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Macular changes detected by Fourier-domain optical coherence tomography in patients with hypotony without clinical maculopathy

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ABSTRACT.

Purpose: **To investigate macular changes in eyes with postoperative hypotony without clinical maculopathy using high-resolution Fourier-domain optical coherence tomography (FD-OCT).**

Methods: **Fourteen eyes of 12 patients with postoperative intraocular pressure (IOP) ≤ 6 mmHg for at least 4 weeks but with no detectable clinical features associated with hypotony maculopathy were imaged by FD-OCT prospectively. Images were analysed by two retina specialists masked to clinical findings.**

Results: **Most patients were female (83%) and myopic (75%) with a mean age of 65 ± 17 [standard deviation (SD)] years (range 2–86 years). Mean central corneal thickness was 519 ± 34 μm [95% confidence interval (CI) 502–537] and mean IOP before surgery was 20 ± 8 mmHg (95% CI 15–24). During the period of hypotony (mean 15 ± 6 weeks), the average mean IOP was 4 ± 1 mmHg (95% CI 3–5). Abnormal FD-OCT findings (retinal folds and/or intraretinal fluid) were present in eight eyes. These patients had a higher rate of visual symptoms (75% versus 17%), visual acuity loss (≥ 2 lines; 63% versus 17%) and increased mean foveal thickness (250 ± 26 versus 210 ± 12 μm; $p < 0.01$, Mann–Whitney *U*-test) compared with those with normal FD-OCT.**

Conclusion: **FD-OCT identified subclinical macular abnormalities in over half of the eyes with postoperative hypotony. These findings were accompanied by visual disturbances and central macular thickening. FD-OCT can be an important diagnostic tool for this disorder when clinical features are absent.**

Key words: FD-OCT – hypotony maculopathy – macular changes – postoperative hypotony

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Introduction

Hypotony maculopathy usually occurs after glaucoma filtration surgery or ocular trauma in eyes with prolonged low intraocular pressure (IOP) and presents with characteristic fundus abnormalities, including optic disc oedema, vascular tortuosity and chorioretinal folds (Dellaporta 1954; Gass 1972). The latter, particularly evident in the macular region, result in distortion of the neurosensory elements of the retina and are primarily responsible for vision loss (Gass 1972). The extent of decrease in visual acuity is variable (Pederson 1996). Early recognition and timely, appropriate treatment is crucial because delayed normalization of IOP may result in permanent structural and functional damage.

Mild maculopathy may be difficult to detect or may be overlooked. Diagnostic tests, such as fluorescein angiography, can be useful in detecting subclinical chorioretinal folds in patients with hypotony and decreased visual acuity (Costa & Arcieri 2007). Time-domain optical coherence tomography (OCT) has been reported to be able to demonstrate macular

changes, such as subretinal fluid and folds, in cases of hypotony maculopathy (Kokame et al. 2001; Martínez de la Casa et al. 2003; Weyll et al. 2006).

Motion artifacts related to long acquisition time limit the creation of a detailed retinal map using time-domain OCT (Alam et al. 2006). Fourier-domain OCT (FD-OCT) provides a 20–40 times reduction in image acquisition time, and is associated with a high axial image resolution of up to 3 μm in some devices (Nassif et al. 2004; Leung et al. 2008; Keane et al. 2009). These improvements permit real-time, *in-vivo* imaging with fewer motion artifacts and with resolution approaching histological detail, which was shown to be useful in cases of diabetic macular oedema, for instance (Soliman et al. 2008).

There are no published studies using FD-OCT in eyes with hypotony and decreased visual acuity but with no signs of maculopathy. Because hypotony maculopathy is an important cause of vision loss and can be overlooked, we prospectively evaluated the clinical applicability of a high-resolution FD-OCT device in detecting subclinical macular changes in eyes with postoperative hypotony and whether these findings were associated with visual acuity loss and symptoms.

Materials and Methods

This prospective study was carried out at the New York Eye and Ear Infirmary and the New England Eye Centre. The study was approved by the institutional review board of both sites and written informed consent was obtained from all patients.

Initially, three eyes of three patients with clinically established postoperative hypotony maculopathy (macular chorioretinal folds with or without vascular tortuosity and oedema of the optic disc) underwent FD-OCT (3D OCT-1000; Topcon Medical Systems Inc., Paramus, New Jersey, USA). These macular scans were used to determine abnormal findings associated with hypotony maculopathy, including intraretinal or subretinal fluid, intraretinal cysts and chorioretinal folds. Patients with postoperative hypotony (IOP ≤ 6 mmHg for at least 4 weeks after filtering surgery) without clinical maculopathy were then enrolled and imaged. Eyes with shallow anterior chambers, marked intraocular inflammation and/or significant corneal oedema were excluded, because eyes with these conditions are prone to poor image acquisition with OCT and can also have decreased visual acuity. Other exclusion criteria were any previous eye disease other than glaucoma and other causes of chorioretinal folds, such as posterior scleritis, presence of scleral buckle, retrobulbar mass lesions, choroidal tumours or neovascularization. Data recorded included demographics, glaucoma diagnosis, previous surgical procedures, lens status (phakic or pseudophakic), refractive error [spherical equivalent (SE)], central corneal thickness (CCT), type of procedure that led to hypotony and use of antifibrotic agents. Best-corrected Snellen visual acuity was recorded before the surgical procedure and on the day of image acquisition. IOP data were collected prior to surgery and from the onset of hypotony (first measured IOP ≤ 6mmHg) until the date of image acquisition.

The FD-OCT device used in this study had transverse and axial resolutions of 20 and 5 μm, respectively. The '3D macular scan' protocol was used (Topcon Medical Systems, Inc., Paramus, NJ, USA). This is a raster scan composed of 256 × 256 (vertical × horizontal) axial scans covering a 6 × 6 mm macular region. A built-in correlation-based algorithm is used to cancel axial eye motion artifacts. All evaluated images were obtained with an image quality score of at least 50. Two patients were excluded because of low quality scores. Images were analysed for the presence of predefined macular abnormalities by two retina specialists masked to the patient's clinical findings. In addition, five normal eyes were included among those with hypotony to determine the specificity of the examiners regarding FD-OCT evaluation. Because of the typical orientation of chorioretinal folds in the 0–180° axis, careful review of all radial line B-scans was performed. Two serial macular measurements were used to determine the foveal thickness of each eye. Descriptive analysis was used to compare characteristics between patients with and without abnormal FD-OCT findings. Because of the small sample size and non-parametric distribution of the data (Kolmogorov–Smirnov test, $p < 0.05$), the comparison of continuous variables between groups was performed using the Mann–Whitney *U*-test; Fisher's exact test was used for comparisons between categorical variables. *P*-values of < 0.05 were considered statistically significant.

Results

Fourteen eyes of 12 patients were studied. The baseline characteristics of all patients are summarized in Table 1. The majority were female (83%) and myopic (75%), with a mean age of 65 ± 17 [standard deviation (SD)] years (range 27–86). Mean CCT was 519 ± 34 μm [95% confidence interval (CI) 502–537] and mean IOP before surgery was 20 ± 8 mmHg (95% CI 15–24). During the period of hypotony (mean 15 ± 6 weeks), the average mean IOP was 4 ± 1 mmHg (95% CI 3–5). Twelve eyes had hypotony after trabeculectomy or trabeculectomy revision with mitomycin C, and two eyes after transconjunctival needle revision with 5-fluorouracil.

Fifty-seven per cent of the eyes with hypotony (8/14) had at least one of the predefined abnormal FD-OCT findings on the B-scans (Fig. 1). Compared to those with normal FD-OCT results, these patients had a higher rate of visual symptoms (75% versus 17%, $p = 0.04$) and visual acuity loss (≥ 2 lines; 63% versus 17%, $p = 0.12$). Mean foveal thickness was greater in eyes with an abnormal FD-OCT [250 ± 26 μm (95% CI 232–269 μm)] than in eyes with normal FD-OCT [210 ± 12 μm (95% CI 198–222 μm); $p < 0.01$]. None of the five normal eyes had any FD-OCT abnormality. Peripheral choroidal detachment was detected in the clinical examination only in eyes with abnormal FD-OCT findings, corresponding to 50% (4/8) of these eyes (Table 2).

Discussion

Most of our patients with postoperative hypotony without clinical maculopathy had abnormal findings on FD-OCT imaging. These results were corroborated both subjectively (visual disturbances) and objectively (macular thickening).

This is the first study to identify subclinical macular abnormalities in

Table 1. Characteristics of patients with postoperative hypotony without clinical maculopathy.

Eyes	Age	Diagnosis	Last surgery	SE	CCT (μm)	Preoperative IOP (mmHg)	Period of hypotony	Postoperative IOP* (mmHg)	BCVA loss (Snellen)
Patients with normal FD-OCT									
1	86	CACG	Trab MMC	2	494	16	12 weeks	5	1 line
2	67	POAG	Trab MMC	−5	498	10	24 weeks	4	0 lines
3	83	XFG	Trab MMC	−1	496	26	7 weeks	5	2 lines
4	27	XFG	Rev MMC	−3	510	10	16 weeks	3	0 lines
5	57	NTG	Trab MMC	−7	600	18	22 weeks	5	0 lines
6	60	POAG	Trab MMC	−4	573	22	21 weeks	3	0 lines
Mean	64	N/A	N/A	−3	528.5	17	17 weeks	4.2	0.5 line
Patients with abnormal FD-OCT									
1	85	XFG	Trab MMC	2	562	40	12 weeks	5	4 lines
2	70	CACG	Rev MMC	−2	502	20	7 weeks	5	5 lines
3	56	PG	Trab MMC	−5	505	32	24 weeks	4	0 lines
4	67	POAG	TCNR 5FU	−6	496	13	18 weeks	5	1 line
5	86	CACG	TCNR 5FU	2	493	15	12 weeks	3	3 lines
6	79	CACG + PIS	Trab MMC	3	509	17	6 weeks	3	4 lines
7	38	PG	Trab MMC	−3	532	30	8 weeks	4	5 lines
8	60	XFG	Rev MMC	−3	509	14	22 weeks	3	0 lines
Mean	67.7	N/A	N/A	−1.5	514	22.5	14 weeks	4	2.1 lines

FD-OCT, Fourier-domain optical coherence tomography; CACG, chronic angle-closure glaucoma; POAG, primary open-angle glaucoma; XFG, exfoliative glaucoma; NTG, normal-tension glaucoma; PIS, plateau iris syndrome; PG, pigmentary glaucoma; Trab, trabeculectomy; Rev, revision of a trabeculectomy; TCNR, transconjunctival needle revision; SE, spherical equivalent; CCT, central corneal thickness; IOP, intraocular pressure; BCVA, best-corrected visual acuity; N/A, non-applicable.
* Mean IOP during the period of hypotony.

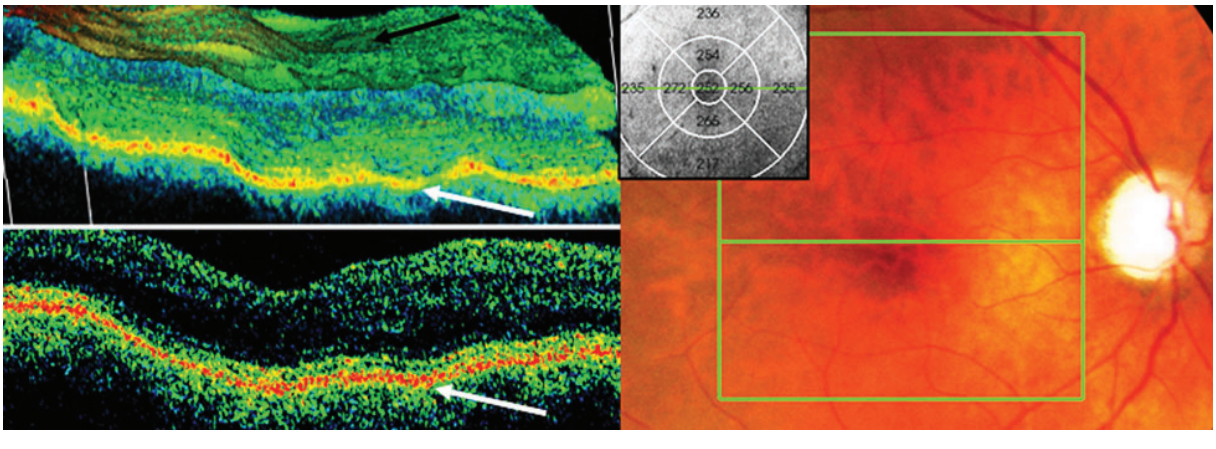

Fig. 1. Normal fundus photograph of a patient with postoperative hypotony without clinical maculopathy (right). Fourier-domain optical coherence tomography (FD-OCT) B-scan (lower left) showing intraretinal fluid and chorioretinal folds (white arrow). FD-OCT 3D macular scan (upper left) confirming the chorioretinal folds (white arrow) beneath the foveal area (black arrow). Retinal thickness map of the same eye (centre).

patients with postoperative hypotony using high-resolution OCT technology. In addition, we demonstrated that patients with macular changes detected by FD-OCT had a higher rate of visual acuity loss and symptoms, and greater mean foveal thickness than those with normal FD-OCT. Two previous case reports have demonstrated the applicability of time-domain OCT in the diagnosis and follow-up of hypotonous eyes without clinical evidence of maculopathy (Martínez de la Casa et al. 2003; Budenz et al. 2005). Evaluating eight eyes with postoperative hypotony and normal fundi, Klink et al. (2000) found a significant correlation between visual acuity and foveal thickness on OCT. They also observed that increased macular thickness in these patients could be reversed after normalization of IOP – as opposed to cystoid macular oedema, which may lead to permanent visual impairment. Although we found intraretinal fluid in four eyes using FD-OCT, none of our patients had cystoid macular oedema. The fact that subclinical abnormalities identified in these eyes were associated with visual acuity loss and symptoms such as metamorphopsia, micropsia and blurred vision corroborates the hypothesis that even in eyes without clinically apparent maculopathy, pathological changes are present.

Hypotony maculopathy has been reported to occur in up to 20% of eyes following glaucoma filtering surgery, and reports of this complication have become more frequent after the introduction of adjunctive antifibrotic agents (Kitazawa et al. 1993; Shields et al. 1993). In the present study, we excluded other potential causes of vision loss in eyes with hypotony such as corneal oedema, induced

Table 2. Fourier-domain optical coherence tomography (FD-OCT) findings in patients with postoperative hypotony without clinical maculopathy*.

Hypotony eyes (n = 14)	
FD-OCT findings	
Chorioretinal folds	6/14 (43%)
Intraretinal fluid	4/14 (29%)
Cystoid macular oedema	0/14 (0%)
Associated clinical findings	
Peripheral choroidal detachment	4/14 (29%)
FD-OCT foveal thickness measurement (μm)	
Eyes with normal FD-OCT	210 ± 12
Eyes with abnormal FD-OCT	250 ± 26†
Average in normal eyes‡	216 ± 18

* Data are given as mean ± standard deviation unless indicated otherwise.
† There was a significant difference between eyes with normal and abnormal FD-OCT results (Mann–Whitney U-test; $p < 0.01$).
‡ Values are based on a normative database of 35 patients.

astigmatism, inflammation and disorganization of the anterior segment. The higher incidence of macular abnormalities in hypotonous eyes presenting with greater visual acuity loss corroborates the need for a more thorough retinal evaluation in these patients.

Fundus examination can be challenging in eyes with postoperative hypotony, and mild chorioretinal folds can be overlooked during clinical examination (Costa & Arcieri 2007). Because delayed treatment is associated with the development of permanent chorioretinal changes and subretinal fibrosis, these eyes are likely to have an increased risk of visual impairment (Costa et al. 1993; Nuyts et al. 1994). The visual prognosis in eyes with hypotony maculopathy depends primarily on the duration of the hypotony (Jampel et al. 1992). These facts emphasize the importance of identifying early macular changes in hypotonous eyes, even when the ocular examination is unrevealing. Our findings suggest that FD-OCT can play an important role in early diagnosis.

Although our study was prospective, we did not evaluate the effect of treatment on retinal anatomy or the impact of the FD-OCT findings on the long-term visual outcomes of these patients. Additionally we did not compare the results obtained with Fourier-domain and time-domain technologies in the early diagnosis of hypotony maculopathy. Considering that these macular changes were not found in control eyes and that Fourier-domain technology leads to less motion artifacts compared with older technologies, we believe that these findings were abnormal and not related to motion artifacts.

In summary, FD-OCT identified subclinical macular abnormalities in over half of the eyes with postoperative hypotony. These findings were accompanied by visual disturbances and central macular thickening. Because hypotony maculopathy is a serious condition that requires prompt diagnosis and treatment, we recommend that FD-OCT be considered in eyes with hypotony and decreased vision.

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