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Contribution of Optical Coherence Tomography in the Diagnosis and Follow-up of Primary Open-Angle Glaucoma

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Abstract

Objective: To study the contribution of OCT in the diagnosis and follow-up of POAG at the ophthalmological clinic of the University Hospital Center in the Suru Lere area and at the ophthalmological clinic of HIA - CHU.

Method: This is a descriptive and analytical study, retrospective over a period of 7 years from 1st January 2015 to 31st December 2021.

Results: We identified a total of 30 patients, i.e. 60 glaucomatous eyes, in whom at least two OCTs were performed. The average age of the patients was 51.23 ± 12.16 years with extreme values of 23 to 72 years. In our series, 17 patients were male (56.65%), i.e. an M/F sex ratio of 1.30, employees were in the majority and represented 66.67% of patients, patients with no history represented 60 %. The main risk factors were hypertension, HT0 with respectively 20%, 13.33%. Visual loss was the main reason for consultation, 56.67%. The average cup/disc ratios on clinical examination of the papilla are respectively 0.57 ± 0.19 on the right and 0.58 ±0.18 on the left. In our series, the means of the three OCTs for the C/D ratios were established respectively at 0.70, 0.71 and 0.62 for the right eye and respectively 0.70, 0.71 and 0.65 for the left eye. Regarding the mean of the per papillary RNFL, the means of the three OCTs are respectively 86.27; 83.93; 86.29 for the must eye and 89.20 respectively; 83.47; 85.07 for the left eye. For the ganglion cell complex the results were respectively 85.63; 81.73, 71.71 for the right eye and 86.07 respectively; 81.23 and 71.86 for the left eye. There was a significant correlation between fundoscopic and tomographic vertical C/D ratios.

Conclusion: It appears from this work that OCT is an essential material examination and plays an important role in both the diagnosis and the follow-up of glaucomatous disease.

Keywords: Glaucoma; Diagnosis; Progression; Tomography

Abbreviations: OCT: Optical Coherence Tomography; POAG: Primary Open-Angle Glaucoma; ONH: Optic Nerve Head; MCC: Macular Ganglion Cell Complex; OCT: Optical Coherence Tomography; OCT-SD: Spectral Domain OCT.

Introduction

Primary open-angle glaucoma (POAG) is a chronic progressive optic neuropathy corresponding to a loss of retinal ganglion cells and characterized by morphological changes in the optic nerve head (or papilla) associated with typical visual field damage [1]. Its management has improved with the development of structural imaging of the optic nerve using optical coherence tomography (OCT). The identification of structural changes, lesions of the retinal nerve fibers (RNF), the optic nerve head (ONH) and the macular ganglion cell complex (MCC), is an essential component in the diagnosis and management of glaucoma [2]. Optical coherence tomography (OCT), which has been used in ophthalmology for over 25 years, enables the entire thickness of the retina to be examined in vivo. The new OCT-SD (spectral-domain OCT) now provides objective quantification of damage in different structures of the retina. New acquisition programs and the use of new analysis algorithms, on larger volumes of tissue, have recently become available and have improved the diagnostic accuracy of the parameters obtained. They also allow better interpretation of the particularities of certain clinical forms at different stages of glaucomatous optic neuropathy [2]. Furthermore, glaucomatous structural damage precedes the first deficits in visual function, and it has been shown that the first deficits revealed by the automated visual field appear when 20 to 40% of ganglion cells are destroyed [3]. Analysis of the axons of these retinal ganglion cells, whether in the optic nerve head or in the retina, is therefore essential for diagnosing glaucomatous damage and its progression [3].

Study Method

This was a descriptive and analytical cross-sectional study, with retrospective data collection from 1 January 2015 to 31 December 2021. It was carried out in the Eye Departments of the armed force training hospital and Suru-Léré University Hospital Center in the Southern of Benin. It involved the records of patients received in the above-mentioned eye departments for follow-up during the study period, and in whom the diagnosis of GPAO was retained on the basis of clinical and tomographic arguments. We carried out an exhaustive recruitment of patients with established glaucoma who met the selection criteria. All patients aged 18 and over who were clinically diagnosed with glaucoma and who had at least 2 papillary OCTs including retinal nerve fiber and ganglion cell complex analysis were included. The database was cleaned with Epi info and the data analyzed with SPSS 21. Variables were described using statistical tables. Proportions were compared using the CHI2 test where conditions allowed (p<5%). Authorizations were obtained from the heads of the selected hospital. Anonymity was maintained and guaranteed throughout the study.

Results

Of the 285 glaucoma patients identified, 30 patients (60 glaucomatous eyes) met our inclusion criteria.

Socio-Demographic Data

The mean age of the patients was 51.23 ± 12.16 years, with extremes ranging from 23 to 72 years. The most common age group was 50 to 59 years. Male patients accounted for 56.67% of the total, with a sex ratio of 1.30:1. Employees were in the majority, accounting for 66.67% of patients.

Clinical Data

Risk Factors for GPAO

Patients with no previous history of GPAO accounted for 60% of the patient population. The main risk factors were arterial hypertension and ocular hypertonia (20% and 13.33% respectively).

Reason for Consultation

Visual impairment was the main reason for consultation (56.67%). The different reasons for consultation are shown in Table 1.

	Effective	Percentage
Asymptomatic	8	26,67
Decreased Visual Acuity	**17**	**56,67**
Headache	8	26,67
Visual Fog	4	13,33
Several Functional Signs	5	16,67

Table 1: Different reasons for consultation.

Clinical Characteristics of the Optic Disc

The mean C/D ratios on clinical examination of the optic disc were 0.57 ± 0.19 on the right and 0.58 ± 0.18 on the left. Table 2 shows the distribution of eyes according to the clinical characteristics of the optic disc.

	Œil droit	Œil gauche
Vertical C/D ratio	0,57 ± 0,19	0,58 ± 0,18
Non-compliance with the rule ISNT	86,7% (N=30)	96,7% (N=30)
Nasal rejection of vessels	80% (N=30)	96,7% (N=30)
Peripapillary atrophy	13,3% (N=30)	10% (N=30)
Circumlinear vessels	10% (N=30)	13,3% (N=30)

Table 2: Distribution of eyes according to clinical characteristics of the optic disc.

Analysis of the evolutionary profile of the fundoscopic vertical C/D ratio.

The evolutionary profile of the fundoscopic C/D ratio in both eyes is presented in Table 3 below.

	Right Eye						Left Eye					
	N	Average	Standard Division	Mini	Maxi	P Value	N	Average	Standard Division	Mini	Maxi	P Value
C/D 1	**30**	0,57	0,18	0,30	1,00	0,000	**30**	0,58	0,18	0,40	1,00	0,000
C/D 2	**30**	0,60	0,17	0,30	1,00	0,000	**30**	0,62	0,18	0,40	1,00	0,000
C/D 3	**14**	0,54	0,11	0,40	0,80	0,000	**14**	0,60	0,16	0,40	0,90	0,000

Table 3: Distribution of patients according to the fundoscopic evolution of the vertical C/D ratios in both eyes.

Tomographic data analysis of the optic nerve head. The parameters of the optic nerve head to be analyzed were the size of the disc, the area of the neuroretinal ring and the vertical C/D ratio in Table 4.

	Right eye		Left eye	
	Average	Standard Deviation	Average	Standard Deviation
Papilla size (mm)	2,52	0,35	2,50	0,36
Surface of the ANR (mm2)	1,22	0,59	1,11	0,52
Cup /disc vertical ratio	0,72	0,14	0,70	0,13

Table 4: Distribution of eyes according to tomographic characteristics of the optic nerve head.

Quantification of Parapapillary RNFL Thickness and Ganglion Cell Complex in GPAO

The mean value of RNFL thickness in the right and left eyes was 82.53 (± 11.45) µm and 76.25 (± 9.25) µm, respectively. The mean thickness of the ganglion cell layer in the right and left eyes was 90.15 (± 8.71) µm and 89.51 (± 10.33) µm respectively. The thickness of the RNFL decreased with the severity of the GPAO. Table 5 below shows the distribution of eyes according to RNFL and ganglion complex thickness.

	Right Eye		Left Eye	
	RNFL (µm)	CGL (µm)	RNFL (µm)	CGL (µm)
Onset	91,56	87,54	90,33	88,13
	(±7,12)	(±07,43)	(±12,24)	(±10,71)
Slightly	78,18	76,84	72,15	72,62
	(±8,24)	(±10,34)	(±7,51)	(±6,43)
Severe	62,11	67,77	69,42	66,32
	(±7,89)	(±12,42)	(±8,88)	(±13,62)
Average	82,53	90,15	76,25	89,51
	(±11,45)	(±8,71)	(±9,84)	(±10,33)
P-value	0	0	0	0

Table 5: Distribution of eyes by thickness of peripapillary RNFL and ganglion complex.

Analysis of the Evolutionary Profile of Tomographic Parameters of the Optic Disc

The cup/disc ratio Table 6 shows the distribution of patients according to the tomographic evolution of the vertical C/D ratios in both eyes. The evolution of the vertical C/D ratios does not show a linear increase over time but rather a saw tooth pattern.

	Right Eye						Left Eye					
	N	Average	Standard Deviation	Mini	Maxi	P Value	N	Average	Standard deviation	Mini	Maxi	P Value
1-Oct	**30**	0,70	0,15	0,38	1,00	0,000	**30**	0,70	0,13	0,48	1,00	0,000
2-Oct	**30**	0,71	0,15	0,40	1,00	0,000	**30**	0,71	0,14	0,48	1,00	0,000
3-Oct	**14**	0,62	0,12	0,40	0,83	0,000	**14**	0,65	0,11	0,45	0,90	0,000

Table 6: Distribution of patients according to tomographic evolution of vertical C/D ratios in both eyes.

The neuroretinal ring Table 7 shows the distribution of patients according to the tomographic evolution of the ANR in both eyes.

	Right Eye						Left Eye					
	N	Average	Standard Deviation	Mini	Maxi	P Value	N	Average	Standard Deviation	Mini	Maxi	P Value
1-Oct	**26**	1,21	0,60	0,09	2,40	0,000	**25**	1,18	0,57	0,05	2,35	0,000
2-Oct	**21**	1,06	0,54	0,003	1,92	0,000	**20**	1,09	0,55	0,05	1,88	0,000
3-Oct	**10**	1,20	0,39	0,60	1,83	0,000	**10**	1,16	0,49	0,30	1,89	0,000

Table 7. Distribution of patients according to the tomographic evolution of the ANR in both eyes.

Thickness of peripapillary retinal nerve fibers (RNFL). Table 8 shows the distribution of patients according to tomographic changes in mean RNFL thickness in both eyes.

	Right Eye						Left Eye					
	N	Average	Standard Deviation	Mini	Maxi	P Value	N	Average	Standard Deviation	Mini	Maxi	P Value
1-Oct	**30**	86,27	18,95	42	113	0,000	**30**	89,20	14,01	62	109	0,000
2-Oct	**30**	83,93	15,85	45	109	0,000	**30**	83,47	15,41	47	109	0,000
3-Oct	**14**	86,29	13,21	58	103	0,000	**14**	85,07	16,08	51	110	0,000

Table 8: Distribution of patients according to tomographic changes in RNFL thickness in both eyes.

The macular ganglion complex (MGC) Table 9 shows the distribution of patients according to the tomographic evolution of the LMC in both eyes. The evolution of the LMC decreased linearly over time.

	Right Eye						Left Eye					
	N	Average	Standard Deviation	Mini	Maxi	P Value	N	Average	Standard Deviation	Mini	Maxi	P Value
1-Oct	**30**	85,63	12,08	54	109	0,000	**30**	86,07	12,06	54	107	0,000
2-Oct	**30**	81,73	13,70	54	105	0,000	**30**	81,23	14,15	54	106	0,000
3-Oct	**14**	74,71	16,08	53	105	0,000	**14**	71,86	19,09	38	106	0,000

Table 9. Distribution of patients according to the tomographic evolution of the LMC in both eyes.

Correlation Between Fundoscopic and Tomographic Vertical Cup/Disc Ratios

In our series, there was a significant correlation between fundoscopic and tomographic vertical C/D ratios. The greater the vertical cup/disc ratios at clinical level, the greater the ratios at tomographic level. Table 10 illustrates this correlation.

Correlation				
		OCT1_ratio cup /disc vertical	OCT2_ratio cup /disc vertical	OCT3_ratio cup /disc vertical
Opht1_ratio C/D vertical	Correlation of Pearson	0,798	0,770	0,699
	P Value	0,000	0,000	0,000
	N	60	60	28
Opht2_Ratio C/D vertical	Correlation of Pearson	0,812	0,764	0,751
	P Value	0,000	0,000	0,000
	N	60	60	28
Opht3_Ratio C/D vertical	Correlation of Pearson	0,813	0,838	0,776
	P Value	0,000	0,000	0,000
	N	28	28	28
The correlation is significative 0.01 (bilateral).				

Table 10: Correlation between fundoscopic and tomographic vertical C/D ratios.

Discussion

Socio-Demographic Data

The mean age of the patients was 51.23 ± 12.16 years, with extremes of 23 and 72 years. These results are similar to those found by Nouhou DA, et al. [4] in Niger in 2022, who reported a mean age of 50.44 ± 15.81. The patients were predominantly male, with a sex ratio of 1.30. Similar results were reported by authors such as Yawa, et al. in Lomé in 2017 [5], who found a sex ratio of 1.41. In contrast, Odoulami-Yehouessi, et al. [6] found a female predominance with a sex ratio of 0.75. This difference could be explained by a selection bias (larger sample size). Employees represented 66.67% of the population in our study. Our results corroborate those of Odoulami-Yehouessi, et al. [6] (50%), according to whom this target group would be able to afford consultations.

Clinical Data

Risk Factors for CAPM

The majority of patients (44.82%) had no previous medical history. However, among the past history found, hypertension predominated (18.39%). Al-Najmi Y, et al. [7] in Saudi Arabia in 2019 reported that hypertension and diabetes were the most common general pathologies in 52.8% and 59.7% of cases respectively, and no family history of glaucoma was found. This could be explained by the fact that vascular factors lead to hypo perfusion of the optic nerve and progressive destruction of retinal ganglion cells.

Fundoscopic Characteristics of the Papilla

The mean C/D ratios on clinical examination in the right and left eyes were 0.57 ± 0.19 and 0.58 ± 0.18 respectively. Non-compliance with the ISNT rule was observed in 86.7% of the right eye and 96.7% of the left eye. Nouhou DA, et al. [4] also found results similar to ours, with mean C/D ratios of 0.58 ± 0.15 in the right eye and 0.60 ± 0.12 in the left eye; non-compliance with the ISNT rule was observed in 96.67% of the right eye and 95.56% of the left eye. The clinical appearance of the papilla is a good indicator of glaucoma detection. This examination should be performed carefully and regularly during all ophthalmological visits in all patients, and could contribute to the detection of GPAO.

Tomographic Data- Tomographic Characteristics of TNO

All the parameters of the optic nerve head can be modified in glaucoma. Some are altered at an earlier stage. The parameters reported to date as the most discriminating in OCT-SD of the optic nerve head are the area of the neuroretinal ring and the vertical C/D ratio [6]. In our series, we found a mean papilla area of 2.52 ± 0.35 mm2 in the right eye and 2.49 ± 0.35 mm2 in the left eye; a mean RNA area of 1.21 ± 0.59 mm2 in the right eye and 1.11 ± 0.51 mm2 in the left eye; a mean C/D ratio of 0.72 ± 0.14 in the right eye and 0.69 ± 0.12 mm2. These results are in line with those of Vonor K, et al. [8] who, in their study of the characteristics of the papilla in glaucomatous and normal subjects on OCT in a population of black Africans in 2018, found a mean papilla

area of 2.80 ± 0.55 mm2, a mean RNA area of 1.26 ± 0.44 and a mean C/D ratio of 0.68 ± 0.13. They suggest that the larger the papilla area, the larger the neuroretinal ring area and the higher the vertical C/D ratio.

Depending on the pathological status, the neuroretinal ring was thinner in glaucomatous patients compared with normal patients, and the vertical C/D ratio was higher in glaucomatous patients compared with normal patients. Tomographic characteristics of the retinal nerve fibre layer and ganglion cells: the mean RNFL values in our series for the right and left eyes were 82.53 (± 11.45) µm and 76.25 (± 9.25) µm respectively. These results are superimposed on those of Nouhou DA, et al. [4] with mean RNFL values of 80.53 (± 13.28) µm and 79.35 (± 14.22) µm respectively in confirmed glaucoma patients. Koffi DA, et al. [9] reported a higher mean FNR thickness of 98.48 ± 17.39 µm with extremes of 42 and 134 µm in the right eye and 98.57 ± 17.06 µm with extremes of 34 and 198 µm in the left eye. This could be explained by the fact that the author only included suspected cases of large papillary excavation in his study. The mean thickness of the ganglion cell layer in the right and left eyes was 90.15 (± 8.71) µm and 89.51 (± 10.33) µm respectively. Our results show greater thicknesses than those of Nouhou DA, et al. [4], who found a mean ganglion cell layer thickness in established glaucoma patients of 71.85 (± 10.13) µm in the right eye and 71.19 (± 11.38) µm in the left eye. However, Delbarre, et al. in 2013 [10], found a thickness greater than ours, i.e. 95.68 µm in the glaucoma group. This variability in results could be due to selection bias.

Analysis of the Evolutionary Profile of Tomographic Parameters

In our series, the means of the three OCTs for the C/D ratios were 0.70, 0.71 and 0.62 respectively for the right eye and 0.70, 0.71 and 0.65 respectively for the left eye. With regard to the mean peripapillary RNFL, the means for the three OCTs were 86.27, 83.93 and 86.29 µm for the right eye and 89.20, 83.47 and 85.07 µm for the left eye respectively. For the lymph node cell complex, the results were 85.63, 81.73 and 71.71 µm for the right eye and 86.07, 81.23 and 71.86 µm for the left eye respectively. Analysis of the results of the evolution of the C/D ratios between OCT 1 and OCT 2 reveals an increase in this ratio and therefore a widening of the excavation over time; but at OCT 3, we note rather a non-rational decrease in this ratio which is as much lower than the ratio at OCT 2 as at OCT 1. The increase or stabilization of the cup/disc ratio over time is normal given that the progressive loss of nerve fibers increases excavation and therefore this ratio. The same is true of the mean peripapillary RFNL. In fact, a decrease in fiber thickness is noted between OCT 1 and 2, but at OCT 3 the thickness is increased compared with the 2 OCTs for the right eye, and increased compared with OCT 2 only for the left eye was 14. Analysis of the results of the 14 patients who were able to perform the 3 OCTs shows that the progression of the glaucomatous disease was slower than that of the other patients in the series, which had an impact on the overall mean C/D ratio. The same is true of the mean RFNL. On the other hand, these results could be linked to the diversity of the equipment used. It is recommended that the same device be used for follow-up OCT in order to better assess the progression of glaucomatous disease. Unfortunately, there is a wide disparity of OCT brands across the country, with less than a dozen machines, but each one is just as different as the next in terms of brands, standards and specific features.

This makes it difficult for patients to carry out the various OCT examinations using the same brand of equipment. Added to this are problems with the maintenance of the equipment, which means that when it breaks down, patients are obliged to carry out follow-up OCT examinations using a different brand of equipment. Various studies have been carried out to investigate the progression of glaucomatous disease using an OCT device. A study by Garcia, et al. in 2011, followed by Garvin, et al. in 2013, showed that the repeatability and reproducibility of peripapillary retinal nerve fiber thickness measurements for the machines studied were excellent, with correlation coefficients of around 99% [11,12]. These coefficients remained high and comparable in healthy subjects and glaucoma patients, whatever the stage of severity, glaucoma suspects and other optic neuropathies. With regard to the thickness of the ganglion complex, the results were comparable to the data for peripapillary nerve fibers, with coefficients of variation of around 1 to 2 microns [13,14]. Our results show a progressive alteration of the macular ganglion complex from OCT 1 to OCT 3, reflecting the progression of the disease over time. Various studies have been carried out to investigate the progression of glaucomatous disease using an OCT device. A study by Garcia, et al in 2011, followed by Garvin, et al. in 2013, showed that the repeatability and reproducibility of peripapillary retinal nerve fiber thickness measurements for the machines studied were excellent, with correlation coefficients of around 99% [11,12].

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is rapid [15,16]. Measurement of macular thickness can be useful for the early detection of glaucoma. Macular damage is therefore often detected earlier, and the progression of glaucomatous disease can be monitored more accurately and reliably by monitoring changes in the macular ganglion complex, even though there is still a role for monitoring the development of Cup/Disc in the TNO and the thickness of the FNRL. There are several reasons for this improved accuracy in measuring the ganglion complex. It has been described that 50% of retinal ganglion cells are located in the macula. Although SD OCT methodology has been updated compared to TD OCT, the structural complexity of the optic disc and the per papillary zone (presence of blood vessels, per papillary atrophy, and papillary dysversions) may interfere with the accurate measurement of TNO parameters or RNFL thickness in some individuals. On the other hand, the macula is a relatively simple structure with no large vessels and is therefore relatively easy to scan in order to obtain reliable data. Thus, measurement of macular thickness is potentially important in the diagnosis of glaucoma and the monitoring of glaucomatous changes [17]. Diagnosing the progression of glaucoma is a fundamental element in the management of glaucoma patients. Rapid identification of this progression means that treatment can be adjusted earlier and the risk of irreversible visual field damage in these patients can be limited.

The progression of glaucoma is usually documented on the visual field, but structural damage may precede visual field deterioration, and OCT analysis may enable treatment to be adjusted earlier [18,19]. The detection of progression is also useful in doubtful cases of glaucoma, making it possible to classify subjects as glaucomatous or not during follow-up, depending respectively on the progression or stability observed on OCT measurements. Given the current state of the resources available to us, these progression analyses mean that the same OCT machine must always be used for a given patient, and successive examinations must be reliable and reproducible.

Correlation Between Fundoscopic and Tomographic Vertical Cup/Disc Ratios

In our study, the mean fundoscopic C/D ratios were 0.57, 0.59 and 0.54 for the right eye and 0.58, 0.62 and 0.59 for the left eye respectively, compared with 0.70, 0.71 and 0.62 for the right eye and 0.70, 0.71 and 0.65 for the left eye on OCT. Referring to these results, and to the correlation table, we can conclude that in our series, there is a significant correlation between fundoscopic and tomographic vertical C/D ratios. The greater the clinical vertical Cup/Disc ratios, the greater the tomographic ratios. As a result, fundoscopic C/D ratios are underestimated. This situation could lead to an underestimation or misjudgment of the severity of the progression of glaucomatous disease and have an impact on therapeutic decisions and the various indications for treatment. OCT (coupled with the fundus) is therefore more than necessary for monitoring the progression of glaucomatous disease, as it could have a major impact on indications and treatment decisions. Treatment algorithms could be based much more on OCT results in order to be more effective.

Conclusion

Nowadays, OCT is an essential examination and plays an important role in both the diagnosis and follow-up of glaucomatous disease. It also provides a more accurate estimate of the parameters of the optic nerve head, in particular the vertical C/D ratio in relation to the fundus. However, for a more reliable and credible analysis of the various follow-up OCTs, it is important to perform them on the same machine.

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