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Mini Review

Artificial Intelligence and Machine Learning in Ophthalmology: Novel Frontiers

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Abstract

In this era of technology, the integration of computers into the daily life activities of an average human is inevitable. This is largely attributed to the advancement of artificial intelligence (AI). It is a boon for the healthcare sector where it has widespread applications. It provides us with a basic necessity called data among other things. Ophthalmology too has evolved leaps and bounds largely due to improved data collection and analysis. The development of algorithms further helps to perform complicated tasks with ease. In glaucoma, intraocular pressure monitoring to the Optic nerve head and retinal nerve fiber layer analysis is reliant on AI analysis and reporting. The same is the case with diabetic retinopathy and the need for Anti-vascular endothelial growth factors (VEGF) treatment. Hence, to keep up with recent times, up-to-date information regarding AI is vital.

Keywords: *Diabetic Retinopathy; Glaucoma; Machine Learning; Deep Learning; Artificial Intelligence*

Introduction

In the evolutionary history of the human race, artificial intelligence (AI) happens to be the fourth industrial revolution [1]. AI is defined as human critical thinking and intellectual pursuits augmented by utilizing synthetic intelligence technology. Alan Turing introduced AI in the 1950s [2]. It was followed by machine learning (ML), in the 1980s which is an important subset of AI. ML is defined as a set of methods that automatically identify configurations in data and then incorporate this information to predict future data under ambiguous conditions. The use of ML incorporates genome-wide data [3]. Deep learning (DL) uses multiple levels of abstraction to process input data with representation-learning methods automatically recognizing the intricate structures in high-dimensional data through projection onto a lower-dimensional manifold [1].

The popularity and applications of AI have increased rapidly in every possible field. The uses of AI in healthcare comprise triage, risk assessment, AI-assisted disease diagnosis, target drug development, providing personalized treatment, and genetic research [3].

The global population explosion has steered the healthcare system towards a massive struggle in providing adequate eye care at the population level. This has led to projections of increasing levels of visual impairment (VI) and blindness from major eye diseases in the near future. This liability of VI has overwhelmed international efforts to develop the physical infrastructure in the form of eye clinics and tertiary care hospitals and the adept readiness of eye care providers to relieve the same [4].

Ophthalmology has extensive room for the advancement and utilization of AI as it is an image-centered data-rich field. Disease-based learning is accomplished using DL algorithms. The precise and distinguished features of the pathology are allocated to the image by the physician. This photograph acts as a basic threshold for the machine to recognize and learn. The output is verifiable against the disease criteria well-defined by the professionals [1].

Visual field charting using automated perimetry, and fundus photographs using various devices including non-mydriatic cameras and optical coherence tomography (OCT) imaging are some of the areas where DL is applied in everyday Ophthalmology. It is successful in the classification and detection of retinopathy of prematurity (ROP), glaucoma-like disc, grades of diabetic retinopathy (DR), macular edema subtypes, and dry and wet age-related macular degeneration (ARMD) [1].

Various sub-specialties within ophthalmology are dependent on AI for day-to-day functioning.

Glaucoma and AI

The timely recognition of glaucomatous visual field changes is important as recent studies show central visual field defects in the early stage of the disease. Imaging studies also show similar trends alongside consistent results [4]. Another achievement is the development of a contact lens for continuous monitoring of intraocular pressure (IOP) as increased levels of IOP lead to the progression of glaucomatous changes like an enlarged cup/disc ratio [2].

Li., *et al*. established that DL has high sensitivity and specificity to practically categorize referable glaucomatous optic neuropathy. Casual-associational network (CASNET) is a glaucoma-based consultation program established to guide clinical decision-making [3].

In a study done by Milea., *et al*. retinal cameras including Topcon, Zeiss, and Cannon were used to detect papilledema. The Deep Learning System (DLS) was tested against two expert neuro-ophthalmologists on assessing 800 new fundus photos. The classification was divided into normal disc, papilledema and other optic disc abnormalities. The classification done using DLS was accurate in 678 of 800 (84.7%) photographs. Meanwhile Expert 1 classified 675 of 800 (84.4%) correctly and Expert 2 classified 641 of 800 (80.1%) [2].

AI and DR

With the modernization and changing lifestyle, DR is on the rise and leading to substantial blindness. DR screening is the most important approach for blindness prevention. When combined with well-timed referral and management, DR screening can routinely detect abnormalities such as drusens at the macula, hard exudates, clinically significant macular edema and choroidal neovascularization (CNVM). These tools include OCT scans and fundus photographs obtained by certain healthcare professionals, including Ophthalmologists, optometrists and other trained professionals [1].

Blindness prevention from DR by regular screening, timely referrals and apt treatment is the need of the hour. However, it is a great challenge considering the limited availability of adequate resources for the same. Large populations can be screened successfully using just a fundus camera with minimal manpower and maximal efficiency to identify referable disease for further treatment [3]. Teleophthalmology enables community-based screening as a part of primary eye care service. Identification of pre-defined disease parameters can speed up the consultation process with a specialized ophthalmologist [4].

Food and Drug Administration (FDA) in the United States approved IDx-DR (Digital Diagnostics, Corville, IA, USA). It was the first USFDA-accepted autonomous AI device in medicine. It is incorporated in other devices like Topcon TRC NW400 (Topcon, Tokyo, Japan) digital fundus camera. They are built to help detect diabetic macular edema and retinopathy in patients [3]. The identification of macular pathology is made easier with DL incorporated in OCT scanning with high repeatability and reliability. Further, it's practically convenient to obtain OCT scans and identify complex physical information. Pioneer OCTs were programmed with DL which classified age-related macular disease (AMD) [3]. Automatic detection of exudative AMD was done using spectral domain D-OCT in a model developed by Treader., *et al*. The precision of disease identification by DL alone is 80% and by both the prototypes and retina specialists can be even up to 90% [5].

AI and ROP

Increased preterm deliveries, decreased neonatal mortality and limited neonatal intensive care units in developing nations have raised the need for ROP screening. The artificial intelligence-based ROP deep learning (i-ROP DL) system was developed to diagnose and monitor the progression or regression of the disease and its treatment response. It even created a severity score for ROP that made a similar diagnosis with more than six out of eight international experts in diagnosing ROP [1]. The made-in-India, 3 nethra camera by Forus Health Incorporated (Based in Bengaluru, Karnataka) also has high accuracy in identifying the ROP staging by retinal photographs [3].

AI on other Ophthalmology fronts

Cataract detection on slit lamp photography and automated choice of the finest suitable intraocular lens during preoperative planning for cataract surgery is done with the assistance of AI [4].

Scheimpflug camera is a device that can identify preclinical keratoconus. It is also used during refractive surgery and to assess corneal power postoperatively. Planning surgical correction of horizontal strabismus according to eyelid and periorbital measurements done by AI [4,5].

Some physicians find it difficult to entrust DL-based tools because of their "black box" nature. The decision-making ability of algorithms is difficult to comprehend i.e. the explanation of why certain patients are given certain diagnoses [5]. Another important task is spreading awareness among the general population to build trust in AI technology to deliver clinical care. The AI software will give incorrect reporting if the quantity of training images is not proportional to the test population. Diversification during data collection and the inclusion of various ethnicities is necessary. Other factors that influence AI reporting include variations in image quality, the extent of the field of view and image amplification. Modification in national and international legislation is needed across the globe to ease in medicolegal implications of AI tools [1]. It is difficult for AI to regularly inculcate huge datasets which construct and modify algorithms. Feeding imperfect data to AI will result in flawed processing of the information. When this produces inadequate results, it is known as the "garbage in, garbage out" phenomenon [2].

Asia is a massive landmass with diverse biology, spending habits, and consumption patterns. While health systems are still developing nationwide, few individuals have resources and access when compared to developed nations. A vast majority is still living under conditions with restricted health resources, insufficient infrastructure, and income disparity. These social elements have a profound impact on the efficacy of healthcare services [4].

Conclusion

AI and ML perform screening of enormous numbers of patients with exceptional outcomes and accuracy. They may also aid in clinical predictions that update patients on their probable clinical course/prognosis with or without treatment. Upcoming times might adopt intelligent systems in additional practices of clinical work. Even in the shadows of ethical, regulatory, and legal issues, AI continues to revolutionize current disease diagnostic patterns and generate momentous clinical impact in today's scenario. Though AI has emerged as a promising tool in Ophthalmology, it cannot replace the skill and knowledge of the users. It can enhance the diagnostic skills and monitoring parameters of the various ocular diseases in addition to the clinical judgments of the stakeholders.

Conflict of Interest

No financial interest or any conflict of interest exists.

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