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AI-BASED APPLICATIONS IN OPHTHALMOLOGY: A DISCUSSION ON FUTURE CHALLENGES IN ITS USE FOR DIAGNOSIS AND TREATMENT IN THE AREA

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Abstract: Objective: Explore the scope of applications of artificial intelligence in ophthalmology, discussing the technical-ethical-regulatory challenges they may face. Methods: Bibliographic review through the PubMed database, 730 articles were found subsequently submitted to the criteria of the PVO strategy (research, variables and outcome), through the search strategy (Artificial intelligence) AND (Ophthalmology) AND (Diagnosis) AND (Treatment). After applying the selection criteria, 24 articles were selected to compose the present study. Review: AI programs already implemented and in experimentation are discussed, such as the IDx-dr system, an AI technology approved by the FDA to allow the diagnosis of diabetic retinopathy, the "Redcheck" platform, which in Brazil facilitates the screening of ocular changes and assists the ophthalmologist in preparing quick reports, among other highlighted artificial intelligence alternatives. Final considerations: Contact with the programs already implemented allowed us to see the potential of AI to assist ophthalmological medicine, despite having contact with the limitations already found with regard to validity and effectiveness on a large scale, certification of efficiency and ethical commitment to the implementation of AI. Finally, it was concluded that there is a need to carry out more studies to provide comprehensive evidence for the safe implementation of AI, already respecting its established potential in the medical world and in ophthalmology.

Keywords: ophthalmology, Artificial Intelligence; Treatment; Diagnosis.

INTRODUCTION

The year 2020 was marked by several digital innovations, mainly in the area of healthcare and the use of Artificial Intelligence (AI) tools. In addition to changing the tracking, diagnosis and monitoring of diseases, aiming for a more accurate profile of the progression of certain pathologies and refining and/or personalizing treatments. This way, digital technologies can also be applied in the ophthalmological area. Telehealth and AI use become applicable when it comes to providing ophthalmological services, a fact that is already being developed in several aspects such as: in the treatment of retinopathy of prematurity, correction and prediction of refractive errors, among others (Li et al, 2021).

An example of its applicability would be in macular degeneration. Age-related macular degeneration (AMD) is a condition that causes visual impairment due to the formation of drusen in the retinal pigment epithelium. Artificial Intelligence (AI), Machine Learning (ML) and Deep Learning (DL) algorithms are used to diagnose and classify AMD with high accuracy, surpassing manual assessment. These technologies also help determine the need and quantity of anti-VEGF medications for treatment. However, the lack of regulation in the use of these services can lead to delayed diagnoses in high-risk populations, resulting in vision loss (Bayle et al., 2019).

Keskinbora and Güven (2020) used AI learning to identify optic nerve injuries caused by glaucoma based on fundus photographs. It is worth noting that glaucoma is the second biggest cause of vision loss in the world. It is characterized by an increase in intraocular pressure due to the impediment of aqueous humor drainage, causing, over time, irreversible damage to the optic nerve and preventing vision, if not treated correctly. Such research was followed by studies that used this learning technology and databases with a much larger collection compared to previous machine learning studies, generating a satisfactory result in sensitivity and specificity in the diagnosis and follow-up of glaucoma lesions.

In addition to applications of Artificial Intelligence to generate new data through optical coherence tomography and computerized visual field tests, studies have also been published describing software capable of evaluating patients based on data resulting from both exams mentioned above.

AI has a wide field of application, taking advantage of already established digital techniques, such as optical coherence tomography in diseases such as retinopathy of prematurity (ROP), a disease that can lead to visual loss, affecting more than 30 thousand children annually. Treatments such as laser, photocoagulation and cryotherapy have been effective, but early detection is crucial to preserving vision from birth (Li et al., 2021). Researchers like Popescu et al. (2023) believe that AI can be particularly beneficial in diseases such as diabetic retinopathy, macular degeneration, glaucoma and retinopathy of prematurity, helping to identify patients at risk of vision loss early.

From this perspective, this review aims to discuss various pathologies and the importance of AI and how it can focus on the clinical work flow of ophthalmologists for both diagnosis and treatment. Increasing AI and telecommunications technologies can potentially transform the delivery of the data-rich, image-dependent specialty of ophthalmology globally. For Popescu et al. (2023), artificial intelligence is the process of employing the processing power of a computer to carry out numerous activities. Artificial intelligence has important potential to carry out diagnoses and is capable of improving medical performance, but it still requires some more in-depth studies. However, briefly, over the years, it is believed that through technologies and AI, screening and early detection of ophthalmic diseases will become routine in medical practices.

METHODOLOGY

Narrative bibliographic review developed according to the criteria of the PVO strategy, an acronym that represents: population or research problem, variables and outcome. Used to prepare the research through its guiding question: "What are the applications of artificial intelligence (AI) in ophthalmology, and what future challenges could impact its implementation and effectiveness? The searches were carried out by searching the PubMed Central (PMC) database. The descriptors were used in combination with the Boolean term "AND" :(Artificial intelligence) AND (Ophthalmology) AND (Diagnosis) AND (Treatment)". From this search, 730 articles were found, subsequently submitted to the selection criteria.

After the initial screening, 51 articles were reviewed. The inclusion criteria were: articles in English published between 2019 and 2024 and that addressed the themes proposed for this research, studies of the type review, meta-analysis, observational and clinical trials, available in full. The exclusion criteria were: duplicate articles, available in abstract form, which did not directly address the proposal studied and which did not meet the other inclusion criteria. After analysis and application of the inclusion and exclusion criteria, a total of 24 articles were selected to compose the present study.

DISCUSSION

The AI has advanced rapidly, allowing us to correlate clinical cases and laboratory results efficiency. It has been shown to be extremely valuable in the early diagnosis of eye diseases (Du et al., 2023). Furthermore, AI can be applied to tracking eye diseases in various ophthalmological situations (Campbell et al., 2021).AI has proven to be an indispensable tool in several areas of ophthalmology, contributing significantly to the improvement of clinical results and patient experiences (Tan et al., 2023). The most common approaches include image processing and using electronic medical records as databases. According to Anton et al. (2022), the diseases most benefiting from these advances include diabetic retinopathy, glaucoma, age-related macular degeneration, and cataracts.

In India, a telemedicine program called "Save Our Vision" was developed with the aim of screening and combating Retinopathy of Prematurity (ROP). With improvements in diagnostic methods, the incidence of ROP has increased. Three criteria are needed to establish the diagnosis of ROP: the vascularization of the retina (zone), the degree of the disease (stage) and the degree of dilation and tortuosity of the posterior retinal vessels (plus disease). Brown et al. created an AI algorithm to diagnose "Plus Disease", used in premature children in North America, which can quantify a severity score through photographs, correlating classifications of zones, stages and plus disease. However, improvements are needed due to variables such as referrals, loss to follow-up, and even mortality (Campbell et al., 2021).

In South Korea, an AI algorithm was implemented to handle eye emergencies at the Daegu Armed Forces Hospital, analyzing patients between May and December 2011. The system uses three input pieces of information: general patient data, reported symptoms, and events occurred. The outputs are classified into four colors indicating the urgency of the service: red (immediate), orange (up to 24 hours), yellow (up to 7 days) and green (non-emergency).But according to Ahn,2020). Further studies are needed to improve the method, with a larger and more varied sample.

In relation to myopia, one of the main causes of visual loss due to refractive error, AI can identify at-risk individuals early and effectively. A system developed by Wu et al. is capable of predicting Optical Coherence Tomography (OCT) in high degrees of myopia, based on fundus images. In 2020, Sogawa et al. described an AI model that accurately distinguishes OCT images with or without macular lesions in myopes, such as neovascularization of choroidmyopic or retinoschisis (Du et al., 2023). In 2018, the FDA (Food and Drug Administration) approved the first AI system for tracking eye changes related to diabetes. The IDx-DR system uses neural networks to detect diabetic retinopathy through analysis of ocular images. Google has also developed an AI that identifies diabetic retinopathy and diabetic macular edema, successfully tested on patients at Aravind Eye Hospital in India. In Brazil, the red check platform facilitates the tracking of ocular changes and assists ophthalmologists in preparing quick reports. This technology has the potential to help countries with a shortage of ophthalmology specialists (Kuiava; Kuiava; Chielle; Syllos, 2021).

However, there are limitations regarding the diagnosis of eye diseases using AI. The external validation of the studies is limited, which questions the generalization of the use of AI in large populations and its real applicability. The diversity of image formats and ocular devices makes the technique difficult to implement (Du et al., 2023). Additionally, data privacy and security restrictions, as well as insufficient understanding of algorithms in many eye care settings pose significant challenges (Dow et al., 2022). It is unlikely that machines will completely replace human professionals (Kuiava; Kuiava; Chielle; Syllos, 2021).

Specifically, in diabetic retinopathy, Tan et al. (2023) highlight the use of the deep learning tool "Ai-doctor", which automates the workflow from identification to treatment planning. This tool seeks to eliminate the biases presented by Fluorescein Angiography, which requires human interpretation to determine the extent of retinal ischemia.

Furthermore, Tan et al. (2023) emphasize the need for AI to detect multiple conditions simultaneously, not being limited to a single disease. Gong, Kras, and Miller (2021) demonstrated that deep learning can identify diabetic retinopathy and age-related macular degeneration simultaneously, delivering results comparable to those obtained by human raters. Currently, the main use of deep learning is in disease screening, and it can be combined with manual assessments to increase the sensitivity of diagnoses (Li; Zhao; Zou, 2022).

Considering treatment, deep learning algorithms have the potential to aid in decision-making about clinical interventions, such as in cataract surgery, where AI can accurately determine the intraocular lens power required to achieve the desired post-operative refractive outcome (Anton et al., 2022).

For the future, studies are investigating the application of AI in the prognosis and advancement of glaucoma through biomarkers, potentially surpassing imaging diagnosis performed by humans (Pucchio et al., 2023). Recent discoveries include the use of neural networks to diagnose corneal graft rejection using Optical Coherence Tomography, which can increase the success of surgeries (Tahvildari; Singh; Saeed, 2021).

However, the rapid evolution of AI in ophthalmology has also brought advances in carrying out exams via telemedicine and apps, facilitating patient adherence, especially those with chronic conditions such as diabetes and sickle cell anemia. These technologies allow personalized consultations in primary care settings or even at home, reducing costs and avoiding overload on ophthalmological services (Anton et al., 2022; Pucchio et al., 2023; Li; Zhao; Zou, 2022; Tan et al., 2023; Cai; Scott, 2021).

In addition to assisting in diagnosis, AI is fundamental in the development of tools such as a quantitative vascular severity score to investigate retinopathy of prematurity through fundus images (Cai; Han; Scott, 2021) and in the automated interpretation of photographs of ultra-wide field in patients with sickle cell retinopathy (Cai; Han; Scott, 2021). Gong, Kras, and Miller (2021) report that programmed deep learning systems can simultaneously detect diabetic retinopathy (DR) and age-related macular degeneration (AMD) with sensitivity and specificity comparable to that of human raters.

Pucchio et al. (2023) highlight that supervised AI is valuable for glaucoma diagnosis, providing greater accuracy, which facilitates early detection and treatment of ocular conditions, in addition to saving significant time (Anton et al., 2022; Li; Zhao; Zou, 2022;

Although biomarkers are not frequently mentioned, they are easily accessible and important for predicting disease progression, prognosis, and treatment outcomes (Pucchio et al., 2023; Bassi et al., 2022). Deep learning systems can predict these biomarkers, the outcomes of anterior segment surgeries, decrease the rate of progression of some diseases, identify at-risk populations, and offer timely treatment (Tahvildari; Singh; Saeed, 2021; Gong; Kras; Miller, 2021; Bassi et al., 2022).

However, the implementation of AI in medicine faces challenges, including the lack of standardization among AI systems, such as the frequency of updates and data sources, which change regularly in the medical field (Anton et al., 2022; Li; Zhao; Furthermore, it is necessary to unify systems so that a single software can be used on all patients, regardless of ocular conditions, age or ethnicity (Li; Zhao; Zou, 2022; Tan et al., 2023; Cai; Han; Scott, 2021). It is also crucial that AI is able to evaluate individual patients, considering their entire clinical history, not just the disease examined (Pucchio et al., 2023; Li; Zhao; Zou, 2022; Tahvildari; Singh; Saeed, 2021).

Clinicians must be adequately trained to use AI effectively without compromising their clinical judgment (Pucchio et al., 2023; Tahvildari; Singh; Saeed, 2021). A significant challenge is the “black box” dilemma, where AI reasoning processes are not transparent, which can compromise confidence in its results (Pucchio et al., 2023; Tahvildari; Singh; Saeed, 2021; Cai; Han; Scott, 2021).

To overcome these obstacles, it is essential to develop systems or applications that can diagnose multiple eye diseases simultaneously. Zhao et al. developed a deep learning system (Ai-Doctor) to automate from diagnosis to treatment planning of DR and retinal vein occlusion based on fluorescein angiography (FFA) (Tan et al., 2023). It is also necessary to deepen studies to understand and standardize these systems so that they can be applied universally, maintaining their performance (Cai; Han; Scott, 2021). Additionally, the use of biomarkers can be expanded for more accurate and immediate diagnoses and prognoses, as indicated by recent studies on biofluids using AI for glaucoma (Pucchio et al., 2023; Bassi et al., 2022).

The increasing use of AI in screening, diagnosis and treatment in ophthalmology and medicine in general raises several complex ethical concerns that need to be meticulously addressed (Tan et al., 2023; Abdullah et al., 2021). Raising significant ethical concerns, especially with regards to data privacy and security. The collection and use of medical data to train and operate AI systems can result in privacy violations, leading to discrimination, emotional distress, and loss of trust. Such violations can discourage patients from seeking healthcare services, as highlighted by Abdullah et al. (2021).

Furthermore, the integration of electronic medical records with AI systems increases the risk of exposing sensitive patient information. Maintaining data confidentiality and protecting patient privacy therefore becomes a critical imperative. Another challenging aspect is responsibility and culpability in situations where the use of AI in diagnoses and treatments results in adverse consequences. It is crucial to establish clear rules of accountability that guide doctors, who can be held legally responsible for both following and ignoring AI recommendations. Ultimately, ethically implementing AI in medicine requires a collaborative approach involving clinicians, healthcare organizations, and technology manufacturers. Developing and enforcing regulations and policies that ensure AI operations are aligned with the best interests of patients and society is essential to promoting responsible and ethical medical practices (Abdullah et al., 2021).

Additionally, challenges such as the generalization of AI systems to different populations, variability in the effectiveness of algorithms, the need for informed consent from patients, and prioritization of cases in overburdened healthcare systems are critical ethical issues that must also be considered. To address these complexities, regulatory, technological and social strategies that promote ethical, fair and responsible use of AI are needed. These strategies include the development of robust regulations, technological advances in data protection and privacy, and ongoing discussions about the ethical principles that guide the use of AI in clinical practice (Balyen; Peto, 2019).

FINAL CONSIDERATIONS

In contemporary medical practice, AI has become an available and valuable tool for diagnosis, treatment, staging and recording for monitoring the most diverse pathologies. Ophthalmology, especially with regard to the diagnosis and monitoring of patients with diabetic retinopathy, glaucoma and cataracts, is among the specialties privileged by the assistance provided by the development of artificial intelligence. The implementation of programs such as "Save Our Vision" in India to screen for diabetic retinopathy and the IDx-dr system, an AI technology approved by the American health regulatory agency (FDA), with the ability to analyze images and also identify ocular changes promoted by diabetes reinforce how AI has been adding to the current scenario of ophthalmological medical practice. However, it is understood that even with the approval of a regulatory agency and the recent beginning of the use of artificial intelligence programs, there is a lack of external validation of studies conducted on the subject, raising questions about its applicability on a large scale. and real effectiveness, in addition to ethical-moral issues regarding data storage, doctor-legal responsibility in the face of the possibility of failures and the ability to manage and certify algorithms, systems and programs. The potential of artificial intelligence in improving ophthalmic medicine is undeniable; considering everything from the organization of data storage to the treatment of pathologies; however, we conclude that it is essential to program studies to ensure that the implementation of the most recent forms of technology is carried out with robust technical, ethical and scientific support.

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