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Research Article

Ophthalmology and the Benefits of Using Artificial Intelligence: A Literature Review

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Abstract

Artificial intelligence (AI) is a technology that can help in the analysis of therapeutic procedures by improving the speed, efficiency and accuracy of eye imaging. It is often characterized by the replacement of medical presence by systems such as "Deep Learning" and "Machine Learning", since it has the benefit of cost reduction and shorter time to obtain imaging results. Given this, artificial intelligence has emerged as a promising resource for ophthalmologists and patients in the screening process. The aim of the present study was to seek foundations on ophthalmological conditions with the use of AI, as well as to evaluate the effectiveness of its use compared to the physical presence of medical professionals. A literary search was performed based on the descriptor: "{(Ophthalmology)} AND {(Artificial intelligence)}" in the PubMed and Science Direct databases. In total, 1137 articles were found, of which, after using filters and exclusion criteria, 25 articles were selected that related the terms Artificial Intelligence and Ophthalmology and met the objective of this review. Artificial intelligence is being widely used in ophthalmology, proving to be efficient in several ways, such as in the diagnosis and treatment of different pathologies; for example, glaucoma, cataracts, keratoconus and diabetic retinopathy; in ophthalmic surgeries; in the mapping of the cornea and retina. Although the use of AI in ophthalmology has several advantages, it can be stated that there are still limitations regarding its application, such as the lack of qualification of doctors for the use of this tool, the negative perspective related to the unemployment of these professionals - being replaced by the machine - and due to the labor and bioethical situation of the doctor-patient relationship, the presence of a legal apparatus functioning as a brake on the use of Artificial Intelligence in medicine.

Keywords: Artificial Intelligence; Health Technology; Ophthalmology; Anterior Segment of the Eye; Posterior Segment of the Eye

Abbreviations

IA: Artificial Intelligence; ML: Machine Learning; DL: Deep Learning; RD: Diabetic Retinopathy; DMRI: Age Related Macular Degeneration; TCO: Optical Coherence Tomography; MCIV: *In Vivo* Confocal Microscopy; FLF: Slit Lamp Photography; OCP: Posterior Capsular Opacification; FACO: Phacoemulsification; LIO: Intraocular Lens; PAP: Standard Automated Perimetry

Introduction

The technology, in the area of Medicine, has reached considerable levels, especially in the scope of the development and improvement of Artificial Intelligence (AI), as a way to assist the physician in his diagnostic and therapeutic investigation. It is possible that exams, previously dependent on the physical presence of the doctor, such as refractometry and screening for glaucoma, cataracts and retinopathies, will be performed by learning methods such as "Machine Learning" (ML), through the practice of using algorithms to clarify data, which contributes to a high power of data processing, facilitating speed in getting an effective diagnosis and treatment [2,5,6].

Thus, greater importance has been attributed to the "Deep Learning" (DL) system, which consists of an area of study of ML, capable of identifying patterns and interpreting data, such as the frequency of characteristic findings in medical imaging exams, mainly, transforming them into information based on statistics [6,7,20].

In the ophthalmological specialty, LD and ML have stood out, especially, for bringing greater benefits to the professional, and to the patient, from the screening process, to the possibilities of mitigation, or cure, in the pathologies of greater occurrence that, according to BENET (2022), are Diabetic Retinopathy (DR), Age-Related Macular Degeneration (AMD), retinopathy of prematurity, glaucoma and refractive errors. In addition, it presents cost reduction and shorter time to obtain results of imaging exams, such as fundus examinations and Optical Coherence Tomography (OCT) [2,4,19].

It is also probable that the use of AI in the area of ophthalmology will not be limited to the diagnosis and staging of pathologies, being possible, from its database, and its ability to create "super formulas", assist physicians, and health professionals, in performing more efficient and safe surgeries, and its use in cataract surgeries has already been studied. There is also the possibility of predicting the evolution and recovery of a patient in the postoperative period. Moreover, the limits of AI and its use in the field of ophthalmology are not known. We believe that its capacity is ample, and the possibilities are numerous [23,24].

In light of the benefits of AI in ophthalmology, and its contribution to the increased automation of different tasks, mainly related to the use of aids in diagnostics, and improvement in the efficiency of treatments, this article aims to discuss the beneficial mechanisms of AI in various areas of ophthalmology, as well as to discuss the promising use of AI in these conditions [1,4].

Materials and Methods

This was a systematic review, performed through searches on the PubMed and ScienceDirect websites , using the descriptors "Ophthalmology" and "Artificial Intelligence" and applying the following filters: "articles from the last 5 years"; "systematic review only" and "free full text". A total of 1,137 articles were found, of which 346 were from PubMed and 791 from ScienceDirect.

As inclusion criteria, we selected the articles that discussed the use of LD, ML and its functionality in medicine, in relation to diagnosis, monitoring, screening and early detection for eye conditions, with the aim of obtaining a better prognostic profile. Thus, 80 were selected from PubMed and 320 from ScienceDirect.

Articles that were not applied to the ophthalmology specialty, those that talked about AI construction, deepening in AI algorithms, telemedicine, subjects that were not related to the benefits of AI in ophthalmology, that compared the efficiency of the physician in relation to AI, and the works that addressed ethics, morals and challenges of AI in ophthalmology were excluded (Figure 1).

Figure 1: Methodology applied in the selection of articles for systematic review.

Results and Discussions

According to the world literature, some limitations of AI have been observed in the field of ophthalmology, such as the disqualification of future doctors, unemployment, which may arise with the advent of automated robots, and some methods against ethical principles. They also pointed to some AI training challenges, which are subject to numerous variabilities, including field of view, image magnification, and image quality of the participants. With these obstacles, there is still the limited availability of amount of data to detect rare diseases or even common diseases such as cataracts. It should be understood that, in the field of Medicine, especially in the ophthalmological field, it is essential to implement automated screening and diagnosis, by AI, ML and DL, due to the wide use of ophthalmic images, and that they should be studied together (doctors, researchers, scientists), in order to revolutionize and maximize the patient's time, despite some limitations that may exist [4,5,7].

Study of the anterior segment of the eye

In diseases of the anterior segment, an algorithm based on DL was developed, using a database, which was supplied with several images of the cornea, such as length, density and orientation. These photographs of the ocular surface were able to differentiate between the main pathologies of the anterior segment, for example, infectious keratitis, non-infectious keratitis, corneal dystrophies, keratoconus and surface neoplasms and, thus, increase the efficiency of care, through the clinical data of the patient and the examinations of Corneal Tomography (CT), of CT, *In Vivo* Confocal Microscopy (MCIV) and Slit Lamp Photography (FLF) [3,4,6].

At CT, it was possible to detect and classify keratoconus, preoperative screening for corneal refractive surgery, and identification of corneas in post-refractive surgery and iatrogenic ectasia. In the CT scan, there was the possibility of detection of corneal edema, prediction and diagnosis of graft displacement, after endothelial keratoplasty, of the Descemet membrane, and early identification of Fuchs' endothelial dystrophy. In the IVCM, the severity of diabetic neuropathies related to diabetic retinopathy was evidenced, enabling its diagnosis and also the identification of fungal keratitis. In FLF, it was possible to differentiate the various types of keratitis, with specificity of 76.5% of bacterial etiology and specificity of 100% for ulcers of fungal etiology, with precision of 90.7% for corneal dystrophies and possible neoplasms; also, classify the levels and types of cataracts; detect and predict posterior capsular opacification (OCP) and diagnose pediatric cataract [3-5].

In an experimental study, carried out at the Institut de Recherche Contre les Cancers de l'Appareil Digestif, European Institute of Telesurgery, and University Hospital of Strasbourg, in Strasbourg – France, it was seen that the robotic aid was of extreme importance for the success of 25 cataract surgeries. Kitaro cataract wet-lab, Da Vinci Xi robotic surgery and Whitestar Signature phacoemulsification (FACO) training systems were used, which offered dexterity in fundamental stages of FACO, such as corneal incision, capsulorrexis, grooves, cracks, quadrant removal and irrigation/aspiration of the viscoelastic. All surgeries were successful, with total removal of the lens, and with a mean operative time of 26.44 minutes ± 5.15 (SD) [1,3,9].

Regarding the treatment of cataracts, it was concluded that the AI-guided diagnosis seemed to be comparable and, in selected cases, even exceed the accuracy of experienced physicians in classifying the disease, supporting the scheduling of the operating room and the intra- and postoperative management of complications. In the preoperative period, the diagnosis and classification of cataracts, through AI-based image analysis, detected the ideal power of the intraocular lens (IOL) to achieve the desired postoperative refraction, in comparison with traditional IOL calculation formulas [23,24].

During surgery, innovative, AI-based video analysis tools are under development, driving a paradigm shift for documentation, storage, and cataloguing of surgical video libraries, with applications for teaching and training, complication review, and surgical research. In addition, computer-aided devices with situation recognition can be connected to surgical microscopes, for automated video capture and cloud storage upload. AI-based software can provide workflow analysis, tool detection, and video segmentation for skill assessment by the surgeon and ophthalmology resident [12,23].

AI, too, has been applied in the field of cataract surgery complications, to improve patient care, in terms of diagnosis, prognosis, and planning. Injection of antibiotics into the anterior chamber is considered an effective method to reduce the risk of postoperative endophthalmitis. Despite the administration of antibiotics during surgery, the development of a posterior capsular rupture is a recognized risk factor for postoperative follow-up of endophthalmitis in cataract surgery [4,24].

A study by Li., *et al*. demonstrated that the performance of medical specialists in cornea and LD systems have similar results, when it comes to screening for keratitis, by means of slit lamp imaging.

However, most studies use databases with high-quality images in their tests, which does not necessarily reflect the day-to-day reality in which these AI systems would be used. Soon, Li., *et al*. did a second study, using low-quality as well as high-quality images, comparing their results with those of medical experts and the results of the previous study. The results showed that a system, which uses low-quality images in its database, could achieve that of a specialist with three years or less of clinical experience, but proved inferior to that of a specialist with seven years of experience. However, it was realized that the use of low quality and high quality images with AI could lead to an advancement of these systems, when analyzing low quality images, which would improve their performance in offices [5,23,27].

Keratoconus is a condition in which there is a protrusion of the cornea, which can cause irregular astigmatism, myopia and, over time, can lead to a progressive thinning and wear of the cornea, as well as lead to scarring and vision loss. AI is proving to be an important tool that can help in the early and efficient diagnosis of this condition. The Support vector machine (SVM)-type algorithm is a form of DL that allows the integration of different parameters and, according to Tahvildari and Bir Singh, is one of the mechanisms that have more accuracy (95%) in the detection of keratoconus, as well as neural networks (NN), which replicates functions of the human brain, through complex algorithms and the random forest (RF) method [12,25].

There are already several systems capable of detecting the presence of keratoconus in the cornea, however, they do not have high sensitivity or specificity, and have very high prices. For these reasons, a group of Brazilian ophthalmologists started a project to create an application that, through the use of AI, would capture topographic images of the cornea, with smartphone cameras, and could detect, through this image, the presence of keratoconus in patients, even before it was visible by a slit lamp. The application was able to correctly detect 201 cases out of 212 and obtained sensitivity of 95% and specificity of 98.68%. This shows us that there is the possibility of easy use, and affordable price, of tools that will help general practitioners, as well as ophthalmologists, in the detection of pathologies in the cornea with the use of AI [12,25,26].

The use of AI in glaucoma

Glaucoma is an asymptomatic disease with an insidious manifestation, in which fundus examinations, retinography, TCO and Standard Automated Perimetry (PAP) are used in order to facilitate the distinction of healthy individuals and those with glaucoma, through the thickness of the layer of nerve fibers of the retina, calculated the mean deviation, the standard deviation and the characteristics of the visual field test [5,17].

The application of AI can be in the detection of the disease, in the analysis of its progression or in the verification of its absence. If used to classify patients, AI could distinguish whether the patient has glaucoma or a non-glaucomatous optic neuropathy. However, to develop this algorithm, AI would have to be informed in a clear and standardized way of what the practical definition of glaucoma would be [14,15,17].

If AI-enabled glaucoma detection methods using fundus imaging could be deployed into screening mechanisms, this could help reduce human error (e.g., observer bias and fatigue), and be used for large-scale screening, at a low cost. This could provide much-needed eye care services to remote rural areas, particularly in countries where there is a shortage of qualified ophthalmologists. Even in resource-rich care settings such as developed countries, refinement of AI-powered referral has the potential to meet the overwhelming demand for outpatient visits by reducing false positive referral rates. However, what is still unclear is the complete state of AI-enabled glaucoma detection, i.e., structures that utilize fundus cameras while providing the contours of the excavation and optical disc [14,16,17].

In general, the AI calculates the probability of glaucoma for a new fundus image, not seen as a number between 0 and 100% (e.g., 90%). This probability is interpreted as follows: given the training set that the AI used, and the mathematical/statistical method on which the AI was built, the AI believes that the chance of glaucoma is 90%, that is, among the 10 images that look like the new image, nine have glaucoma and 1 does not. If the probability provided by the AI is 50%, then the AI is not sure whether the new image is glaucomatous or not; however, if the probability is 99%, that doesn't mean the AI is sure it's glaucoma [14-16].

Evaluation of the posterior segment of the eye

In diseases of the posterior segment, some AI models have been implemented over the years to improve the screening and treatment process of the most prevalent ophthalmic diseases, such as DR, through fundus examination and fluorescein angiography and, as treatment and prevention, the use of laser photocoagulation, anti-vascular endothelial growth factor drugs, of intravitreal injections of steroids and vitrectomy. AMD can be diagnosed by means of imaging tests, such as CT and fluorescein angiography, which show characteristic findings, such as macular pigmentary changes, drusen and retinal epithelial atrophy. Retinopathy of prematurity, in which fundus images, with the aid of ML, was able to visualize the presence and assess the severity of this disease, but still presents poor screening.

As pointed out by Trinh, Ghassibi and Lieberman, according to a study conducted in 2016 by the Health Resources and Service Administration, it was estimated that by 2025, there would be a shortage of ophthalmologists in several US states, which encouraged the search for new ways to evaluate and stage patients, for example, the use of AI for the diagnosis of retinal pathologies [18,21].

A very important tool for the evaluation of the retina is the use of fundus photographs. There is a wide variety of ways to get these photographs, and you can even capture them with the aid of a smartphone. The existence of these different modalities of fundus image capture, classification and staging increases the possibilities of using AI. And these modalities are used to collect data for LD and ML, as well as to evaluate patients' fundus images using AI-developed algorithms [20,22].

Currently, more than 400 million people have diabetes mellitus (DM), and about half of them are not aware of their condition, which increases the likelihood of developing complications such as DR, responsible for more than 4 million cases of blindness. About 75% of people with DM and 79% of DR cases are in underdeveloped regions. The number of people with DM is increasing more and more. It is estimated that by 2045, about 600 million people will be diabetic and 40% to 45% will develop DR, a leading cause of vision loss in adults [18,19,22].

Trinh, Ghassibi and Lieberman analyzed two studies that collected imaging data from the EyePACS Database and data from the Singapore National Diabetic Retinopathy Screen Program (SIDRP), which were then fed into DL databases for AI programming in order to compare specificity and sensitivity in scans done by AI algorithms and ophthalmologists. The results of these algorithms for the detection of DR were very promising, since the algorithms reached high sensitivity and specificity rates, being comparable to those of retinal specialists. Another advantage of the use of AI was the ability to be exploited by general practitioners, thus decreasing the workload of physicians and decreasing the number of patients with vision loss as a consequence of DM [18,19,21].

Gargeya and Leng, however, pointed out the flaws present in many algorithms already used, when it came to the detection and staging of DR, such as the use of small and isolated databases, coming from clinical settings, which is not consistent with a daily use, or on a large scale, in which patients differ more, decreasing its accuracy. They then created an automated algorithm for RD detection, using DL and a database of 75,137 RD images from EyePACS, with the aim of correcting the flaws perceived in other tests. They were able to develop a system capable of evaluating people on a large scale, and could efficiently classify thousands of fundus images in those not affected by DR and DR patients, regardless of the degree of severity. This system did not need advanced equipment or computers to function, and its images did not need a clinical report. Tools like this would have the potential to expand, facilitate and ensure the screening of thousands of people, which would help, especially in developing countries and regions where there is no adequate equipment, or sufficiently trained professionals [18,19,22].

Conclusion

In light of the considerations, the use of AI in ophthalmology, despite already having applicability in several situations, remains with limitations. These limitations, in short, are present in the lack of qualification of current physicians, that is, it is not yet common that, during academic training, the future professional has contact with AI and its applicability in medicine. In addition, there is a negative perspective, with regard to unemployment, that is, robots and computers taking the place of the human being at work. However, due to this situation and also to the bioethics present in the doctor-patient relationship, the entire legal apparatus is also configured as a brake on the application of AI in the medical day to day [4,5,7].

In diseases of the anterior segment of the eye, the use of AI increases the efficiency of patient care, through examinations such as CT, increasing the accuracy in the detection of keratoconus (but which does not yet have high sensitivity or specificity and has a very high price). In the preoperative screening of corneal refractive surgery, CT, acting in the detection of corneal edema, IVCM, in which the severity of diabetic neuropathies is evidenced, and FLF, in which it is possible to differentiate the various types of keratitis. In addition, in the treatment of cataracts, AI exceeded the human gaze, with respect to the screening of the disease, while assisting in the postoperative treatment [6,9,23,24].

In turn, in diseases of the posterior segment of the eye, it would act in several different applicability, for each condition. In glaucoma, the application of AI could be in detecting the presence, or absence, of the condition, or in analyzing the progression of glaucoma in the patient. In the DR, in turn, it would act in the screening process, for example, in fluorescein angiography exams, which would also assist in the retinopathy of prematurity and, as treatment and prevention, in the use of laser photocoagulation, among other tools [5,14,17,19,21].

Conflict of Interest

The authors declare that there is no conflict of interest. All authors read and approved the manuscript.

Bibliography

1. BENET David and PELLICER-VALERO Oscar J. "Artificial intelligence: the unstoppable revolution in ophthalmology". *Survey of Ophthalmology* 67.1 (2022): 252-270.
2. ESENGÖNÜL Meltem., *et al*. "A Systematic Review of Artificial Intelligence Applications Used for Inherited Retinal Disease Management". *Medicina* 58.4 (2022): 504.
3. KAPOOR Rahul., *et al*. "The current state of artificial intelligence in ophthalmology". *Survey of Ophthalmology* 64.2 (2019): 233-240.
4. CATANIA Louis J and NICOLITZ Ernst. "Artificial intelligence and its applications in vision and eye care". *Advances in Ophthalmology and Optometry* 3.1 (2018): 21-38.
5. TING Daniel SW., *et al*. "Deep learning in ophthalmology: the technical and clinical considerations". *Progress in Retinal and Eye Research* 72 (2019): 100759.
6. TING Daniel Shu Wei., *et al*. "Artificial intelligence and deep learning in ophthalmology". *British Journal of Ophthalmology* 103.2 (2019): 167-175.
7. TSENG Rachel Marjorie Wei Wen., *et al*. "Considerations for Artificial Intelligence Real-World Implementation in Ophthalmology: Providers' and Patients' Perspectives". *The Asia-Pacific Journal of Ophthalmology* 10.3 (2021): 299-306.
8. BALYEN Lokman and PETO Tunde. "Promising artificial intelligence-machine learning-deep learning algorithms in ophthalmology". *The Asia-Pacific Journal of Ophthalmology* 8.3 (2019): 264-272.
9. BOURCIER Tristan., *et al*. "Robot-assisted simulated cataract surgery". *Journal of Cataract and Refractive Surgery* 43.4 (2017): 552-557.
10. SIDDIQUI Aazim A., *et al*. "Artificial intelligence in cornea, refractive, and cataract surgery". *Current Opinion in Ophthalmology* 31.4 (2020): 253-260.
11. RAMPAT Radhika., *et al*. "Artificial intelligence in cornea, refractive surgery, and cataract: basic principles, clinical applications, and future directions". *Asia-Pacific Journal of Ophthalmology (Philadelphia, Pa.)* 10.3 (2021): 268.
12. MISHRA Kapil and LENG Theodore. "Artificial intelligence and ophthalmic surgery". *Current Opinion in Ophthalmology* 32.5 (2021): 425-430.
13. BENET David and PELLICER-VALERO Oscar J. "Artificial intelligence: the unstoppable revolution in ophthalmology". *Survey of Ophthalmology* 67.1 (2022): 252-270.
14. AL-ASWAD Lama A., *et al*. "Artificial Intelligence for Glaucoma: Creating and Implementing Artificial Intelligence for Disease Detection and Progression". *Ophthalmology Glaucoma* (2022).
15. SCHUMAN Joel S., *et al*. "A Case for the Use of Artificial Intelligence in Glaucoma Assessment". *Ophthalmology Glaucoma* 5.3 (2022): e3-e13.
16. COAN Lauren., *et al*. "Automatic detection of glaucoma via fundus imaging and artificial intelligence: A review". *Survey of Ophthalmology* (2022).
17. BUNOD R., *et al*. "Artificial intelligence and glaucoma: A literature review". *Journal Francais D'ophtalmologie* (2022).
18. TRINH Minh., *et al*. "Artificial Intelligence in Retina". *Advances in Ophthalmology and Optometry* 6 (2021): 175-185.

19. GARGEYA Rishab and LENG Theodore. "Automated identification of diabetic retinopathy using deep learning". *Ophthalmology* 124.7 (2017): 962-969.

20. MORARU Andreea Dana., *et al*. "Artificial intelligence and deep learning in ophthalmology-present and future". *Experimental and Therapeutic Medicine* 20.4 (2020): 3469-3473.

21. SORRENTINO Francesco S., *et al*. "Application of artificial intelligence in targeting retinal diseases". *Current Drug Targets* 21.12 (2020): 1208-1215.

22. ATTIKU Yamini., *et al*. "Current status and future possibilities of retinal imaging in diabetic retinopathy care applicable to low-and medium-income countries". *Indian Journal of Ophthalmology* 69.11 (2021): 2968.

23. LINDEGGER Daniel Josef., *et al*. "Evolution and Applications of Artificial Intelligence to Cataract Surgery". *Ophthalmology Science* 2.3 (2022).

24. TOGNETTO Daniele., *et al*. "Artificial intelligence applications and cataract management: A systematic review". *Survey of Ophthalmology* (2021).

25. TAHVILDARI Maryam., *et al*. "Application of artificial intelligence in the diagnosis and management of corneal diseases". In: Seminars in Ophthalmology. Taylor and Francis, (2021): 641-648.

26. LUCENA Abrahão Rocha., *et al*. "Development of an application for providing corneal topography reports based on artificial intelligence". *Arquivos Brasileiros de Oftalmologia* 85 (2021): 351-358.

27. LI Zhongwen., *et al*. "Comparison of deep learning systems and cornea specialists in detecting corneal diseases from low-quality images". *iScience* 24.11 (2021): 103317.