Annals of Medicine and Medical Sciences (AMMS)
Volume 04, 2025, *Page No.: 441 to 446*
Available at: *http://ammspub.com*

Review Article

OPEN ACCESS

Different Methods for Glaucoma Screening

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Abstract

Glaucoma is the leading cause of blindness globally, behind diabetes. An optic nerve cup-to-disc ratio test may help detect early glaucoma. Goniascope, slit-lamp examination (including dilated optic disc and retinal examination), automated permetry, optical coherence tomography nerve fibre layer (NFL) examination, and Heidelberg Retina Tomograph (HRT) optic disc evaluation. Techniques such as these may be used to analyse retinal pictures and identify and compute the key portions of the images in order to acquire an estimate of optic cup-to-disc ratio. Segmentation methods and procedures will be examined in this research.

Keywords: ***Optic cup segmentation, optic disc.***

Introduction

The eye is the human body's most complex and well-developed sensory organ. It has a number of natural defence mechanisms in place to protect it from infection and injury. Despite this, many individuals suffer from vision problems. Glaucoma, a common ocular condition, may damage the optic nerve, which links the eye to the brain. It refers to a variety of disorders that may damage the optic nerve, resulting in vision loss or blindness. In older people, age-related macular degeneration is the second most prevalent reason of permanent blindness. Glaucoma is defined as acquired damage to the optic nerve and retinal ganglionic cells, often known as "optic neuropathy." If not treated, it might result in irreversible eyesight loss. The development of each eye is distinct, and it is possible that both eyes will be damaged at the same time. Glaucoma is characterized by an elevated intraocular pressure (IOP). Clear water-like fluid fills the eye's anterior chamber, which comprises the cornea, iris, lens, and pupil. The lens and cornea are nourished by this fluid, which provides them with nutrients and oxygen they need. IOP, or intraocular pressure, is a term used to describe the pressure required to preserve the shape of the eye. The trabecular meshwork, which drains the eye's fluid, is a common cause of glaucoma. As a result, aqueous humor cannot flow normally, causing increased pressure in the eye. The optic nerve and retinal nerve fibers are gradually damaged by this strain. Glaucoma is a group of disorders that, if left untreated, develop and cause permanent visual loss. Bleary vision, headache, nausea, vomiting, acute eye discomfort and soreness in the surrounding eye region are some of the most typical glaucoma symptoms. It is important to check for glaucoma since there are several risk factors, including age above 60, race, Intra Ocular Pressure (IOP), family history of glaucoma, Myopia, and diabetes mellitus. To diagnose glaucoma, different screening procedures are used.

Glaucoma may be classified into three types: primary open-angle glaucoma, angle-closure glaucoma, and secondary glaucoma. For example, pseudo exfoliative, pigmentary, Neovascular, and primary congenital are all forms of secondary glaucoma. This covers conditions like inherited familial glaucoma in infants. There are numerous other types of glaucoma, such as those caused by inflammation, lens-related glaucoma, trauma-induced glaucoma, the ICE (Iridocorneal endothelial) syndrome, ciliochoroidal detachment-related glaucoma, epithelial growth-related glaucoma, the Sturge-Weber syndrome, and glaucoma associated with intra-ocular or eye tumours.

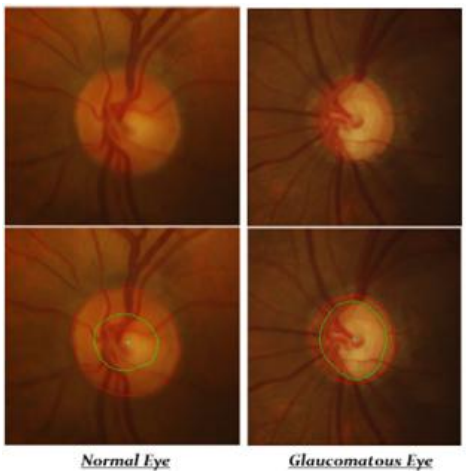

Figure 1: (Sivaswamy et al., 2014) Normal and Glaucomatous eye

Because the distal portion of the optic nerve contains all of the retina's nerve cells, it is critical to look for any signs of glaucoma. The optic disc, where the optic nerve originates, is where retinal

Received: April 19, 2025; **Revised:** May 15, 2025; **Accepted:** May 24, 2025

ganglionic cells meet, and the optic cup is a depression with an irregular shape in the centre.

The optic nerve connects the eye to the brain, carrying visual information. The most prevalent kind of glaucoma is POAG, or primary open-angle glaucoma, which is produced by a clogged drainage system over time. This can cause vision loss if left untreated because it raises the internal pressure of the eye. The pressure in the eye may suddenly rise if the drainage canals in the cornea are fully closed, making primary angle-closure glaucoma (PACG) a highly hazardous type of this condition. In normal-tension glaucoma, this might be owing to abnormalities in the blood flow to the other optic nerve or a weakening of the optic nerve tissue. A medical condition that elevates intraocular pressure in the eye may develop secondary glaucoma, leads to blindness or damage to the optic nerve. Depending on the kind of glaucoma you have, you may experience distinct glaucoma symptoms. There are no evident symptoms in the early stages of primary open-angle glaucoma, but as the disease advances, it may create blind patches. Primary angle-closure glaucoma is a kind of glaucoma characterised by a sudden loss of vision or attack with no warning indications. Glaucoma with normal blood pressure generates blind spots in the visual field.

Detecting glaucoma in its earliest stages is critical, but it can be challenging since some people show no symptoms at all. Eye pressure that is greater than usual may be present in some people. These people are at greater risk of developing glaucoma because they are considered glaucoma suspects. Glaucoma suspects with no symptoms may have normal eye pressure, but that doesn't mean they don't need to be closely followed by an eye doctor. A variety of tests are needed to accurately identify glaucoma.

1. Assessment of intraocular pressure (IOP) using “air puff test” or Gold tonometry.
2. Analysis of visual field and
3. Assessment of the optic nerve head damage (Almazroa et al., 2015).

A gradual loss of eyesight develops over time if the condition is not addressed. In more advanced stages of the illness, glaucoma patients begin to experience symptoms. An early diagnosis and timely treatment of glaucoma can decrease its course, resulting in less loss of optic nerve fibres in the eye. Both high and low-tension glaucomas have the potential to raise IOP. Diagnosing glaucoma requires additional screening tests such as fundus camera, OCT, and Heidelberg retina tomography in addition to IOP measurement. SD-OCT (Spectral domain-Optical coherence tomography) and SAP (Standard automated Perimetry) are also used to identify glaucoma, however their results might be inconsistent, hence the optic nerve head examination (ONH) is utilised (Almazroa et al., 2015).

CNN (convolution neural network) is an automated glaucoma detection technology that is also significant for glaucoma detection. Screening for glaucoma is time-consuming, costly, and labor-intensive, and it is prone to mistake due to inexperienced personnel. Expertise is required to perform this task. The paucity of eye doctors in rural areas and poor nations necessitates the development of an automated method to identify glaucoma (Sreng et al., 2020). Automated glaucoma detection technologies are being studied extensively. This article covered a wide range of glaucoma screening methods for in-depth analysis.

Screening Techniques

Fujimoto's group at the Massachusetts Institute of Technology (MIT) was the first to develop optical coherence tomography (OCT). OCT uses a broadband light source with a short coherence length to conduct micrometer-scale cross-sectional imaging of biological tissue. As of this writing, (Ibne Mokbul, 2017) It is a technique for acquiring optical signals that is employed to capture three-dimensional pictures when it comes to cancer research, (Almazroa et al, 2015).

It employs infrared light to go into the eye and provides high-resolution photographs for the interior retinal structure. It may be used in a variety of medical imaging procedures, including those in neurology, cardiology, and dermatology, amongst others.

Heidelberg 3D computerised retinal scans may be obtained using a non-invasive confocal scanning laser microscope technique known as retinal tomography (like a CT scan). It is utilised in a glaucoma diagnostic process to look at the optic nerve head. It is the gold standard for capturing images of the retina and optic nerve in a single exposure.

Applanation Tonometry: This technique measures the eye's fluid pressure. The cornea is flattened when the eye is numb and the pressure is calculated. Non-contact tonometer, often known as an air puff, is a device that produces a little puff of air. It measures the pressure of the eyeball to oppose the flow of air. Measurement of corneal thickness by use of an ultrasonic wave device is known as pachymetry. One of the instruments used to examine the optic nerve is referred to as an ophthalmoscope. In order to determine whether or not the iris is closer than usual to the cornea, gonioscopy is performed. Closed-angle glaucoma is often tested using this device. Optical coherence tomography in the spectral domain is frequently referred to as Fourier domain spectroscopy. As opposed to TD-OCT, it has a better resolution and faster acquisition speed. Stereo disc photography may be used to capture images of the optic nerve head. It is used to detect glaucoma and high intraocular pressure (IOP). It aids in determining the optical nerve's head's size. It also produces visuals with a sense of depth that are crisp and high-resolution. According to the 2015 study by Khouri and Fechtner, Angiography with fluorescein: Luminescence is used as a metaphor. Fluorescein maintaining luminosity requires a steady supply of light energy. Hydrocarbon sodium fluorescein has a fluorescence wavelength of 520-530 nm and reacts to light energy between 465-490 nm. Either the absorption or emission of green-yellow light occurs once the excitation process is complete. By (Johnson, et al. in 2012), Retinal nerve fibre thickness may be quantified using scanning laser polarimetry, a diagnostic technique (RNFL). A retardation laser beam is used to illuminate the retina and count the reflected light. Weinreb and colleagues (1998). Automatic detection of glaucoma is made possible by the CNN (convolutionary neural network). It offers data sets that can be found easily online. They range from fundamental machine learning to the most advanced deep learning techniques. To put it simply (Sreng et al., 2020) with or without OD extraction, deep learning was used to identify glaucoma. Deep CNN models were built using the extracted OD data in two stages. Inception V3, XceptionNet, VGG16, GoogleNet, and other CNN models are employed.

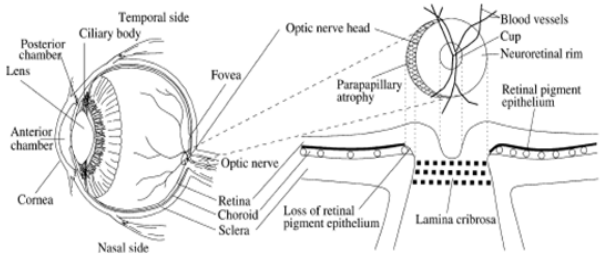

Figure 2: (Chrástek et al., 2005) Anatomy of the eye and optic nerve head

The optic nerve head (ONH) consists of two sections (Optic Nerve Head). Glaucoma damage may be detected with this method. It refers to the brighter region outside of the optic disc and optic cup boundaries between eye halves. Shown above is an example of the second case (Zhou and coworkers, 2019) In glaucoma, the CDR measures how far the optic cup extends from the optic disc. Greater cup-to-disc ratios are indicative with glaucoma. Glaucoma risk variables such as disc diameter (ISNT rule), parapapillary atrophy (PPA), notching, and so forth are taken into consideration. These components are controversial among ophthalmologists, who are divided on their value. There are several advantages to using automatic picture recognition in the diagnosis of glaucoma, including reduced costs and time.

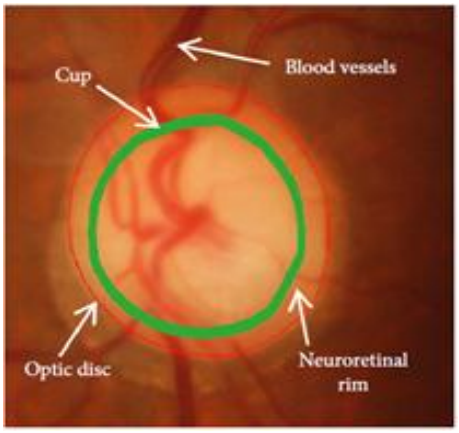

Figure 3: (Zhou et al., 2019) Neuroretinal rim area

Before entering the eye to deliver visual information to the brain, the 1.2 million ganglion cell axons that make up an optic disc pass via the retina and the scleral canal (Almazroa et al., 2015) Understanding the link between optic nerve cupping and vision loss requires examining a patient's optic disc. The neuroretinal rim, the optic cup, and, on rare occasions, Parapapillary Atrophy may all be detected in the optic disc (PA). There is a relationship between parapapillary atrophy and chorioretinal thinning and RPE disruption around the optic disc (figure 3). It's divided into two types:

α-PPA: An abnormality in the structure of the retinal pigment epithelium (RPE)
β-PPA: is a complete loss of retinal pigment epithelium.

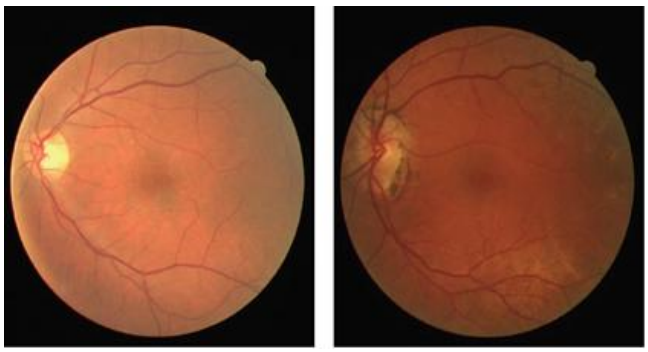

Figure 4: (Almazroa et al., 2015) Retinal image from DRIVE: (a)Normal and (b) pathological image

Database

Publically available data set for retinal images are RIGA, DRIVE, STARE, MESSIDOR, ORIGA, DRISHTI-GS, RIM-ONE.

Pre-processing

To assess the picture and decrease the impacts of blood vessels, a pre-processing step is performed. (Almazroa et al., 2015)

Segmentation

Three types of segmentation approaches as: OD segmentation approach and OC segmentation approach. Optic disc, optic cup segmentation and Optic disc segmentation approach.

An ophthalmologist uses segmented reference to manually label the optic disc for this reason. Localization and segmentation are two steps in the OD process. Segmenting the OD area might be difficult due to disc irregularity, pathological abnormalities (e.g., PPA), and changing imaging settings (Sivaswamy et al., 2014). Another stumbling block is the presence of pathological alterations around the disc, as well as a broad variety of imaging settings (Cheng et al., 2013). Approaches like deformable models and pixel classification-based model methods like circular Hough transform, Thresholding (Zhou and colleagues, 2019) are utilised to model the disc border because of their computing efficiency. The disc has an oval form, according to clinical trials, with a vertical diameter that is 7-10% bigger than the horizontal one. In the case of glaucoma, elliptical fitting is preferred over circular fitting since the latter leads to an overestimation of the disc and an underestimation of the CDR. Cheng et al. published a study on the subject. Optic discs may also be assessed using clinical indicators such as the vertical cup to disc ratio (CDR), the INST rule, and the notching. The ROI is segmented using the Gaussian and Canny filters after OD detection (Region of Interest). For the current Contour model, this is finished. Blood vessels are dilated using this procedure. To separate blood vessels, a median filter is utilised. A Gabor filter and a multithresholding technique are both employed in this scenario.

Optic cup to disc ratio i.e. is CDR is computed as (Cheng et al., 2013)

CDR = VCD/VDD

Glaucoma screening is done using this calculated CDR. Glaucoma is deemed to be present when CDR levels above the cut-off point, else the patient is considered healthy.

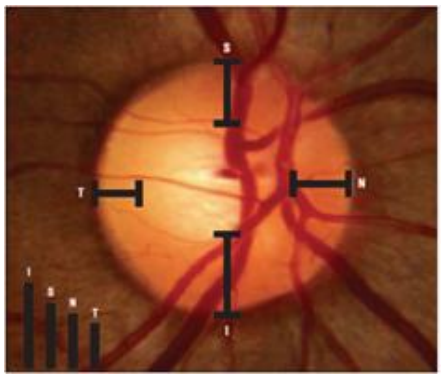

Figure 5: (Almazroa et al., 2015) Measurement of INST

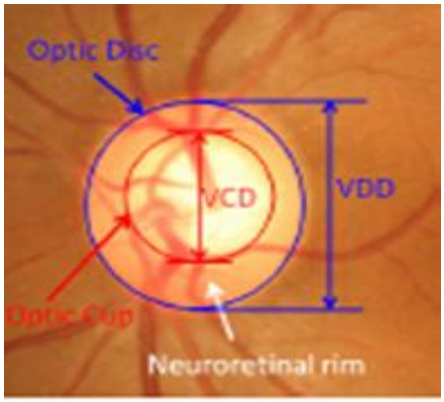

Figure 6: (Cheng et al., 2011) Measurement of CDD

Optic cup Segmentation

2D Fundus pictures are less effective at detecting the cup border than the optic disc segment because of the dense concentration of blood vessels in the cup. For the most part, other displays do not have a white space between the OD and OC. It is difficult to tell the difference between the optic cup and the neuroretinal rim in glaucoma. Linear radical and gradient radical gradient algorithms are used for cup segmentation, respectively. Canny edge detection is used in Kinks, a different method of identifying vessels that can detect all cell vasculature.

OD and OC segmentation

Both the optic disc and the optic cup must be segmented for the CDR and INST exams. As previously noted, the optic cup diameters of glaucoma patients may decrease or expand. The CDR and optic cup size have a significant influence on glaucoma detection. When estimating glaucoma, the neuroretinal region should be included, according to INST. The optic disc and the first optic cup boundaries were computed in the pre-processing stage. In order to build advanced edge detectors, Hough transformations are utilised (optic disc). The OD and OC boundaries for histogram feature extraction were determined using multithresholding and active contour approaches. K-mean clustering and the Gabor wavelet trans-form may be used to separate the OD and OC. The elimination of parapapillary atrophy (PPA) and other methods may be used to segment the OD and OC. Additionally, the Contrast-Enhanced Histogram, Centre Surround Statistics, and Super Pixel Generation techniques may be used. Artificial Intelligence (AI), Neuronal Networks, and Microperimetry (HydroOCT) are three of the newest glaucoma screening technologies (Traber, 2020).

Table I: Optic Disc segmentation

S. No	Author	Dataset	Images	Technique	OD localization	Observation
1	Fraga*et.al*	VARIA	120	Hough Transform Fuzzy Convergence	100%	The study can be done on normal and glaucomatous images
2	Welfer*et.al*	DRIVE DIARETDB1	40 89	Morphological approach	100%	The study can be performed considering other important parts of the retina.
3	Aquino *et.al*	MESSIDOR	1200	Circular Hough Transform	99% localization 86% segmentation	A study can be done on considering other parameters.
4	Tajendrasa and colleagues	DRIVE	30	Hough transform Active contour	100%	A study can be done on considering pathologies of the retina.
5	Cheng *et.al*	ORIGA	650	Hough transform PPA elimination	Overlap error 10%	The study can be done on Optic cup segmentation

Table II: Optic disc, Optic cup and ONH segmentation

S. No	Authors	Dataset	Images	Technique	OD/OC	Clinical indicators CDR/INST	Observation
1	Demon *et.al*	SERI	67	Vessel Kinking	OC	CDR	Study can be done on more images
2	Wei Zhou *et.al*	LSACM-SP in comparison with DRISHTI RIM-ONE	101 455	_	OD/OC	CDR	LSACM-SP outperforms all other approaches confirmed by statistical analysis.
3	Jayanthi Sivaswamy *et.al*	DRISHTI-GS	101	_	OD/OC	CDR	Results against ground truth were obtained and were found consistent with other data sets.
4	F. Fumero *et.al*	RIM-ONE	169	_	ONH	_	It is a gold standard and other data can be compared with it.
5	Jun Cheng	SiMES SCES	650 1676	Super pixel classification	OD/OC	CDR	Other factors can be considered to improve outcomes.

Challenges of Glaucoma Screening

Classifying and describing images is a challenge (Almazroa et al., 2015). Intraocular pressure may be measured using the Goldmann applanation tonometer (GAT), although its accuracy is greatly affected by different factors. Non-contact tonometers (NCT) are often used to assess intraocular pressure (IOP) because to the convenience and quickness they provide. If the IOP is high and the computers are large, this is less accurate. The retinal nerve fibre layer is imaged using the Heidelberg Retinal Tomograph (HRT), an expensive and cumbersome glaucoma screening instrument (RNFL). Using optical coherence tomography is the best way to detect glaucoma (OCT). As a result of the time-consuming nature of visual function evaluation, SWAP is used.

Discussion

Glaucoma is a common cause of blindness in the general population. An optic nerve examination is required to determine whether a patient has glaucoma. The optic disc contains all of the retinal nerve cells since it is the end of the optic nerve's path through the eyeball. It's called a fundus camera. This imaging technique, known as OCT (ocular coherence tomography), is capable of telling apart the optic nerve from the optic cup. With the use of optic cup and disc segmentation algorithms, different retinal images may be generated and the optic disc to cup ratio determined. The optic cup is a depression in the centre of the optic disc where the retinal ganglionic cells come together.

There are a number of techniques to segment the optic disc and cup in order to determine the above features. There are several methods for detecting glaucoma and OD segmentation by combining

circular Hough transformations with different detection algorithms like CNN.

Conclusion and Future Perspectives

Glaucoma segmentation methods are analysed in this study. The optic disc and optic cup are of interest to many people, but further study is required. Comparing glaucomatous retinal pictures will need a wider pool of data. To collect retinal images at greater resolutions and frame rates, a more sophisticated camera is required. The morphology and characteristics of babies, children, and neonates differ greatly from those of later age groups since most screening data originates from adults. This is why it's important to take into consideration these additional data. It is possible to calculate the optic disc and optic cup segmentation using a number of formulae, including the cup to disc ratio and so on. Automated primary glaucoma screening is used using CNN (Convolutional Neural Network). The use of OD, OC, and CNN segmentation may use in the diagnosis, but it cannot replace the experience of an ophthalmologist.

List of Abbreviations

Nerve fibre layer (NFL)
Heidelberg Retina Tomograph (HRT)
Intraocular pressure (IOP)
Iridocorneal endothelial (ICE)
Primary open-angle glaucoma (POAG)
Primary angle-closure glaucoma (PACG)
Spectral domain-Optical coherence tomography (SD-OCT)
Standard automated Perimetry (SAP)
Optic nerve head examination (ONH)
Convolution neural network (CNN)
Massachusetts Institute of Technology (MIT)
Optical coherence tomography (OCT)
Parapapillary atrophy (PPA)
Retinal pigment epithelium (RPE)
Cup to disc ratio (CDR),
Goldmann applanation tonometer (GAT)
Non-contact tonometers (NCT)

Declarations

Ethical Approval and Consent to Participate

Not Applicable

Consent for Publication

I/We authors, hereby give our consent for the publication of identifiable details, including images and/or details within the text, to be published in “Annals of Medicine and Medical Sciences”. I/We understand that this material may be available to the public, including medical professionals, researchers, journalists, and the general public. I/We have had the opportunity to review the material and understand the implications of its publication. I/We understand that once published, the material cannot be removed except in exceptional circumstances. I/We acknowledge that this will reduce my actual privacy to the extent of the content of the manuscript.

Availability of Supporting Data

Not Applicable

Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

Not Applicable

Authors Contribution

All authors have accepted responsibility for the entire content of this manuscript and consented to its submission to the journal, reviewed all the results and approved the final version of the manuscript. All the authors were participated in the preparation, collection and writing of the manuscript.

References

[1] Almazroa A, Burman R, Raahemifar K, Lakshminarayanan V. Optic disc and optic cup segmentation methodologies for glaucoma image detection: a survey. Journal of ophthalmology. 2015;2015(1):180972. doi: 10.1155/2015/180972.

[2] Aquino A, Gegúndez-Arias ME, Marín D. Detecting the optic disc boundary in digital fundus images using morphological, edge detection, and feature extraction techniques. IEEE transactions on medical imaging. 2010 Jun 17;29(11):1860-9. Available at: http://www.ncbi.nlm.nih.gov/pubmed/20562037.

[3] Belyea DA, Alhabshan RN, Mahesh SP, Gertner GS, Ibisevic MM, Habib AS, Dan JA. Utility of Heidelberg retinal tomography as a screening tool for analyzing retinal nerve fiber layer defects. Clinical Ophthalmology. 2014 Nov 28:2409-14. doi: 10.2147/OPTH.S66898.

[4] Broadway, D. C. ‘Visual Field Testing for Glaucoma’, Community Eye Health Journal 2012, 25. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3588129/pdf/jceh_25_79-80_066.pdf. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3588129/pdf/jceh_25_79-80_066.pdf.

[5] Cheng J, Liu J, Wong DW, Yin F, Cheung C, Baskaran M, Aung T, Wong TY. Automatic optic disc segmentation with peripapillary atrophy elimination. In2011 Annual International Conference of the IEEE Engineering in Medicine and Biology Society 2011 Aug 30 (pp. 6224-6227). IEEE. doi: 10.1109/IEMBS.2011.6091537.

[6] Cheng J, Liu J, Xu Y, Yin F, Wong DW, Tan NM, Tao D, Cheng CY, Aung T, Wong TY. Superpixel classification based optic disc and optic cup segmentation for glaucoma screening. IEEE transactions on medical imaging. 2013 Feb 18;32(6): 1019-32.doi: 10.1109/TMI.2013.2247770.

[7] Naiberg MR. Traditional and Novel Cardiovascular Risk Factors and Neurocognitive Functioning in Adolescents with Bipolar Disorder. University of Toronto (Canada); 2017. doi: 10.1167/iovs.07-0472.

[8] Chrástek R, Wolf M, Donath K, Niemann H, Paulus D, Hothorn T, Lausen B, Lämmer R, Mardin CY, Michelson G. Automated segmentation of the optic nerve head for diagnosis of glaucoma. Medical image analysis. 2005 Aug 1;9(4):297-314. doi: 10.1016/j.media.2004.12.004.

[9] Damon WW, Liu J, Meng TN, Fengshou Y, Yin WT. Automatic detection of the optic cup using vessel kinking

in digital retinal fundus images. In2012 9th IEEE international symposium on biomedical imaging (ISBI) 2012 May 2 (pp. 1647-1650). IEEE. doi: 10.1109/ISBI.2012.6235893.

[10] Fraga, A. et al. 'Precise segmentation of the optic disc in retinal fundus images', Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 2012,6927 LNCS (PART 1), :584–591. doi: 10.1007/978-3-642-27549-4_75.

[11] Fumero F, Alayón S, Sanchez JL, Sigut J, Gonzalez-Hernandez M. RIM-ONE: An open retinal image database for optic nerve evaluation. In2011 24th international symposium on computer-based medical systems (CBMS) 2011 Jun 27 (pp. 1-6). IEEE. doi: 10.1109/CBMS.2011.5999143.

[12] Ibne Mokbul M. Optical coherence tomography: basic concepts and applications in neuroscience research. Journal of medical engineering. 2017;2017(1):3409327. doi: 10.1155/2017/3409327.

[13] Johnson RN, Fu AD, McDonald HR, Jumper JM, Ai E, Cunningham ET, Lujan BJ. Fluorescein angiography: basic principles and interpretation. InRetina Fifth Edition 2012 Dec (pp. 2-50). Elsevier Inc. doi: 10.1016/B978-1-4557-0737-9.00001-1.

[14] Prum BE, Rosenberg LF, Gedde SJ, Mansberger SL, Stein JD, Moroi SE, Herndon LW, Lim MC, Williams RD. Primary open-angle glaucoma preferred practice pattern® guidelines. Ophthalmology. 2016 Jan 1;123(1):P41-111. doi: 10.1016/B978-0-7020-5193-7.00029-7.

[15] Manju K, Sabeenian RS, Surendar A. A review on optic disc and cup segmentation. Biomedical and Pharmacology Journal. 2017 Mar 25;10(1):373-9. doi: 10.13005/bpj/1118.

[16] Nduaguba C, Lee RK. Glaucoma screening: current trends, economic issues, technology, and challenges. Current opinion in ophthalmology. 2006 Apr 1;17(2):142-52. doi: 10.1097/01.icu.0000193088.75432.c9.

[17] Nixon MS, Aguado AS. 5—High-level feature extraction: Fixed shape matching. Feature Extraction and Image Processing for Computer Vision. 2020 Jan:223-90. doi: 10.1016/b978-0-12-814976-8.00005-1.

[18] Praveena, A. G., Scholar, P. G. and Systems, C. 'Glaucoma Screening Using Super Pixel Classification Based on Optic Disc and Optic Cup Segmentation', 2015, 3(1): 1192–1202.

[19] Schuman JS. Spectral domain optical coherence tomography for glaucoma (an AOS thesis). Transactions of the American Ophthalmological Society. 2008 Dec; 106:426.

[20] Sivaswamy J, Krishnadas SR, Joshi GD, Jain M, Tabish AU. Drishti-gs: Retinal image dataset for optic nerve head (onh) segmentation. In2014 IEEE 11th international symposium on biomedical imaging (ISBI) 2014 Apr 29 (pp. 53-56). IEEE. doi: 10.1109/isbi.2014.6867807.

[21] Sreng S, Maneerat N, Hamamoto K, Win KY. Deep learning for optic disc segmentation and glaucoma diagnosis on retinal images. Applied Sciences. 2020 Jul 17;10(14):4916. doi: 10.3390/app10144916.

[22] Tjandrasa H, Wijayanti A, Suciati N. Optic nerve head segmentation using hough transform and active contours. TELKOMNIKA (Telecommunication Computing Electronics and Control). 2012 Sep 1;10(3):531-6. doi: 10.12928/telkomnika.v10i3.833.

[23] Traber GL, della Volpe-Waizel M, Maloca P, Schmidt-Erfurth U, Rubin G, Roska B, Cordeiro MF, Otto T, Weleber R, Lesmes LA, Arleo A. New technologies for outcome measures in glaucoma: review by the European Vision Institute Special Interest Focus Group. Ophthalmic research. 2020 Mar 3;63(2):88-96. doi: 10.1159/000504892.

[24] Weinreb RN, Zangwill L, Berry CC, Bathija R, Sample PA. Detection of glaucoma with scanning laser polarimetry. Archives of ophthalmology. 1998 Dec 1;116(12):1583-9. doi: 10.1001/archopht.116.12.1583.