

# ARTIFICIAL INTELLIGENCE AND ITS EFFECTIVE ROLE IN OPTOMETRY

## Abstract

Artificial intelligence is carried out by the computer machine, without the involvement of human support. After introducing robotics AI has been accepted in measure procedures. So Artificial Intelligence and machine learning are the most trending and computer-based technologies can be correlated but never be used as synonyms. This revolutionary concept is frequently used in various fields, but in ophthalmology, it has a concern with the diagnostic tool, especially in Diabetic retinopathy, age-related macular degeneration, retinal vein occlusion, retinopathy of prematurity, congenital and senile cataract and glaucoma.<sup>[1,2]</sup>

**Keywords:** So Artificial Intelligence and machine learning are the most trending.

## Author

### **Dr Mahesh Chandra**

Sr. Optometrist  
Department of Ophthalmology  
Dr Sushila Tewari Hospital and Government  
Medical College  
Haldwani, Uttarakhand, India.

### **Dr. Gaurav Dubey**

Optometry Resident  
Department of Optometry  
Faculty of Paramedical Sciences  
UPUMS  
Saifai Etawah, Uttar Pradesh, India.  
gauravopto25@gmail.com

### **Pratik Sharma**

Tutor  
Department of Optometry  
Era University Lucknow, India.

### **Devanshi Dalal**

Assistant professor  
Department of Optometry  
Babubhai Desaibhai Patel Institute of  
Paramedical Sciences ( BDIPS)  
Charotar University of Science and  
Technology ( CHARUSAT)

### **Shamit Pal**

Assistant Professor  
(Optometry) Department of Ophthalmology  
MMIMS&R Mullana  
Ambala, Haryana, India.

### **Neha Dubey**

Physiotherapy Resident  
Department of Physiotherapy  
Faculty of Paramedical Sciences  
UPUMS Saifai Etawah  
Uttar Pradesh, India.

## I. INTRODUCTION

Artificial intelligence (AI) is a field having a combination of computer science with strong and enriched datasets, to solve the related problem. It is the engineering science of making intelligent machines, associated with computer programs, but AI does not have biological observation to confine itself. (John McCarthy) Stuart Russell and Peter Norvig published the first leading textbook on AI, "Artificial Intelligence: A modern approach."<sup>[3]</sup> Several concepts of artificial intelligence (AI) have been introduced in the easiest words-

*Artificial intelligence is a technology by which we can create intelligent systems to simulate human intelligence.*<sup>[1]</sup>

AI uses algorithms (machine learning) which work with their intelligence (deep learning neural networks). AI has different capabilities so classified into three types<sup>[1]</sup>

- Weak AI
- General AI
- Strong AI

Therefore machine learning extracts knowledge from past pooled data to make decisions instead of any pre-programmed data.

The capability of making accurate predictions or decisions of machine learning based on massive amounts of structured and semi- very widely in Google structured historical data. It works only for specific domains but is used searches, Email spam filters, Face book auto friend tagging, etc. It is further divided into-<sup>[1]</sup>

- Supervised learning
- Reinforcement learning
- Unsupervised learning

## II. TYPES OF AI

1. Weak AI also known as Narrow AI (NAI) or Artificial Narrow Intelligence (ANI) is directed to focus to perform specific tasks. Weak AI performs most of the strongest applications in all over the world such as Siri (Apple), Alexa (Amazon), Watson (IBM), etc.
2. Strong AI is divided into Artificial General Intelligence (AGI) which is a theoretical form and its intelligence is equal to the human, so it can solve the problem, learn and it can schedule for the future. The second one is Artificial Super Intelligence (ASI) sometimes called super intelligence which surpasses the intelligence and ability of the brain of humans.

### III. BASICSOFAI:<sup>[4]</sup>

“Artificial Intelligence” is the term invented in the 1950s. Dr Abramoff and others try to compare the human brain’s mechanisms with “neural networks” and researchers started working on advanced analysis of automated imaging.

AI systems have the automatic capability to detect and measure pathologic conditions through imaging of the eye. Simple automated detectors are a simple form of AI, which gives a mathematical description (rules-based algorithm) to detect the patterns of incoming images (pattern recognition). Positive hits produce a diagnostic indicator.

1. At the earliest (**basic machine learning**), it was not easy to design computer algorithms to obtain final result therefore it was turned towards machine learning, where features of diseases were introduced to the algorithm and instructed to correlate it with the neighbor network, at their output result.
2. **Advanced machine learning** has neurons which is the combination of two interconnected layers of computing units to make a resemblance to the human brain. Among the first layer, inputs of the disease are introduced and forwarded to the next layer through a neural network to achieve diagnostic output. Thus neural network learns it through the associated specific outputs.
3. **Deep learning with convolution** neural networks (CNNs).the deep learning term has a concern with multiple interconnected layers of neurons through the pixel or voxel intensities and is used to finalize their result through repetition and self-correction i.e. thinking. So CNN algorithm teaches itself through the pixel or voxel intensities. In any adverse result output, the algorithm adjusts its parameters (weights) to lower the error (synaptic strength) till the being agreed of the network is to the optimized result.
4. **In disease feature based versus image-based (black box) learning**, the clinical characteristic of the disease are designed by the ophthalmic researcher for machine-learning algorithms and if necessary then it can be adjusted. However, Google Brain (2016) reported an unsupervised black box system; the algorithm takes decisions correctly in itself for the identification of diabetic lesions through photographs but could not say what the lesions look like. One of the vitreoretinal subspecialist consultants of the Google Brain project said it is exciting with deep learning, it is not yet sure what the system is looking at, but it arrives at a correct diagnosis like an ophthalmologist.

### IV. PRINCIPLEOFAI:<sup>[2]</sup>

The AI (artificial intelligence) devices have two specific areas, machine learning and natural language processing.<sup>[5]</sup>Machine learning provides algorithms to create automatically a complex correlation between the available input data (training set) and performance standard (validation set)<sup>[6]</sup> to create a successful decision over the test. Performance standards need a large number of data from authoritative experts.

The deep learning models are powerful tools for the identification and classification of images and have two subtypes :

- Convolutional neural network (CNN)
- Massive-training artificial neural network (MTANN)<sup>[7]</sup>

Both networks have many layers, but the convolutional neural network works within the network and the massive-training artificial neural network, works outside the network, but at the last of the process convolution layer is connected to the whole, as CNN needs many details for the finalization of the result.<sup>[8]</sup>

## V. HISTORY OF ARTIFICIAL INTELLIGENCE.<sup>[3]</sup>

It was a very old thought that the machine can think, but as electronic computing methods grew up with time so many evolutionary milestones have been established-

Alan Turing (1950) published a study, Computing Machinery and Intelligence, answering 'Can machines think?' through the Turing Test to determine the intelligence of machines is the same as that of humans.

John McCarthy (1956) introduced the term 'artificial intelligence' at an AI conference at Dartmouth College and later in the years, Allen Newell, J.C. Shaw, and Herbert Simon create the first time running software program for AI.

Frank Rosenblatt (1967) introduced the “Mark 1 Perceptron” the first computing software based on a neural network and some years later, Marvin Minsky and Seymour Papert publish the book “Perceptrons” holding the landmark work on neural networks.

Neural network (1980) which used a back propagation algorithm is used widely in AI applications.

IBM's (1997) Deep Blue was won by the world chess champion, Garry Kasparov and later on again in 2011 IBM's Watson was won by champions Ken Jennings and Brad Rutter at Jeopardy.

Baidu's Minwa (2015) uses a convolutional neural network in a supercomputer, for the identification and categorization of images according to a higher rate of accuracy than the average human.

Deep Mind's Alpha Go program (2016), based on a deep neural network, beats the world champion Lee Sodol, the Go player, in a five-game match and thereafter, Google purchased this software.

A rise in large language models (2023), such as Chat-GPT, creates an enormous change in the performance of new generative AI.

**VI. DIFFERENCE BETWEEN AI AND ML:<sup>[1]</sup>**

Sl No	AI	ML
1	A.I. makes a machine to simulate human management.	M.L. concludes a subset of AI from past data.
2	The AI targets to make a resemblance of a smart computer system with the human brain.	The ML utilizes initial pre-filled data to process requests.
3	The main subsets are Machine learning and deep learning.	The main subset is Deep learning.
4	A. I. has a very wide range of scope.	M.L. has a limited scope.
5	A. I. performs various complex tasks.	M.L. performs only specific tasks for which they are pre feeded.
6	A. I. is concerned with maximizing the chances of success.	M.L. is concerned with accuracy and patterns.
7	The popular applications of AI are IOS- Siri user-friendly catboats, Online game playing, intelligent humanoid robots, etc.	The popular applications of ML are an Online recommender system, Google search engine, Facebook auto friend tagging, etc.
8	A. I. is divided into Weak, General, and Strong AI.	M.L. is divided into Supervised, Unsupervised and Reinforcement learning.
9	It includes learning, reasoning, and self-correction.	It includes learning and self-correction.
10	A. I. has concerns with semi-structured, Structured and unstructured data.	M.L. deals only with Structured and semi-structured data.

**VII. AIANDEYE**

The anterior of the cornea to the posterior of the retina can be achieved by the new automated tool named artificial intelligence helpful as a diagnostic tool. This computerized analytical assessment for medical potential is driven by the efforts of Google and IBM. <sup>[4]</sup>

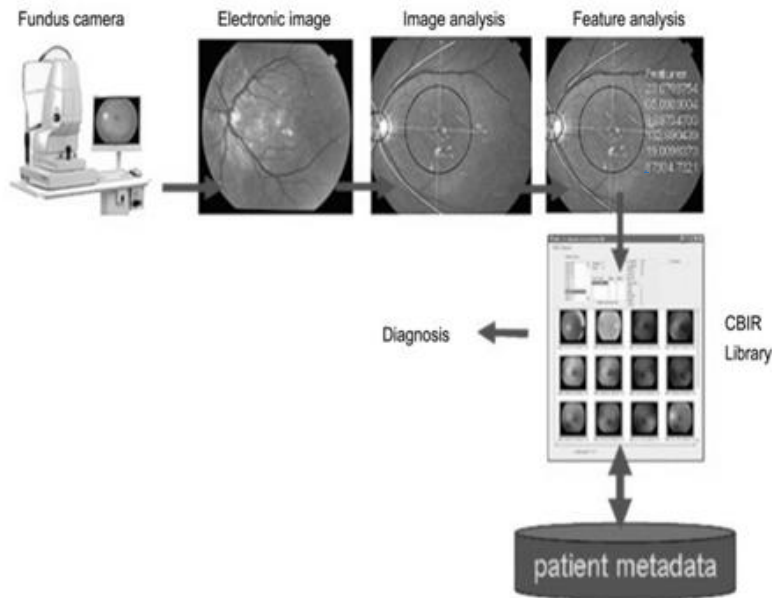
The CASNET-based glaucoma consultation program (1976) for ophthalmic applications of AI, was clinically introduced by the application of Machine Learning based on Artificial Intelligence. <sup>[9]</sup> Ophthalmic diagnosis becomes easy if data-rich imaging is available through Deep Learning algorithms and is emphasized by disease-based learning, where the known characteristics of the disease on the image express themselves for the machine to identify it, and the output is verified by the optometrist or clinician. The most frequent AI tools for cornea (keratoconus), cataract, anterior segment (glaucoma), oculoplastic surgery and retina, including diabetic retinopathy, age-related macular degeneration, and retinopathy of prematurity are available. <sup>[10]</sup>

**VIII. DIABETICRETINOPATHY**

Diabetic Retinopathy is the leading cause of blindness <sup>[11]</sup> where progressive damage through micro- aneurysm, haemorrhage, exudation, cotton-wool spot and neo-vascularization

take place on the retinal vasculature. [12]

For diabetic retinopathy most important is fundus examination, the input for micro-aneurysms and haemorrhage comes in a three-layer feed and is forwarded to the neural network for the classification of the different stages of diabetic retinopathy. Figure1 [13]. Now the characteristics of the disease are extracted to build a model to make the diagnosis. [14]

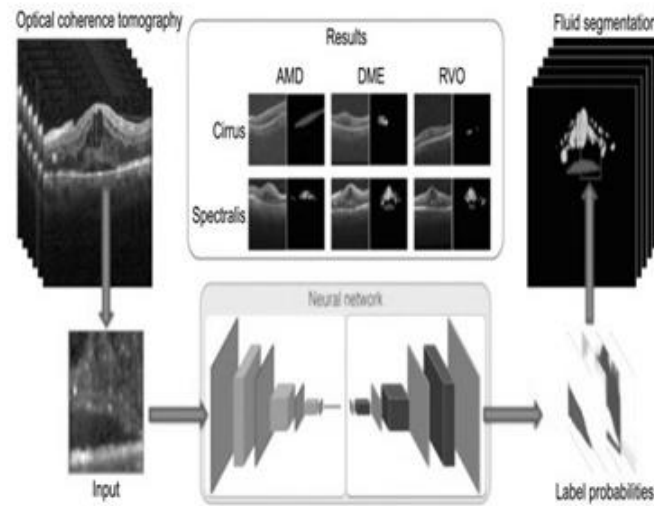


**Figure1:** electronic imaging and Meta data used for the analysis

For diabetic retinopathy most important is fundus examination, the input for micro-aneurysms and haemorrhage comes in a three-layer feed and is forwarded to the neural network for the classification of the different stages of diabetic retinopathy. Figure1 [13]. Now the characteristics of the disease are extracted to build a model to make the diagnosis. [14]

In coordination with the same, some of the studies with the different languages of the AI for the precise verification of the disease are as,

Imani et al [15] develop a technique to detect the morphological component analysis (MCA) for exudates and blood vessel, in the same course Pavle used the CNN. Yazid et al [16] identified the hard exudation and optic disc base, while others reported that they used Lattice Neural Network with Dendritic Processing (LNNDP) enhancement techniques for the detection of blood vessels in retinal images. [17, 18] Akyol et al [19] work on auto-optic disc imaging on the bases of keypoint detection, texture analysis, and visual dictionary techniques. Niemeijer et al [20] work on optic disc imaging by combining k-nearest neighbor (kNN) and cues. Fig-1



**Figure 2:** macular fluid detection in OCT

## IX. RETINALVEINOCCLUSION

According to prevalence retinal vein occlusion (RVO) stepped second for the cause of blindness due to superficial haemorrhage, exudation, and retinal oedema. <sup>[22]</sup> If it has involved the macula, visual acuity decreases up to significant blindness. The people who are diseased are old aged having hypertension, arteriosclerosis or cardiovascular disease. <sup>[23,24]</sup> The machine learning for RVO has low involvement but CNN accompanies patch-based and image-based mechanisms.

## X. MACULARDEGENERATION

AI in coordination with optical coherence tomography (OCT) imaging becomes of immediate interest for age-related macular degeneration (ARMD) and other macular disorders. Two-dimensional imaging provides the anatomical state of the retina with the classification of diseases like choroidal neovascularization (CNV), macular oedema, drusen, geographic atrophy, epiretinal membrane (ERM), vitreomacular traction, macular hole, central serous chorioretinopathy (CSR), etc., along with the referral quality like urgent, semi-urgent, routine, or observational. <sup>[25]</sup>

## XI. RETINOPATHYOFPREMATURITY

In childhood, retinopathy of prematurity is counted as the leading cause of blindness. <sup>[26,27]</sup> Infants with pre-disease require regular observation and those who have advanced stage need treatment. <sup>[28]</sup> The application of AI improves patient care. The disease progression, regression, and response to treatment are based on the patient's severity score.

The automatic identification of ROP for promised results focused on two-level classification (plus or not plus disease) <sup>[29-32]</sup>. The 3 nethra camera, introduced by Forus Health Incorporated, Bengaluru, Karnataka, India, has demonstrated high-performance identification of the different ROP stages. <sup>[33]</sup>

## **XII. ANTERIOR SEGMENT DISEASES**

Cataract and glaucoma are very common issues for the eye. [34, 35] Gao et al [36] proposed a system which automatically graded nuclear cataracts by slit-lamp imaging through CNN. Goh et al. [37] explored the AI application for cataract screening with the help of ophthalmic fundus and slit lamp imaging to automate best-fit intraocular lens possibility.

Wu et al. [38] provided keratoconus identification, [39, 40] and corneal power assessment after refractive surgery. [41] through Scheimpflug camera.

Glaucoma damages the optic nerve and the diagnosis of glaucoma is based on the IOP, the retinal nerve fibre thickness, the examination of optic nerve and visual field [42, 43] thus early detection is very important as it can be slowed down the symptoms by reasonable treatment otherwise, the end stage of glaucoma causes irreversible blindness. [44, 45, 46] Deep Learning algorithms are capable to identify glaucoma through the optic disc and to recognize damage to the glaucomatous nerve fibre layer on wide-angle OCTs, [47] to justify earlier visual field loss. The prediction tool also helps for future possibilities of the disease.

Omodaka et al [48] introduce the ML algorithm; the quantitative parameter, to classify the optic disc imaging for open-angle glaucoma with an accuracy of 87.8%.

The main theme for the glaucoma evaluation is based on access to input images of cup disc ratio [49, 50] grabbed by the fundus images, the visual field [51] or the retinal nerve fibre thickness, examined by OCT [52].

## **XIII. LIMITATIONS AND ETHICAL ISSUES**

Although if the weaker training set of images and its quality is presented to the AI tool, it produces an unlikely accurate outcome because of reference slandered, so datasets should be well refined and could be maintained under certain limits. For example, the AI tool works well for diabetic retinopathy but it may get confused with the central retinal vein occlusion.

The CNN-based system analyzes an image or data on the bases of its own self-generated rules and the surety of outcome becomes troublesome to the observer, this issue is known as the black box problem. Thus if CNN evaluates any of the altered images, then it can result in disease-free. [53] The future aspects indicate some of the attempts at AI-based eyelid and periorbital measurements, for the assistance of the horizontal strabismus surgery. [54]

The following six ethical concerns identified by the WHO-

1. Protects human autonomy,
2. Promotes human well-being and safety in the public interest,
3. Ensures transparency, explain ability, and intelligibility,
4. Fostering responsibility and accountability,
5. Ensures inclusiveness with equity, and
6. Promotes responsiveness and sustainability AI. [55]

These ethical and legal key points were already emphasized by Gerke et al., [56] and



advocated for a high level of public trust. The second issue is very unlikely to be developed whether ophthalmologists will be replaced by AI or a new race of patients will attend to the ophthalmologist/ optometrist, with referable or treatable disease. Here are the chances for a physician-based medical practice versus AI attraction, but AI could not cover the total skill although maximize the efficiency and precision of the diagnosis.

Finally, for any diagnosis machines can help but they cannot produce well enough medical decisions. Although in the future AI will occupy an effective role in medicine and in the current situation, AI has established a big role in research.

## REFERENCE

- [1] javatpoint.com/difference-between-artificial-intelligence-and-machine-learning.
- [2] Xue-Li Du, Wen-Bo Li, Bo-Jie Hu, Application of artificial intelligence in ophthalmology, *Int J Ophthalmol*. 2018; 11(9):1555–1561. 2018 Sep 18. doi:10.18240/ijo.2018.09.21, PMID: 30225234, PMCID: PMC6133903.
- [3] ibm.com/topics/artificial-intelligence.
- [4] Artificial Intelligence, Linda Roach, aao.org/Assets/b3aec83c-95ff-41fc-880d-d514d4ae530d/636441362759230000/november-2017-feature-2-pdf.
- [5] Darcy AM, Louie AK, Roberts LW. Machine learning and the profession of medicine. *JAMA*. 2016; 315(6):551–552.
- [6] Lee A, Taylor P, Kalpathy-Cramer J, Tufail A. Machine learning has arrived. *Ophthalmology*. 2017; 124(12):1726–1728.
- [7] Suzuki K. Overview of deep learning in medical imaging. *Radiol Phys Technol*. 2017; 10(3):257–273.
- [8] Krizhevsky A, Sutskever I, Hinton GE. ImageNet classification with deep convolutional neural networks. *Communications of the ACM*. 2017; 60(6):84–90.
- [9] Weiss S, Kulikowski CA, Safir A. Glaucoma consultation by computer. *Comput Biol Med*. 1978; 8:25–40.
- [10] Ting DSW, Pasquale LR, Peng L, Campbell JP, Lee AY, Raman R, et al. Artificial intelligence and deep learning in ophthalmology. *Br J Ophthalmol*. 2019; 103:167–75.
- [11] Kocur I, Resnikoff S. Visual impairment and blindness in Europe and their prevention. *Br J Ophthalmol*. 2002; 86(7):716–722.
- [12] Jyothi S, Chowdhury H, Elagouz M, Sivaprasad S. Intravitreal bevacizumab (Avastin) for age-related macular degeneration: a critical analysis of literature. *Eye (Lond)* 2010; 24(5):816–824.
- [13] Chaum E, Karnowski TP, Govindasamy VP, Abdelrahman M, Tobin KW. Automated diagnosis of retinopathy by content-based image retrieval. *Retina*. 2008; 28(10):1463–1477.
- [14] Wong LY, Acharya R, Venkatesh YV, Chee C, Min LC. Identification of different stages of diabetic retinopathy using retinal optical images. *Information Sciences*. 2008; 178:106–121.
- [15] Imani E, Pourreza HR, Banaee T. Fully automated diabetic retinopathy screening using morphological component analysis. *Comput Med Imaging Graph*. 2015; 43:78–88.
- [16] Yazid H, Arof H, Isa HM. Automated identification of exudates and optic disc based on inverse surface thresholding. *J Med Syst*. 2012; 36(3):1997–2004.
- [17] Vega R, Sanchez-Ante G, Falcon-Morales LE, Sossa H, Guevara E. Retinal vessel extraction using Lattice Neural Networks with Dendritic Processing. *Comput Biol Med*. 2015; 58:20–30.
- [18] Mirsharif Q, Tajeripour F, Pourreza H. Automated characterization of blood vessels as arteries and veins in retinal images. *Comput Med Imaging Graph*. 2013; 37(7-8):607–617.
- [19] Akyol K, Şen B, Bayır Ş. Automatic detection of optic disc in retinal image by using keypoint detection, texture analysis, and visual dictionary techniques. *Comput Math Methods Med*. 2016; 2016:6814791.
- [20] Niemeijer M, Abramoff MD, van Ginneken B. Fast detection of the optic disc and fovea in color fundus photographs. *Med Image Anal*. 2009; 13(6):859–870.
- [21] Schlegl T, Waldstein SM, Bogunovic H, et al. Fully automated detection and quantification of macular fluid in OCT using deep learning. *Ophthalmology*. 2018; 125(4):549–558.
- [22] Rogers SL, McIntosh RL, Lim L, Mitchell P, Cheung N, Kowalski JW, Nguyen HP, Wang JJ, Wong TY. Natural history of branch retinal vein occlusion: an evidence-based systematic review. *Ophthalmology*. 2010; 117(6):1094–1101.e5.
- [23] Lim LL, Cheung N, Wang JJ, Islam FM, Mitchell P, Saw SM, Aung T, Wong TY. Prevalence and risk

- factors of retinal vein occlusion in an Asian population. *Br J Ophthalmol*. 2008;92(10):1316–1319.
- [24] Liu W, Xu L, Jonas JB. Vein occlusion in Chinese subjects. *Ophthalmology*. 2007;114(9):1795–1796.
- [25] Ting DSW, Cheung CY, Lim G, Tan GSW, Quang ND, Gan A, et al. Development and validation of a deep learning system for diabetic retinopathy and related eye diseases using retinal images from multiethnic populations with diabetes. *JAMA*. 2017;318:2211–23.
- [26] Gilbert C, Foster A. Childhood blindness in the context of VISION2020—the right to sight. *Bull World Health Organ*. 2001;79(3):227–232.
- [27] Gilbert C, Fielder A, Gordillo L, Quinn G, Semiglia R, Visintin P, Zin A, International NO-ROP Group. Characteristics of infants with severe ROP in countries with low, moderate, and high levels of development: implications for screening programs. *Pediatrics*. 2005;115(5):e518–e525.
- [28] Early Treatment For Retinopathy Of Prematurity Cooperative Group. Revised indications for the treatment of retinopathy of prematurity: results of the early treatment for retinopathy of prematurity randomized trial. *Arch Ophthalmol*. 2003;121(12):1684–1694.
- [29] Ataer-Cansizoglu E, Kalpathy-Cramer J, You S, Keck K, Erdogmus D, Chiang MF. Analysis of underlying causes of inter-expert disagreement in retinopathy of prematurity diagnosis. Application of machine learning principles. *Methods Inf Med*. 2015;54(1):93–102.
- [30] Ataer-Cansizoglu E, Bolon-Canedo V, Campbell JP, Bozkurt A, Erdogmus D, Kalpathy-Cramer J, Patel S, Jonas K, Chan RV, Ostmo S, Chiang MF, i-ROP Research Consortium. Computer-based image analysis for plus disease diagnosis in retinopathy of prematurity: performance of the “i-ROP” system and image features associated with expert diagnosis. *Transl Vis Sci Technol*. 2015;4(6):5.
- [31] Bolón-Canedo V, Ataer-Cansizoglu E, Erdogmus D, Kalpathy-Cramer J, Fontenla-Romero O, Alonso-Betanzos A, Chiang MF. Dealing with inter-expert variability in retinopathy of prematurity: a machine learning approach. *Comput Methods Programs Biomed*. 2015;122(1):1–15.
- [32] Campbell JP, Ataer-Cansizoglu E, Bolon-Canedo V, et al. Expert diagnosis of plus disease in retinopathy of prematurity from computer-based image analysis. *JAMA Ophthalmol*. 2016;134(6):651–657.
- [33] Chen JS, Coyner AS, Ostmo S, Sonmez K, Bajimaya S, Pradhan E, et al. Deep learning for the diagnosis of stage in retinopathy of prematurity: Accuracy and generalizability across populations and cameras. *Ophthalmol Retina*. 2021;5:1027–35.
- [34] Tandon R. Re: Waltz et al.: Clinical outcomes of TECNIS toric intraocular lens implantation after cataract removal in patients with corneal astigmatism (*Ophthalmology* 2015;12:239–47). *Ophthalmology*. 2016;123(1):e4.
- [35] Murthy GV, Gupta SK, Bachani D, Jose R, John N. Current estimates of blindness in India. *Br J Ophthalmol*. 2005;89(3):257–260.
- [36] Gao X, Lin S, Wong TY. Automatic feature learning to grade nuclear cataracts based on deep learning. *IEEE Trans Biomed Eng*. 2015;62(11):2693–2701.
- [37] Goh JHL, Lim ZW, Fang X, Anees A, Nusinovici S, Rim TH, et al. Artificial intelligence for cataract detection and management. *Asia Pac J Ophthalmol (Phila)* 2020;9:88–95.
- [38] Wu X, Liu L, Zhao L, Guo C, Li R, Wang T, et al. Application of artificial intelligence in anterior segment ophthalmic diseases: Diversity and standardization. *Ann Transl Med*. 2020;8:714.
- [39] Kovács I, Miháltz K, Kránitz K, Juhász É, Takács Á, Dienes L, et al. Accuracy of machine learning classifiers using bilateral data from a Scheimpflug camera for identifying eyes with preclinical signs of keratoconus. *J Cataract Refract Surg*. 2016;42:275–83.
- [40] Hidalgo IR, Rodriguez P, Rozema JJ, Dhuhghail SN, Zakaria N, Tassignon MJ, et al. Evaluation of a machine-learning classifier for keratoconus detection based on Scheimpflug tomography. *Cornea*. 2016;35:827–32.
- [41] Koproński R, Lanza M, Irregolare C. Corneal power evaluation after myopic corneal refractive surgery using artificial neural networks. *Biomed Eng Online*. 2016;15:1–2.
- [42] Musch DC, Gillespie BW, Niziol LM, Lichter PR, Varma R. Intraocular pressure control and long-term visual field loss in the Collaborative Initial Glaucoma Treatment Study. *Ophthalmology*. 2011;118(9):1766–1773.
- [43] Oddone F, Lucenteforte E, Michelessi M, Rizzo S, Donati S, Parravan M, Virgili G. Macular versus retinal nerve fiber layer parameters for diagnosing manifest glaucoma: a systematic review of diagnostic accuracy studies. *Ophthalmology*. 2016;123(5):939–949.
- [44] Murthy GV, Gupta SK, Bachani D, Jose R, John N. Current estimates of blindness in India. *Br J Ophthalmol*. 2005;89(3):257–260.
- [45] Damms T, Dannheim F. Sensitivity and specificity of optic disc parameters in chronic glaucoma. *Invest Ophthalmol Vis Sci*. 1993;34(7):2246–2250.
- [46] Ohnell H, Heijl A, Brenner L, Anderson H, Bengtsson B. Structural and functional progression in the

- early manifest glaucoma trial. *Ophthalmology*. 2016;123(6):1173–1180.
- [47] Christopher M, Belghith A, Weinreb RN, Bowd C, Goldbaum MH, Saunders LJ, et al. Retinal nerve fiber layer features identified by unsupervised machine learning on optical coherence tomography scans predict glaucoma progression. *Invest Ophthalmol Vis Sci*. 2018;59:2748–56.
- [48] Omodaka K, An G, Tsuda S, Shiga Y, Takada N, Kikawa T, Takahashi H, Yokota H, Akiba M, Nakazawa T. Classification of optic disc shape in glaucoma using machine learning based on quantified ocular parameters. *PLoS One*. 2017;12(12):e0190012.
- [49] Chen Xianyu, Xu Yanwu, Wong Damon Wing Kee, Wong Tien Yin, Liu Jiang. Glaucoma detection based on deep convolutional neural network. *Conf Proc IEEE Eng Med Biol Soc*. 2015;2015:715–718.
- [50] Cerentini A, Welfer D, Cordeiro d'Ornellas M, Pereira Haygert CJ, Dotto GN. Automatic identification of glaucoma using deep learning methods. *Stud Health Technol Inform*. 2017;245:318–321.
- [51] Asaoka R, Murata H, Iwase A, Araie M. Detecting Preperimetric glaucoma with standard automated perimetry using a deep learning classifier. *Ophthalmology*. 2016;123:1974–1980.
- [52] Muhammad H, Fuchs TJ, DeCuir N, DeMoraes CG, Blumberg DM, Liebmann JM, Ritch R, Hood DC. Hybrid deep learning on single wide-field optical coherence tomography scans accurately classifies glaucoma suspects. *J Glaucoma*. 2017;26(12):1086–1094.
- [53] Lynch SK et al. Catastrophic failure in image-based convolutional neural network algorithms for detecting diabetic retinopathy. Presented at: ARVO 2017 Annual Meeting; May 10, 2017; Baltimore.
- [54] de Almeida JD, Silva AC, Teixeira JA, Paiva AC, Gattass M. Surgical planning for horizontal strabismus using support vector regression. *Comput Biol Med*. 2015;63:178–86.
- [55] Ethics and governance of artificial intelligence for health. [Last accessed on 2022 Mar 10]. Available from: <https://www.who.int/teams/health-ethics-governance/emerging-technologies/big-data-and-artificial-intelligence>.
- [56] Gerke S, Minssen T, Cohen G. Ethical and legal challenges of artificial intelligence-driven healthcare. *Artificial Intelligence in Healthcare*. 2020:295–336.