Artificial Intelligence and Glaucoma

Ilgaz Yalvac[1]

ABSTRACT

Glaucoma is a group of eye diseases characterized by optic neuropathy, a specific pattern of visual field defect and increased intraocular pressure (IOP). The rise in IOP leads to compression of the optic nerve that causes progressive and permanent visual loss.

Artificial intelligence (AI) is defined as the creation of automated systems to perform tasks that are regarded as requiring human intelligence, such as visual perception, decision-making, and feature recognition. The approach of to diagnosis and progression of glaucoma with AI is discussed in this review.

INTRODUCTION

Glaucoma is a group of eye diseases characterized by optic neuropathy, a specific pattern of visual field defect and increased intraocular pressure. The rise in intraocular pressure leads to compression of the optic nerve that causes progressive and permanent visual loss.[1] Current knowledges estimate that 112 million people will have glaucoma by the year 2040, early detection and intervention can help prevent vision loss from glaucoma.[2]

Artificial intelligence (AI) is defined as the creation of automated systems to perform tasks that are regarded as requiring human intelligence, such as visual perception, decision-making, and feature recognition. Recent progress in AI and the collation of large medical datasets have spurred great interest in the development of deep learning algorithms that would more quickly and accurately identify glaucomatous damage on diagnostic tests compared to subjective evaluation and other traditional methods.[3]

There are multiple goals of artificial intelligence in glaucoma. The first aim has been detection of glaucoma by classifying visual fields, optic nerve imaging, or other clinical data. Second, artificial intelligence has been utilized to detect worsening earlier than conventional algorithms. Finally, machine learning has been applied to studying risk factors for glaucoma, and quality of life.

Artificial Intelligence, Machine Learning, Deep Learning

Artificial intelligence (AI) is defined as the creation of automated systems to perform tasks that are regarded as requiring human intelligence, such as visual perception, decision-making, and feature recognition.[3-4]

Machine learning (ML) is a subset of AI that is concerned with setting up computer algorithms to recognize patterns in data, without human programmers having to dictate all aspects of this recognition. But ML algorithms require human-designed code to transform raw data into input features, as these algorithms are not particularly good at learning features directly from raw data.[5]

Deep learning (DL) is the latest transformation of the AI and is different in that it allows for more complex inputs, and for several intermediate layers. These changes allow for the networks to make more sophisticated decisions.[6] It uses layered algorithmic architectures to analyze data. The input data is filtered through multiple layers, with each successive layer obtaining the output from the previous layer as its input. The architecture is inspired by the way biological neurons are interconnected to process information in the brain. Convolutional Neural Networks (CNNs) use a specialized kind of linear operation.[7]

1- MD; FEBO, Yeditepe University Medical School Ophthalmology Department, Istanbul, Turkey

Received: 14.09.2021
Accepted: 17.09.2021

Glo-Kat 2021; 16: 127-130

DOİ: 10.37844/glauc.cat.2021.16.22

Correspondence Adress:
Ilgaz Yalvac
Hossohbet sokak 13/29, Beşiktaş, Istanbul, Turkey
Phone: +90 532 221 52 46
E-mail: iyalvac@yahoo.com

Deep Learning Models in Glaucoma Screening with Fundus Photography

Fundus photography represents a relatively low-cost option for screening of certain eye diseases and has been successfully incorporated into tele-ophthalmology.[8-9]

Once a deep learning model is successfully to recognize the presence of disease on fundus photographs, it can then be easily deployed to provide gradings on previously unseen photos in real time and deep learning algorithm could be developed to screen for glaucoma. The algorithm can be developed for images that were considered “referable” for a glaucoma specialist, based on subjective grading of the photographs. Phene et al; showed that; the deep learning algorithm tended to underdiagnose glaucoma in high myopes, thus increasing the false-negative rate, but overcalled glaucoma in physiologically enlarged cups, thus inflating the false-positive rate.[10] As usual; ophthalmologists tend to undercall glaucoma in small optic discs but overcall it in physiologically enlarged cups.[11] However the DL-based algorithm can detect glaucomatous optic discs at a high accuracy level by using only monoscopic fundus images, which are easier to obtain in a large population. This highlights its potential application in population-based disease screening or tele-medicine programs.

Glaucoma Diagnosis with Optical Coherence Tomography

Optical Coherence Tomography (OCT) has become the most used diagnostic tool for detecting glaucomatous structural damage.[12] Measurements of the retinal nerve fiber layer (RNFL), optic nerve head and macula are routinely used in clinical practice for disease diagnosis and detection of progression.[13] Commercial machines use segmentation algorithms to delineate retinal layers, with a specific focus on RNFL. This segmentation process is done automatically by the machine’s software, but it is still largely imperfect and up to 40% of OCT-RNFL scans can contain segmentation errors that significantly limit their accuracy.[14] Another difficulty in the interpretation of OCT scans arises from the multiple parameters and regions that are analyzed. It can be difficult for the clinician to integrate all the information derived from global and sectoral RNFL thickness measurements, as well as topographic optic nerve head parameters and macular assessment. Despite these obstacles; deep learning algorithms can learn features from data automatically, as long as enough data are given to machine.[15]

Mariottoni et al.; demonstrated that a segmentation-free deep algorithm could be trained to predict RNFL when assessing a raw OCT scans The segmentation-free predictions were highly correlated with the conventional RNFL thickness.[16] Thompson et al.; showed that a deep learning algorithm can be trained using the raw OCT scans to directly discriminate glaucomatous from healthy eyes.

Although the studies report the general success of AI systems in identifying glaucomatous eyes, the majority of studies were unable to demonstrate superiority in diagnostic accuracy in comparison to using the best single conventional OCT parameter (e.g. rim area and average RNFL thickness).[18]

Glaucoma Diagnosis with Standard Automated Perimetry

Artificial intelligence strategies to diagnose glaucoma using data sets derived from visual field testing have been studied since 1994.[19] Using standard automated perimetry (SAP) data, AI can classify the severity of field loss from early to advanced damage by using artificial neural network (ANN), data analysis. With systems, the machine is able to identify the best parameters for a given algorithm to perform a particular task and machine is able to identify the best parameters for a given algorithm to perform a particular task.[20-21]

Andersson et al. were the first to report the potential outperformance of clinicians by a trained ANN in making a diagnosis of glaucoma based upon visual field test data. The ANN performed comparably to clinicians with high specificity and sensitivity.[22]

Other studies have demonstrated that evaluation of VF tests with ML classifiers and trained ANN perform conventional parameters, such as the Glaucoma Hemifield Test,Mean Deviation, and Pattern Standard Deviation.[23-24]

Elze et al; proposed a technique of “archetypal analysis” to classify patterns of visual field loss in glaucoma. They showed that the patterns detected by their, such as arcuate, partial arcuate, etc., corresponded well to classification by human graders in the Ocular Hypertension Treatment Study.[25]

It should be noted, however, that archetypal analysis is a statistical technique closely resembling traditional factor analysis and bearing no relationship to deep learning artificial neural networks.

However, neural network performance is affected by training sets, which need to be large in size and well balanced in phenotype with to the normal and glaucomatous data sets, as well as in defect severity and defect location.

Misclassification may still be an issue in more challenging cases.

Glaucoma Progression

Detection of glaucoma progression is a very important component of the clinical management of patients with glaucoma, in order to identify those individuals at risk of developing glaucoma-related visual impairment. Identifying progression over shorter time intervals is often challenging and requires the identification of structural or functional change at the earliest possible time point. Because AI algorithms have the potential to incorporate structural or functional changes over time, they have the potential to provide more accurate and timely identification of likely glaucoma progression.[26-29]

CONCLUSION

Deep learning is an exciting technique that holds enormous promise in glaucoma.

However, it should be noted that no matter how exciting AI technologies can be, validation of new diagnostic tests should be based on rigorous methodology

with particular attention paid to how the reference standards are defined and the settings where the tests are going to be applied in practice. Although significant progress has been made with AI and deep learning in glaucoma, a lot of work remains to be done.[30]

REFERENCES

1. Budenz DL, Barton K, Whiteside-de Vos J, et al. Prevalence of glaucoma in an urban West African population: the Tema Eye Survey. JAMA Ophthalmol. 2013;131:651-8.
2. Hennis A, Wu SY, Nemesure B, Honkanen R, Leske MC, Barbados Eye Studies G. Awareness of incident open-angle glaucoma in a population study: the Barbados Eye Studies. Ophthalmology. 2007;114:1816-21.
3. Zheng C, Johnson TV, Garg A, Boland MV. Artificial intelligence in glaucoma. Curr Opin Ophthalmol 2019, 30:97-103.
4. Ting DSW, L Pasquale, Peng L, Campbell P, Lee AY, Raman R, et al. Artificial intelligence and deep learning in ophthalmology. Br J Ophthalmol 2019;103:167-75.
5. Hinton G. Deep learning: a technology with the potential to transform healthcare. JAMA 2018; 320:1101-2.
6. Li Z, He Y, Keel S, Meng W, Chang RT, He M. Efficacy of a deep learning system for detecting glaucomatous optic neuropathy based on color fundus photographs. Ophthalmology. 2018;125:1199-206.
7. Girard JAM, Schmetterer L. Artificial intelligence and deep learning in glaucoma: Current state future prospects. Progress in Brain Research. 2020 Volume 257, ISSN 0079-6123.
8. Rahimy E. Deep learning applications in ophthalmology. Curr Opin Ophthalmol 2018; 29:254-60.
9. Owsley C, McGwin G Jr, Lee DJ et al. Diabetes eye screening in urban settings serving minority populations: detection of diabetic retinopathy and other ocular findings using telemedicine. JAMA Ophthalmol. 2015;133:174-81.
10. Phene S, Dunn CR, Hammel N; etal. Deep Learning and Glaucoma Specialists The Relative Importance of Optic Disc Features to PredictGlaucoma Referral in Fundus Photographs. Ophthalmology 2019;126:1627-39.
11. Liu S, Graham SL, Shulz A; et al. A Deep Learning based algoriidentifies glaucomatous discusing monoscopic Fundus Photographs. Ophthalmology Glaucoma 2018;1:15-22.
12. Leung CK, Cheung CY, Weinreb RN; et al. Retinal nerve fiber layer imaging with spectral domain optical coherence tomography: a variability and diagnostic performance study. Ophthalmology. 2009;116:1257-63.
13. Salazar U, Misra V, Swaminathan S. Artificial intelligence and complex statistical modeling in glaucoma diagnosis and management. Curr Opin Ophthalmol 2021, 32:105-17.
14. Asrani S, Essaid L, Alder BD, Santiago-Turla C. Artifacts in spectral-domain optical coherence tomography measurements in glaucoma. JAMA Ophthalmol. 2014;132:396-402.
15. Ran AR, Tham C, Chan PP; et al. Deep learning in glaucoma with optical coherence tomography: a review. Eye (2021) 35:188-201 Eye (2021) 35:188-201.
16. Mariottoni EB, Jammal AA, Urata CN, et al. Quantification of retinal nerve fibre layer thickness on optical coherence tomography with a deep learning segmentation-free approach. Scientific Reports. 2020;10:402.
17. Thompson AC, Jammal AA, Berchuck SI, Mariottoni EB, Medeiros FA. Assessment of a segmentation-free deep learning algorithm for diagnosing glaucoma from optical coherence tomography scans. JAMA Ophthalmol. 2020;138:333-9.
18. Mursch-Edlmayr AS, Ng WS, Diniz-Filho A; et al. Artificial Intelligence Algorithms to Diagnose Glaucoma and Glaucoma Progression: Translation to Clinical Practice. Transl Vis Sci Technol. 2020 Oct 15;9:55.
19. Goldbaum MH, Sample PA, White H; et al. Interpretation of automated perimetry for glaucoma by neural network. Invest Ophthalmol Vis Sci. 1994;35:3362-73.
20. Li F, Wang Z, Qu G, et al. Automatic differentiation of Glaucoma visual field from non-glaucoma visual filed using deep convolutional neural network. BMC Med Imaging. 2018;18:35.
21. Bizios D, Heijl A, Bengtsson B. Trained artificial neural network for glaucoma diagnosis using visual field data: a comparison with conventional algorithms. J Glaucoma. 2007;16:20-8.
22. Andersson S, Heijl A, Bizios D, Bengtsson B. Comparison of clinicians and an artificial neural network regarding accuracy and certainty performance of visual field assessment for the diagnosis of glaucoma. Acta Ophthalmol. 2013;91:413-7.
23. Brigatti L, Hoffman D, Caprioli J. Neural networks to identify glaucoma with structural and functional measurements. Am J Ophthalmol. 1996;121:511-21.

24. Asaoka R, Murata H, Iwase A, Araie M. Detecting preperimetric glaucoma with standard automated perimetry using a deep learning classifier. Ophthalmology. 2016;123:1974-80.

25. Elze T, Pasquale LR, Shen LQ; et al. Patterns of functional vision loss in glaucoma determined with archetypal analysis. J R Soc Interface. 2015;12:20141118.

26. Brigatti L, Nouri-Mahdavi K,Weitzman M, Caprioli J. Automatic detection of glaucomatous visual field progression with neural networks. Arch Ophthalmol. 1997;115:725-8.

27. Medeiros FA, Zangwill LM, Weinreb RN. Improved prediction of rates of visual field loss in glaucoma using empirical Bayes estimates of slopes of change. J Glaucoma. 2012;21:147-54.

28. Medeiros FA, Zangwill LM, Girkin CA, Liebmann JM,Weinreb RN. Combining structural and functional measurements to improve estimates of rates of glaucomatous progression. Am J Ophthalmol. 2012;153:1197-1205.e1191.

29. Murata H, Araie M, Asaoka R. A new approach to measure visual field progression in glaucoma patients using variational bayes linear regression. Invest Ophthalmol Vis Sci. 2014;55:8386-8392.

30. Mayro EL, Wang M, Elze T, Pasquale L. The impact of artificial intelligence in the diagnosis and management of glaucoma. Eye. 2020; 34:1-11.