Moorfields Eye Hospital patients test vision at home using app. Optometry today. Feb 25, 2021. Available from: https://www.aop.org.uk/ot/science-and-vision/technology/2021/02/25/moorfields-eye-hospital-patients-test-vision-at-home-using-app
12. AREDS2-HOME Study Research Group, Chew EY, Clemons TE, et al. Randomized trial of a home monitoring system for early detection of choroidal neovascularization home monitoring of the Eye (HOME) study. Ophthalmology. 2014;121(2):535-544.
13. Caffery LJ, Taylor M, Gole G, et al. Models of care in tele-ophthalmology: A scoping review. J Telemed Telecare. 2019;25(2):106-122.
14. Big Picture. Available from: https://landing.bigpicturemedical.com/
15. Consultant connect. Available from: http://www.consultantconnect.org/
16. Attend Anywhere. Available from: https://www.attendanywhere.com/
17. Alakidi A, Mihaylova V, Liochkova M, et al. Priority spheres and preferences for the general practitioner’s lifestyle. Part I. General Medicine. 2020;22 (4):3-10.
18. Kitova-John M, Tsigarovski G, Kitov B. Risk factors for the development of burnout syndrome by medical specialists. General Medicine. 2020;22(3):73-79.
19. Kitov B, Epifanceva E, Asenova R, Kitova T. Stress and its importance for the human body. General Medicine, 2020;22(6):74-80.