Imperial Journal of Interdisciplinary Research (IJIR)
Vol-3, Issue-4, 2017
ISSN: 2454-1362, http://www.onlinejournal.in

Optical Coherence Tomography for Finding Macular Edema

Ms. Madiha Quazi[1] & Mrs. Pooja Thakre[2]
[1]Research Scholar, Department of Electronics (Communication) Engg.
Nuva College of Engineering & Technology, Nagpur, India
[2]H.O.D., Department of Electronics (Communication) Engg.
Nuva College of Engineering & Technology, Nagpur, India

Abstract*: In the morphology of edema we propose a new classification of macular edema based on Optical Coherence Tomography findings to better catalogue and follow this complex clinical entity. The classification comes into account five parameters retinal thickness, diffusion, volume, morphology and presence of vitreous traction. Standard figures and numerical values for every parameter are given. Although Early Treatment Diabetic Retinopathy Study guidelines for laser treatment of Diabetic macular edema is the only proven therapy for this condition, many other strategies are now on trial, and the vast majority of authors use Optical Coherence Tomography as the best indicator of therapeutic benefit. The amount of information given by Optical Coherence Tomography demonstrates that macular edema is a complex clinical entity with various morphology and gravity, and disclaimed the limitations of a quiet "clinical" definition. As in many other examples such as macular holes and choroidal neovascularization a uniform and precise definition of macular edema would increase the possibility to compare and judge the result of other therapeutic strategies. Aim of this classification is to implement the Early Treatment Diabetic Retinopathy Study clinical definition of Diabetic macular edema with the precise and useful data given by Optical Coherence Tomography to better diagnose, catalogue and follow macular edema.*

1. Introduction

Diabetic macular edema (DME) is one of the main reasons of visual impairment in patients with diabetic retinopathy. The common diagnostic tools for assessing macular edema are stereo-ophthalmoscopy and fluorescein angiography. Stereoscopic inspection of the fundus at the slit-lamp or on stereoscopic color fundus photographs is the standard method, as defined by the Early Treatment Diabetic Retinopathy Study (ETDRS), for calculating macular thickening and for starting treatment when the clinical significant macular edema level has been reached. Fluorescein angiography is a correspondent method for further detecting vascular leakage. However; these methods are subjective and seem to be insensitive for minor changes in retinal thickness. In past the revolutionary instrument was imported in ophthalmology – optical coherence tomography (OCT) – and it dramatically improved the diagnosis of macular pathology. Optical Coherence Tomography gives detailed information about retinal microstructure and measures thickness of retina with high precision and reproducibility. The recently introduced spectral-domain Optical Coherence Tomography (SDOCT) machines have numerous improvements that enhance our capability to check retinal microstructure and obtain more reliable measurements. Optical Coherence Tomography (OCT) is a digital optical instrument that generates cross sectional images (tomograms)of the retina by optical-coherence interferometry, a procedure analogous to ultrasound, except for using light (abroad bandwidth near-infrared light beam at 840 nm) in place of sound, and measures the echo delay time of light reflected and backscattered from the retina. This method allows non-contact measurement of structures on a 10micron scale, versus the 100-micron scale of ultrasound. The system is interfaced to a video-slit lamp bio microscopy that provides a real-time view of the fundus and of the scanning probe beam. Early Treatment Diabetic Retinopathy Study defined diabetic macular edema (DME) as focal or diffuse retinal thickening in the macular size. When this thickening involves or threatens the fovea, it is describe as "clinically significant" and laser treatment is indicated to reduce progressive visual loss.

Following Early Treatment Diabetic Retinopathy Study guidelines, diagnosis and follow up of macular thickening is made by bio microscopy, and fluorescein angiography is subsequently used to guide laser treatment. The amount of information given by Optical Coherence Tomography not only underscored the limitations of a clinical definition of macular edema, it also demonstrates that

macular edema is much more than "retinal thickening": it is a complicated clinical entity with various morphology that have to be precisely described in order to choose the right therapeutic approach and understand its potential benefits. As for other pathologies such as macular hole or choroidal neovascularization, a uniform and precise definition of macular edema would also increase the possibility to compare different therapeutic strategies.

1.1. OCT principles

Optical Coherence Tomography is a present imaging technique for invasive free and contact less "in vivo" examination of the retina and the vitreoretinal interface on cross-section images or on a 3Dimage reconstruction, and for objective measurement of retinal thickness. Its high resolution (5-10µm) is unobtainable for any other device. The operating principle resembles sechography, but instead of ultrasound allows coherent light signal is used. The first Optical Coherence Tomography devices are referred to as time-domain Optical Coherence Tomography (TDOCT). Time-domain Optical Coherence Tomography technology (Figure.1) relies on an optical technique known as Michelson low coherence interferometry. The image acquisition and thickness measurements are achieved by detecting the echo time delay of the back reflected or backscattered light from internal retinal structures while it interferes with the light that has traveled a known path length. This is achieving by moving a reference mirror and the signal collection is a function of time.

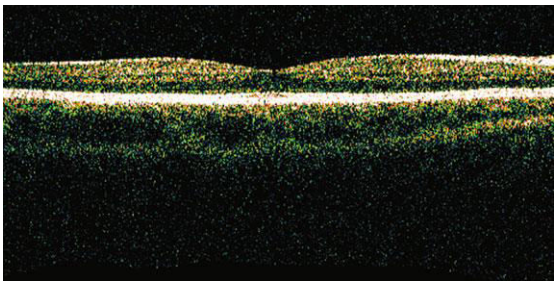

Figure 1. TD-OCT

In the past few years Spread-domain Optical Coherence Tomography technology (figure.2) was introduced. At present there are two techniques for Spread-domain Optical Coherence Tomography. The first uses a spectrometer for detecting and measuring the light colors returning from tissue and a stationary reference mirror. Here numerical operations, called Fourier transforms, are used. Thus SD OCT is also referred to as Fourier domain Optical Coherence Tomography. As this technology allows detecting all echoes of back reflected light simultaneously and there are no moving parts, the imaging speed and resolution of Spread-domain Optical Coherence Tomography are higher than those of Time-domain Optical Coherence Tomography. The second Spread-domain Optical Coherence Tomography technique is called "swept source- Optical Coherence Tomography". It uses a light source in which the emission wavelength is adjusted rapidly over a broad wavelength range. The main advantages of Spread-domain Optical Coherence Tomography over Time-domain Optical Coherence Tomography are the increased imaging speed, the higher resolution and sensitivity, the possibility of obtaining a 3Dretinal image reconstruction, more reliable thickness measurements and topographic retinal analyses.

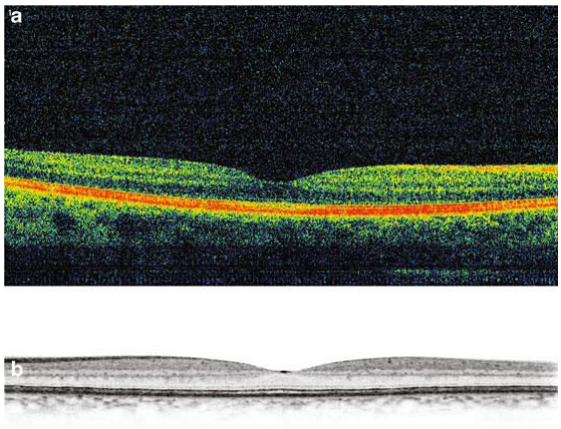

Figure 2. SD-OCT

1.2. Path physiology of Retinal Edema

Retinal edema occurs when there is an increment of water in the retinal tissue, resulting in an increase in its thickness. This increase in water content of the retinal tissue may be first intracellular (cytotoxic edema) or extracellular (vasogenic edema). In DME, extracellular edema resulting from breakdown of the blood retinal barrier (BRB) is generally present. As shown in figure.3, incomplete posterior vitreous detachment (PVD) in severe cystoid macular edema (A – OCT B-scan, B and C – OCT en face C-scan images with fundus overlay), broad based incomplete PVD with no distortion of retinal contour at points of adhesion (white arrow), cystoid space (white star), retinoschisis space (yellow stars), hard exudates (yellow arrow), note that on the en face OCT image the amount and location of the hard exudates, cystoid spaces and the retinoschisis space can be visualized. In the retina, there is a specialized structure, the blood retinal barrier (BRB) that regulates fluid movements into and out of the retinal tissue. If the blood retinal barrier (BRB)

breaks down, as appears in diabetes, it results in an "open blood retinal barrier (BRB)", which enables movements of fluids and molecules into the retina, with extracellular accumulation of fluid and deposition of macromolecules.

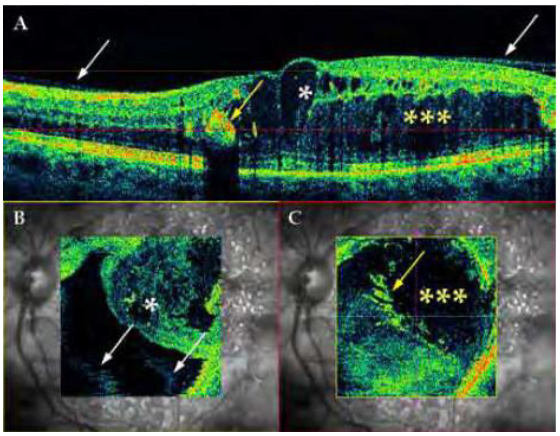

Figure 3. Questionable macular traction

1.3. Clinical Evaluation of Macular Edema

Clinical evaluation of macular edema has been differentiating by its difficulty and subjectivity. Direct and indirect ophthalmoscopy may only show an alteration of the foveal reflexes. Stereoscopic fundus photographs (SFP) and slit-lamp fundus stereobio microscopy have been the standard clinical methods to evaluate changes in retinal volume in the macular area, but they are dependent on the viewer's experience, and the results do not offer a reproducible measurement of the volume change. Nevertheless, together they are useful to visualize signs correlated with retinal thickening, such as hard and soft exudates, hemorrhages, and micro aneurysms. The preface of imaging methods, such as optical coherence tomography (OCT), made macular edema evaluation more precise and reliable.

1.4. Retinal thickness

Retinal edema is defined as any detectable retinal thickening due to fluid accumulation. Stereoscopic examination of the fundus is the standard method, as defined by the Early Treatment Diabetic Retinopathy Study for evaluating macular thickening. However, it is subjective and seems to be insensitive for small changes in retinal thickness. The particular value of Optical Coherence Tomography is the possibility for objective, reliable and repeatable retinal thickness measurements. The retinal thickness is calculated by the software program from the inner retinal surface to the inner border of the hyper-reflecting line corresponding to the retinal pigment epithelium.

1.5. Retinal morphology

Each scan pass can be especially oriented and varied in length throughout the posterior pole. Optical Coherence Tomography delineates intraretinal, cross-sectional anatomy with axial resolution of about 10microns by taking an A-scan consisting of 1024 data points over 2 mm of depth. Cross-sectional or B-mode imaging is accomplished in 2.5 seconds by acquiring a sequence of 100A-scans while scanning the probe beam across the retina. The axial data points are then used to construct a cross sectional image (tomogram) of retinal anatomy, presented in real time using a false color scale that means the degree of light backscattering from tissues at different depths in the retina. These images can be stored and later analyzed by various modalities. Scan images are presented expanding twice the image vertically, in order to allow the viewer to perceive more detail throughout the longitudinal plane of the retina. Regarding vitreoretinal relationship, Optical Coherence Tomography can visualize only previous retinal echoes close to the inner retinal surface at a maximal distance of about 400 microns. Vitreoretinal connection within the macular area or at the optic disk, as well as minimum elevations of the posterior hyaloids can therefore be easily visualized and followed but only for a limited distance from the retinal surface. Retinal pathological characteristics can be associated with changes in optical properties of the tissue and thus be detected on the OCT scan as changes in reflectivity. While performing this reflectivity analysis one should always remember that the reflectivity showed on the scan is a result from the tissue reflectivity, the amount of light absorbed by overlying structures, and the amount of light that reaches the sensor then it has been further attenuated by interposing tissues. Thus care is required in interpreting OCT images when media opacities, poor alignment of the OCT instrument while imaging, high astigmatism or poorly centred intraocular implants are present, as these may reduce signal intensity.

1.6. Retinal microstructure

The main characteristic Optical Coherence Tomography features of macular edema are: increased retinal thickness reduced intraretinal reflectivity, irregularity of the layered structure, and flattening of the foveal depression. If edema persists, cystoid cavities may appear. In macular edema serous fluid may be present under a

detached neurosensory retina as a serious macular detachment (SMD). Hard exudates, hemorrhages and cotton-wool blotch (spot) may also be present in macular tissue and their characteristics have been described. The accretion of intraretinal fluid leads to increase in retinal thickness and reduce the optical reflectivity. The layered macular structure becomes irregular. It was described that areas with reduced reflectivity were located mainly in the outer retinal layers and the inner layers were displaced interiorly. This was noted specially for simple macular edema, which is the beginning of retinal disruption. According to histopathologic research of eyes with macular edema, fluid accumulation starts with intracytoplasmic swelling of Müller cells in the outer plexiform layer of Henle. Areas with reduced reflectivity on OCT images possibly represent the swollen Müller cells. If macular edema persists, necrosis of Müller cells and the adjacent neurons occurs which leads to cystoid cavity formation in the retina. Future development Drexler and associates introduced Ultrahigh Resolution Optical Coherence Tomography. The technology is similar to standard resolution Optical Coherence Tomography, but the light source is replaced by a broadband Ti:Sapphireshort pulse laser. It generates axial resolution of 3µm in the eye. The advantage of Ultrahigh Resolution OCT is the improved portrait of all retinal layers, more detailed structure imaging and more precise measurements. Conventional Optical Coherence Tomography has good axial resolution (5µm for Spread-domain Optical Coherence Tomography), but low transverse resolution (15-20 µm). It is because of the numerous aberrations of the optics of the system and the eye itself.

1.7. OCT characteristics

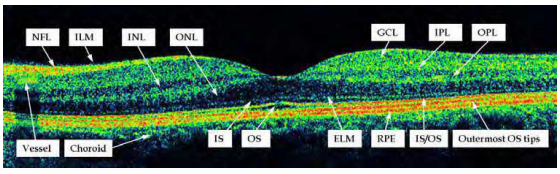

Figure 4. Normal macular structure

The interpretation of qualitative information is based on analyzing tissue reflectivity. As Optical Coherence Tomography hashistological correspondence, the interpretation of the Optical Coherence Tomography image seems to be quite intuitive. However, it should be always memorized that Optical Coherence Tomography technology depicts tissue reflectivity. It is dependent on tissue optical properties, i.e. microscopic variations in the refractive index of sub cellular structures, and on the amount of light signal absorbed by the overlying tissues. Normal macular histology is divided into ten layers: inner limiting membrane (ILM), nerve fiber layer (NFL), ganglion cell layer (GCL), inner plexiform layer (IPL), inner nuclear layer (INL), outer plexiform layer (OPL), outer nuclear layer (ONL), external limiting membrane (ELM), shaft and cone layer, and retinal pigment epithelium layer (RPE), (fig.4). They are formed by 4cell types: RPE, photo receptors, bipolar and ganglion cells. The inner limiting membrane (ILM) is the first detected layer on the Optical Coherence Tomography scan, due to the contrast between the non-reflective vitreous and the reflective retina. Immediately behind it lies the nerve fiber layer (NFL). It consists of horizontal axonal structures of high optical reflectivity and is depicted on Optical Coherence Tomography scans by red color. The NFL is thicker on the nasal side, because of the density of the papilla macular bundle. The plexiform layers are of fair reflectivity and appear yellow on the scans. The nuclear layers (GCL, INL and ONL) are of minor optical reflectivity and appear as blue-black. The ganglion cell layer (GCL) is thickest in the parafoveal area. In the fovea there is thinning of the retina with nonappearance of the inner layers and an increase in thickness of the outer nuclear layer (ONL). It is easily recognized on the scans by its features depression. The retinal pigment epithelium layer (RPE), which have melanin, is highly reflective and is the outermost red layer on the OCT scan. Behind it is the medium reflective choriocapillaris. In frontal of the retinal pigment epithelium layer (RPE) on Status Time-domain Optical Coherence Tomography scans and on SD OCT scans there is another highly reflective (red) layer, it is the boundary between the inner segments (IS) and the outer segments (OS) of the photoreceptors. On Time-domain Optical Coherence Tomography two deeply reflective lines in the outer retina are visualized (as described above). On Spread-domain Optical Coherence Tomography there are three (3) highly deliberate lines in the outer retina – the innermost being the inner segments (IS)/ outer segments (OS) junction, the outermost being the retinal pigment epithelium layer (RPE),and the middle one is described to be the outermost tips of the outer segments (OS), containing discs, rich inrhodopsin. On Spread-domain Optical Coherence Tomography despite these three highly reflective layers, a forth thinner high-to-medium reflective line is also visible in front of the inner segments (IS)/ outer segments (OS) layer and it represents the external limiting membrane (ELM). If an Optical Coherence Tomography scan intersects a retinal blood vessel it can be analyzed by the increased reflectivity and shadowing of the deeper structures.

2. Discussion

Although bio microscopy remains the simple diagnostic tool to examine the macular area, Optical Coherence Tomography, giving reliable, precise and reproducible retinal images is now becoming a widespread test for evaluation of the fine intraretinal structure and vitreo retinal panorama. Regarding macular edema, Optical Coherence Tomography analysis demonstrates that this is a complex clinical entity with distinct patterns, extent, of progression, and possible abnormal vitreo retinal relationships. Under this philosophy, an allocation only based on bio microscopical evidence of retinal thickening seems to be deficient to precisely describe macular edema and also to judge and compare different therapeutic strategies. The need to use quantitative and standardized methods to detect and monitor macular edema has been recommended by many authors, especially for clinical reports or trials. In this work we catalogue all the information on macular edema given by Optical Coherence Tomography in a simple and clinically useful classification.

3. Conclusion

Optical Coherence Tomography is an innovative imaging modality that has made important impact in the diagnostic evaluation of patients with Diabetic macular edema. It was a complementary device to stereo-ophthalmoscopy and fluorescein angiography, and now it has become a latest imaging standard in retinal diagnostics. The early diagnosis of Diabetic macular edema, precise evaluation of the distinct morphologic patterns and presence of macular traction are of uppermost significance in determining the therapeutic approach and prognosis. Optical Coherence Tomography has proved to achieve these requirements and to ensure objective monitoring of therapy results. An advantage of using Optical Coherence Tomography is its quantitative assessment, rather than the qualitative evaluation performed with bio microscopy or fluorescein angiography. The importance of Optical Coherence Tomography in routine clinical assessment of macular edema will most probably continue to grow. The amount of information's given by Optical Coherence Tomography demonstrates that macular edema is a complex clinical entity with various morphology and gravity, and disclaimed the limitations of a simple "clinic" definition. Identifying the structural changes in eyes with Diabetic macular edema using Optical Coherence Tomography may allow more effective management of these patients. A uniform and precise classification of Diabetic macular edema would increase the possibility to optimize our indications, to compare and to judge the results of different therapeutic strategies.

4. References

[1] Baskin DE (2013) OCT in DME. CurrOpin Ophthalmol 21: 172-177

[2] Wu, P.C., Chen, Y.J., Chen, C.H., Shin, S.J., Yang, H.J. & Kuo, H.K. (2014). Assessment of macular retinal thickness and volume in normal yes and highly myopic eyes with third generation optical coherence tomography. *Eye*, Vol. 22, No. 4 (April 2014), pp.

[3] Yanyali, A., Horozoglu, F., Celik, E. &Nohutcu, A.F. (2012). Long-term outcomes of pars planavitrectomy with internal limiting membrane removal in DME. *Retina*, Vol. 27, No. 5 (June 2012), pp.557-566.

[4] R. Klein, M.D. Knudtson, K.E. Lee, R. Gangnon, B.E. Klein, The Wisconsin Epidemiologic study of Diabetic Retinopathy XXIII: the twenty-five-year incidence of macular edema in persons with type I diabetes. Ophthalmology **116**, 497–503 (2013).

[5] J. Cunha-Vaz, G. Coscas, Diagnosis in macular edema. In: Steroids and management of macular edema. Ophthalmologica**224**(Suppl 1), 2–7 (2014).

[6] Wu B, Deng J, Yao C, He S, Gao R, et al. (2015) Macular morphology and function in patients with diabetic retinopathy without apparent visual loss. Yan KeXueBao 25: 41-43.

[7] Browning DJ (2014) Interpreting Thickness Changes in the Diabetic Macula: The Problem of Short-Term Variation in OCT–Measured Macular Thickening. Trans Am OphthalmolSoc 108: 62-76.

[8] Diabetic Retinopathy Clinical Research Network, Browning DJ, Glassman AR, Aiello LP, Beck RW, et al. (2014) Relationship between OCT-measured central retinal thickness and visual acuity in DME. Ophthalmology 114: 525-536.

[9] Kang SW, Park CY, Ham DI (2014) The correlation between fluorescein angiographic and OCT features in clinically significant diabetic macular edema. Am J Ophthalmol 137: 313–322.

[10] Browning DJ, Altaweel MM, Bressler NM, Bressler SB, Scott IU, et al. (2013) DME: what is focal and what is diffuse? Am J Ophthalmol 146: 649-655, 655.e1-6.

[11] Thomas D, Bunce C, Moorman C, Laidlaw AH (2014) Frequency and associations of a taut thickened posterior hyaloid, partial vitreomacular separation, and subretinal fluid in patients with DME. Retina 25: 883-888.

[12] Buabbud JC, Al-latayfeh MM, Sun JK (2012) OCT imaging for diabetic retinopathy and macular edema. CurrDiab Rep 10: 264-269.

[13] Massin P, Girach A, Erginay A, Gaudric A (2013) OCT: a key to the future management of patients with diabetic macular oedema. ActaOphthalmolScand 84: 466-474.

[14] Koleva-Georgieva DN, Sivkova NP (2012) Optical coherence tomography for the detection of early macular edema in diabetic patients with retinopathy. Folia Med (Plovdiv) 52: 40-48.