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Optical Coherence Tomography (OCT): Cataract or Pupil Size?

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Authors' contributions

This work was carried out in collaboration between all authors. Authors PD and KC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors TS and GI managed the analyses of the study. Author KM managed the literature searches. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Purpose: To evaluate the impact that the pupil size and the crystalline lens opacification have on optical coherence tomography (OCT) accuracy and the necessity of pupil dilation for the examination of the nerve retinal fibber layer and the macula.
Methods: One hundred fifty six eyes of 156 patients separated in two distinct groups, were examined with OCT (Stratus 3000), before and after pharmacological mydriasis. The first group consists of 78 patients with clear optical media while the second consists of 78 patients with lens opacification according the Lens Opacities Classification System III (LOCS III). The fast RNFL thickness protocol was used to evaluate RNFL thickness and the fast macular scan pattern thickness for the macula thickness and volume.
Results: No significant statistically differences were found between the pupil size, the quality of the signal (P>10%) and also between the pupil size and all of the parameters examined, of both groups (P>10%). Instead the signal quality was found significant different before and after mydriasis (P<0,001) without influence on the measurements accuracy.
Conclusion: Pupil dilatation increases the signal strength of the examination but has no impact on

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the accuracy of the OCT scan. OCT for the RNFL and the macular thickness parameters can be performed with physiological pupil size and in cases in which mydriasis is difficult, incomplete or is contraindicated.

Keywords: Pupil dilatation; accuracy of OCT; mydriasis and signal strength; opacities of the optic media.

1. BACKGROUND

Optical Coherence Tomography (OCT) is a non contact imaging method of the fundus that uses laser and the principle of interferometry to measure the differences of reflected light [1]. It provides high-resolution (10 to 15 μm) cross-sectional images of optically accessible tissues [2]. It is used to record the structures of the retina, the parameters of the optic nerve head (ONH) and the thickness of the macula and the peripapillary nerve fiber layer (RNFL) [3-5].

OCT acquires information regarding the depth and the density of the scanned tissues. Several factors may lead to incorrect measurements, like lids proptosis, the incorrect positioning of the examined, fixation losses, [6] uncorrected refractive errors [7] the presence of cells, blood or floaters inside the anterior chamber or the vitreous cavity, opacities of the optical media, pupil size [8] and artifacts [9-10].

The purpose of the present study is to compare the parameters of the retinal structures, acquired with OCT with and without pupil dilatation, in patients with different grade of cataract and to estimate the impact that pupil dilatation and cataract have on OCT accuracy.

2. MATERIALS AND METHODS

This study was performed in our department from September 2009 to December 2009. One hundred fifty six subjects who met the inclusion criteria were recruited. The study followed the guidelines of the Declaration of Helsinki and was approved by the ethics committee of the hospital. Informed consent was obtained from all the participants.

The study included patients of every age and sex with spherical refractive error within the range of – 9.00 diopters (D) to + 6.00 D. Lens status were recorded and only phakic patients were recruited. The degree of cataract was classified following the Clinical Importance of The Lens Opacities Classification System III (LOCS III) [11]. From each patient only the eye with the better corrected visual acuity was included. Exclusion criteria included ocular pathologic features in which OCT scan could not be performed like vitreous hemorrhage, corneal opacities, cataracts of grade 5 (LOCS III), that need examination by applanation ultrasound biometry and others. Eleven patients with lens cataract (grade 4) were also excluded because no OCT image was obtained even after myriasis. Patients with full thickness macular hole, retinal detachment and adverse effects to mydriatics were also excluded. Patients with history of ocular surgery, including cataract surgery have also been excluded.

Patients were divided in two groups according the LOCS III. The first group consists in 78 eyes of 78 patients with lens opacities of grade 0, 1 and 2 and the second group consists of 78 eyes of 78 patients with lens opacities of grade 3 and 4.

All participants underwent complete ophthalmologic examination, including best corrected visual acuity, biomicroscopy in the slit lamp, intraocular pressure (IOP) measurement with the Goldmann applanation tonometer, and examination of the fundus with a plus 90-D lens. Pupil size, before and after mydriasis was estimated and OCT scan (Stratus 3000 software, v. 4.0; Carl Zeiss Meditec) of the macula and the RNFL was performed. Comparison of RNFL and macula thickness, between the two groups, was estimated.

2.1 Optical Coherence Tomography

OCT was performed by a single examiner. The internal fixation technique was used. The eyes of each subject were scanned twice, without pupil dilatation and after pharmacological mydriasis. The fast RNFL thickness protocol (consisting of three scans each of 256 measuring points, captured in 1.8 sec) was selected to evaluate the RNFL thickness measurement. The RNFL Thickness Average Analysis was used for the analysis of the acquired scans and the evaluation of the calculated parameters.

The fast macular scan pattern was used to calculate the thickness and the volume of the

fovea. The standard printout (retinal thickness/vol Tabular analysis program) was used.

OCT examination was performed in eyes under physiologic pupil size, in a room with the lights on, to avoid the physiological pupil mydriasis of the darkness that could probably influence the results. The examiner gave instructions to each subject, inserted the data and prepared the OCT scan pattern. The patient was instructed to look straight into lens of the machine, while the examiner was looking at the display and observing the central dark circle of the iris. A brighter ellipsoidal shape could be seen in the inferior part of the iris and the lens of the OCT was centered on it. The patient was encouraged to look at the internal green-orange fixation point while the examiner observed the signal of the scan and the image of the fundus. Scanning of the RNFL required the focalization of the circle scan around the optic disk. Each patient was scanned twice; the first time without pupil dilatation. Then a drop of 1% tropicamide and 2.5% phenylephrine were instilled in each eye and thirty minutes later, the second scan of the fovea and RNFL was performed.

2.2 Statistical Analysis

The SPSS software version 14.0 (SPSS, Inc., Chicago, IL) was used for the statistical analysis. The demographic data of the patients were described by mean values ± standard deviation. The paired Student t test was used to estimate the significance of the results with and without mydriasis of the two groups. The probability (P) <0.05 was considered statistically significant. The Pearson correlation coefficient (r) was used to evaluate the correlations between RNFL and macula thickness and the other parameters with the signal strength, of the two groups. P<0.05 was considered statistically significant.

3. RESULTS

One hundred fifty six eyes of 156 patients, 71 male and 85 female that met the inclusion criteria were enrolled to our study. Seventy eight subjects were included in the first group and 78 in the second one. Mean best corrected visual acuity of the two groups was of 8,64 and 2,28 decimal. Nuclear cataract was diagnosed in the 62,82% and 41,03% of subjects of the two groups, cortical cataract in the 30,77% and 37,18% while posterior subcapsular cataract was diagnosed in the 6.4% and 21,79% respectively. The demographic data of the two groups are reported in Table 1.

A significant difference was observed for the quality of signal before and after mydriasis of both groups (P<0,01).

Instead no significant differences were observed for the RNFL parameters, before and after pupil dilatation (P>10%) of both groups (Table 3). No significant differences were also observed for the foveal parameters before and after pupil dilatation (P>10%) of both groups (Table 4).

Table 1. Demographic data

	Group 1 (lens opacities grade 0,1 and 2)	**Group 2 (lens opacities grade 3 and 4)**	**Total**
Number of patients	78	78	156
Sex			
Male	32	39	71
Female	46	39	85
Age (mean)	51,63	74,48	
BCVA (mean ± SD)	8,64 ± 0,36	2,28 ± 0,82	
Status of lens (LOCS III)			
NC	49	32	81
C	24	29	53
P	5	17	22
Quality of signal			
Before Mydriasis (mean ± SD)	8,45 ± 0,66	4,4 ± 2,3	
After Mydriasis (mean ± SD)	9,04 ± 0,2	5,7 ± 1,2	

Group 1 = patients with lens opacities grade 0,1 and 2, BCVA = Best Corrected Visual Acuity, SD = standard deviation, LOCS III = Lens Opacities Classification System III, NC= nuclear cataract, C = Cortical cataract, P = posterior subcapsular cataract

4. DISCUSSION

OCT represent a valuable tool in the daily clinical practice. In the past several studies arrived at the conclusion that pupil dilatation influence OCT accuracy, as the manufacturer recommends, especially when pupil size is less than 3 mm. In our study we try to assess whether physiological pupil size without pharmacological mydriasis and/or lens opacities really influence RNFL and macula OCT parameters [12-15].

In our study a significant difference of the signal quality (P<0,01) before and after pupil dilatation has been found for both groups but with no influence on OCT examination of the retinal nerve fibber layer and macula measurements (P>10%). These results suggest that the quality of signal is related to the pupil size and also that RNFL thickness and macular thickness and volume depend on the optic media limpidity more than the pupil size. Opacities of the lens and vitreous body represent the main factors of poor scan signal quality and in certain cases totally blocks measurements of retina structures.

Wu et al found that signal strength, RNFL thickness and the presence of a low analysis confidence were important predictors of the variability of OCT measurements and that greater signal strength was often correlated to a greater RNFL thickness [16]. Cheung et al. [17] found a significant correlation between the RNFL thickness and the signal strength. They suggested that the RNFL thickness was strongly related to the quality of image and they recommended the greater possible signal strength for the RNFL measurements.

Table 2. Paired t test of the quality of signal before and after mydriasis of the two groups

Quality of signal	t-test (probability)	
	Group 1 (n=78)	Group 2 (n=78)
before – after mydriasis	2,21 (p<0,01)	2.01 (p<0,01)

Table 3. Paired t test of OCT RNFL parameters

Parameters RNFL (n=156)	T test results (probability)	
	group 1(degree of freedom = 76)	group 2 (degree of freedom = 76)
Savg	0,724 (P>10%)	0,854 (P>10%)
Navg	0.474 (P>10%)	0.596 (P>10%)
I avg	0,772 (P>10%)	0,652 (P>10%)
T avg	0.161 (P>10%)	1.086 (P>10%)
Avg thickness	0.324 (P>10%)	0.935 (P>10%)
Iavg	0.772 (P>10%)	0.512 (P>10%)
Savg	0.724 (P>10%)	1.23 (P>10%)
Imax	1.434 (P>10%)	1.087 (P>10%)
Smax	0.233 (P>10%)	0.764 (P>10%)
Max-min	0,689 (P>10%)	0,856 (P>10%)
Smax/Navg	0.650 (P>10%)	0.748 (P>10%)
Imax/Tavg	0.057 (P>10%)	0.125 (P>10%)
Smax/Tavg	1.094 (P>10%)	1.425 (P>10%)
Smax/Imax	0.985 (P>10%)	0.846 (P>10%)
Imax/Smax	1.150 (P>10%)	0.786 (P>10%)
1 sector	0.183 (P>10%)	0.475 (P>10%)
2 sector	0.544 (P>10%)	0.725 (P>10%)
3 sector	0.988 (P>10%)	1.025 (P>10%)
4 sector	0.849 (P>10%)	0.745 (P>10%)
5 sector	0.491 (P>10%)	0.569 (P>10%)
6 sector	0.139 (P>10%)	0.268 (P>10%)
7 sector	1.080 (P>10%)	0.874 (P>10%)
8 sector	1.078 (P>10%)	0.987 (P>10%)
9 sector	0.680 (P>10%)	0.764 (P>10%)
10 sector	0.562 (P>10%)	0.851 (P>10%)
11 sector	0.161 (P>10%)	0.235 (P>10%)
12 sector	0.632 (P>10%)	0.789 (P>10%)

S = superior, T = temporal, I = inferior, N = nasal, avg = average

Table 4. Paired t test of OCT foveal parameters

Parameters FOVEA (n=156)	T test results (probability)	
	Group 1 (degree of freedom = 74)	Group 2 (degree of freedom = 74)
Foveal Minimum	0,454 (P>10%)	0,785 (P>10%)
Fovea 1	0,478 (P>10%)	0,987 (P>10%)
S inner 2	0,866 (P>10%)	0,657 (P>10%)
T inner 3	0,296 (P>10%)	0,742 (P>10%)
I inner 4	1,662 (P>10%)	1,458 (P>10%)
N inner 5	0,285 (P>10%)	0,698 (P>10%)
S outer 6	0,265 (P>10%)	0,754 (P>10%)
T outer 7	0,281 (P>10%)	0,458 (P>10%)
I outer 8	1,036 (P>10%)	1.258 (P>10%)
N outer 9	0,071 (P>10%)	0,487 (P>10%)
S/I outer	1,023 (P>10%)	1.125 (P>10%)
T/N inner	1,306 (P>10%)	1,456 (P>10%)
T/N outer	1,082 (P>10%)	1,321 (P>10%)
Fovea Volume	0,462 (P>10%)	0,687 (P>10%)
T inner Volume	0,379 (P>10%)	0,754 (P>10%)
S inner Volume	0,860 (P>10%)	0,984 (P>10%)
N inner Volume	0,182 (P>10%)	0,215 (P>10%)
I inner Volume	1,581 (P>10%)	1,324 (P>10%)
T outer Volume	1,225 (P>10%)	1,215 (P>10%)
S outer Volume	0,231 (P>10%)	0,468 (P>10%)
N outer Volume	0,421 (P>10%)	0,684 (P>10%)
I outer Volume	0,990 (P>10%)	0,774 (P>10%)
T macula Volume	0,145 (P>10%)	0,354 (P>10%)

S = superior, T = temporal, I = inferior, N = nasal

We have also found that the amount of light improves the quality of signal but this has little influence on OCT variability and tissue thicknesses. On the other hand the degree of lens clarity has direct impact on OCT results. In both groups with and without cataract no significant differences were calculated in OCT measurements (p>10%) for RNFL and macula, before and after mydiriasis and signal improvement while lens opacification decrease and even block OCT imaging.

Zafar et al. [18] examined RNFL thickness of 10 healthy eyes before and after papillary dilatation, and found no significant differences using both the fast and the regular OCT-3 protocol scans Savini et al. [19] found that when the diameter of the pupil exceeded the 3 mm there was no need of the mydriasis for the examination but they recommended the mydriasis when the pupil size was equal or less than 3 mm. They also observed that the lens opacity decreased the thickness of the RNFL because the weaker signal affected the demarcation of the outer boundary line of the RNFL. We have also found no significant differences before and after pupil dilatation (p>10%) for the average RNFL thickness, the RNFL thickness of the four quadrants and of the 12 hours around the optic disk all the other parameters calculated. In our study both groups with and without cataract show no significant differences in OCT measurements (p>10%) for RNFL and macula, before and after mydiriasis and signal improvement while lens opacification decrease and even block OCT imaging.

Smith et al. [20] found that lens opacity was related to a poorer reproducibility when the pupil was undilated. We have found no difference on OCT reproducibility in patients with cataract of the second group, when mydriatics were applied. Instead we have excluded eleven eyes with dense cataract because no imaging was obtained. These eyes had a dense cataract, the quality of the signal was equal a 0 and did not change after dilation. The OCT scans, for the other patients of the second group, were all reproducible and with no significant difference of the RNFL and the macula thickness before and after mydriasis.

We have not found a significant difference of the macular thickness and volume in any of the nine

foveal sectors examined (p>10%). To our knowledge there are no other studies that have examined the necessity of pupil dilation for the foveal thickness and volume measurements.

The limitations of the present study is that it is focused in Stratus OCT, a valuable imaging method still in use in several clinics worldwide.

We believe that the pupil size is a factor that does not influence the accuracy of the OCT measurements. Instead lens clarity influence scans imaging and signal quality. We suggest that the pupil dilatation is not necessary for the scan of the RNFL and the macula and we believe that OCT examination can be performed in patient with poor pupil response to mydriatic drops, like diabetic patients or patients with pseudoexfoliation syndrome and even in patient in which pupil dilatation is not recommended, such as in the early postoperative time [14]. we finally believe that cataract surgery is necessary for patients, with retinal diseases in which OCT imaging is important, such as in patients with diabetic retinopathy, age related macular degeneration and others [21].

5. CONCLUSION

In conclusion we believe that lens opacification influence OCT signal strength. Pupil dilatation is not necessary to be applied for the determination of the RNFL and the macular parameters. OCT can be performed even in cases in which mydriasis is difficult, poor or is contraindicated. Cataract surgery must be performed to improve image quality of OCT scans.

CONSENT

As per international standard or university standard, patient's written consent has been collected and preserved by the authors.

ETHICAL APPROVAL

As per international standard or university standard, written approval of Ethics committee has been collected and preserved by the authors.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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