En face OCT: a novel imaging approach

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Introduction

Optical coherence tomography (OCT) is a noninvasive high resolution optical imaging technology based on interference between signal from an object under investigation and a local reference signal. It has become an essential imaging technique for evaluation and management of retinal, corneal and optic nerve disorders.

Newer techniques such as image averaging and enhanced depth imaging (EDI) have given us the ability to better assess vitreous, retina and choroid in a nicer manner. Image averaging involves obtaining multiple B-scans from the same retinal location that are then averaged together to increase the signal-to-noise ratio, typically in proportion to the square root of the number of images averaged. When multiple images are averaged, the software reduces the ‘speckle.’ This sharpens the continuity and enhances the retinal and choroidal features. While, enhanced depth imaging (EDI) involves setting the choroid adjacent to the zero delay line, allowing visualization of choroid up to the sclera.

Several other approaches have been investigated to provide accurate localization and meaningful contextual orientation of OCT cross-sections to fundus landmarks.

One of this modalities is called en-face OCT, which is C-scan sections obtained by sectioning the 3D volume generated from a series of B-scan images taken at different transverse coordinates.

En face technology constitutes a useful and necessary complement to the conventional cross-sectional B scans. It brings important new information to the clinician. It highlights details of the retina that surgeons cannot see in B scans and provide a direct, front view of retinal layers.

Application of this approach in routine clinical practice is relatively new and its clinical interpretation along with other traditional imaging scanning methods is being studied.

The capability to image live thin sections of the retina provides a uniquely exciting capability for the ophthalmologist.

Development of the En Face Image

A tridimensional (3D) data set could be displayed in a series of two-dimensional (2D) cross-sectional images in any orientation desired. B-scan images are approximately perpendicular to the retinal surface and en face images are nearly parallel to the retinal surface. In other words, when looking at images of fundus cameras, they are oriented in en face

FIGURE 01 - In the example, the inner limiting membrane (ILM) contour nicely depicts the reflectance of the retina as well as the folding aspect of the epiretinal membrane (A). En face slab of the inner plexiform layer (B) retinal pigmented epithelium (C) and the choroid (D).
manner. Therefore, en face OCT imaging is much easier for interpretation because ophthalmologists are more familiar with transversal images.

C scan is flat and posterior pole is concave. Retinal surface at the posterior pole shows two depressions that are well evident on the flat sections: the macular depression and the inter papillomacular concavity as a bean-shaped depression.

The most important problem is that rarely the planar section is perfectly parallel to the posterior. Very frequently the section plane is vertically or laterally tilted, such as in myopics. Tilted plane sections are difficult to analyze and understand. Images from myopic, emmetropic and hypermetropic eyes are very different. If the ocular concavity is marked, due to high myopia, it is even more difficult to get a section parallel to the posterior. In these cases, artifacts are frequent and sometimes difficult to distinguish from pathological retinal anomalies. For these reasons flat C scans are not very much used anymore. They are considered obsolete.

**En Face Generated to Follow Natural Surface Contour of the Retina**

The en face should be generated following a natural surface contour of the retinal layers, with uniform or varying thickness.

The en face image is similar to a fundus image; the advantage of OCT is the ability to generate depth resolved en face images with intensity integrated over a small depth range to visualize retinal structures layer-by-layer.

En face reference plane can be adapted in different layers of the retina providing pathological details affecting each layer.

Eye motion during image acquisition could introduce artifacts in the en face image, causing distortion of retinal features, such as disruption of the blood vessel patterns, and intensity variation. Motion corrected 3D data will have advantage over conventional 3D OCT data set in generating more accurate and reproducible en face images.

**Interpreting the En Face Image**

En face scan procedures are easy to perform and images are easy to understand after a short learning period. It has the advantage that ophthalmologists are more familiar with the interpretation of transversal images since they are of similar orientation as those found in fundus cameras.

Finally, interpreting en face images needs to consider contour, thickness and location of the en face slab. Keeping in mind that the anterior retinal features could affect the appearance of the en face images of the posterior layers, B scan images can provide helpful complementing view when interpreting en face images.

One can follow the irregularities of a pathologic vitreoretinal boundary, epiretinal membranes and vitreoretinal tractions using En face OCT with high quality imaging that would not be obtained from longitudinal scans alone.

For the moment, only Optovue and Zeiss OCT devices provide frontal scans adapted to retinal concavity, scans generated to follow a retinal surface contour. All the other clinically available devices produce classical planar C scans.

**Clinical applications**

En face scans adapted to the normal concavity of the inner limiting membrane (ILM), inner plexiforme layer or the retinal pigment epithelium (RPE) enable imaging of finer details of epiretinal membranes, macular edema, pigmented epithelial detachment (PED) and drusen.

They bring new elements for the diagnosis and follow-up of retinal diseases and provide a good overview of the retina under study allowing the assessment of all the scanned area within the retinal cube. They give us unusual points of view of the ocular pathologies and highlight details surgeons could not have seen without this technology.

**Inner limiting membrane (ILM)**

Frontal scans generated to follow the inner limiting membrane (ILM) contour may help us to evaluate vitreomacular interface disorders such as vitreomacular traction, epiretinal membrane (ERM) formation and macular holes.

In the example, the inner limiting membrane (ILM) contour nicely depicts the reflectance of the retina as well as the folding aspect of the epiretinal membrane, as shown in Figure 1.

**Retinal Pigmented Epithelium (RPE)**

Frontal scans are placed at constant depth following any retinal layer contour.
When using the RPE as reference plane for the en face scan, irregularities of a pathologic RPE may depict the delineation of a drusen or the PED and most importantly gives us quantitative information such as drusen size, volume, area and elevation. It may also help differentiate in small, intermediate, large and very large size following Age Related Eye Disease (AREDS) protocol, as shown in Figure 2. The same principle can be applied to geographic atrophy.

**Central Serous Chorioretinopathy (CSC)**

Central serous chorioretinopathy (CSC) is a common disease in young to middle aged adults characterized by an idiopathic serous detachment of the retina secondary to one or more retinal pigment epithelium (RPE) leakage. Diagnosis basically relies on fluorescein angiography (FA), B-scan OCT and indocyanine angiography (ICG).

En face OCT is able to identify the focal leakage site observed in FA as well as in ICG without the need of intravenous dye, therefore, it has been considered a major diagnostic innovation.

Retinal pigmented epithelium detachment location, size and area, as well as serous retinal detachment, hyper-reflective dots, presence of thickened fibrinous fluid may also be appreciated using the RPE as reference plane and without the potential side effects of the aforementioned older diagnostic techniques (Figure 3).

This ensures prompt diagnosis when use of contrast imaging technique is contraindicated (i.e. allergy, pregnancy) and supports a rapid and secure diagnosis and follow-up of patients with central serous chorioretinopathy.

**En Face OCT in Age-related Macular Degeneration**

En face OCT technology is the most significant advancement in diagnosing and following patients with drusen and geographic atrophy. The newer algorithms are responsible for quantification of drusen volume, size, elevation as well as the area of geographic atrophy. Both of these forms were difficult to precisely assess and monitor patients over the years.

In exsudative form of AMD improved visualization and delineation of retinal substructures with the use of en face OCT constitutes an important adjunct alternative for cross-sectional optical coherence tomography B-scans. A detailed study of the RPE layer shape, walls, dimension, and thickness can

FIGURE 03 - En face OCT is able to identify the focal leakage site as well as the serous retinal detachment and retinal pigmented epithelium detachment location, size and area, using the RPE as reference plane.
be determined by using en face OCT.

In the figure 4, a series of large irregular, multilobular RPE detachments are observed in the posterior pole. These features, along with diverse wall thickness and hyperreflectivity may illustrate the polypoidal aspect of the disease. Fluid accumulation and serous retinal detachment is visible, deeper in the cavity as a hyporeflective, optically empty area.

However, there is no specific algorithm to this date that tracks progression of retinal detachment area and volume when using en face OCT in exsudative AMD.

**En Face OCT Morphologic Changes in Diabetic Maculopathy**

The definition of cystoid macular edema is a morphological one and refers as the accumulation of fluid in multiple cyst-like configurations.

Careful examination of diabetic macular edema with en face OCT demonstrates that how fluid fills a continuous space within the compact retinal architecture.

The cysts are seen throughout the layers of the retina, especially when the En face scans adjusts to the normal concavity of the inner plexiform layer or retinal pigment epithelium (RPE). In this case, a continuous fluid space interrupted by cross-sections of vertical elements connecting the outer to the inner retina is observed. The frontal scan placed inside the retina shows at the inner nuclear layer level numerous small petal-shaped cystoid cells. The frontal or honeycomb pattern is caused by the Henle fibers stellate structure. Cells are grossly ovoid with tips converging toward the fovea. Sometimes a detachment of the ellipsoid zone can be observed in these patients. (Figure 5)

En face technology can also help us to understand the irregularities and extension of the distribution of hard exsudates throughout macular retinal tissue and maybe used as guide during focal/grid laser treatment.

**En Face OCT Imaging in Ocular Toxoplasmosis**

Toxoplasmic retinochoroiditis is the most common form of posterior uveitis in otherwise healthy individuals, and Toxoplasma gondii infection is distributed worldwide. Ocular toxoplasmosis in immunocompetent patients is characterized by an acute inflammatory granulomatous chorioretinal necrotizing inflammation of the retina and choroid. It can be widespread in the eye and involve also the vitreous, ciliary body, iris, anterior chamber, cornea and trabecular meshwork. Therefore, it is very difficult to evaluate these patients with OCT particularly in acute stages.

In Figure 6, en face image at the level of the inner nuclear layer depicts presumed vascular sheathing.

**Future directions**

One of the biggest challenges in en face OCT technology is image quality. Artifacts are common in this modality; therefore, high-speed systems are required especially in patients with difficult fixation.

Improvements in en face OCT imaging are strongly dependent on advances in fundamental OCT detection and imaging technology. Different methods for image detection that enabled advances in en face imaging performance are underdevelopment.

Motion corrected 3D data will have advantage over conventional 3D OCT data set in generating more accurate and reproducible en face images. This technique is now being introduced in a forthcoming OCT device. (Avanti Rtvue).
En face OCT Angiography

Diabetic retinopathy, age-related macular degeneration, and glaucoma are the leading causes of blindness in the whole world. Analysis of ocular circulation is imperative.

Currently, the most widely used technique for examining vascular abnormalities is fundus fluorescein angiography (FA). However, it is an invasive procedure that requires intravenously injection of a dye with possible side effects, such as nausea and anaphylaxis.

En face OCT angiography is a promising depth resolved technology that precise location of vascular abnormalities can be localized using cross-sectional imaging.

The algorithm called split-spectrum amplitude-decorrelation angiography (SSADA) that works by splitting the full OCT spectrum into several narrower bands reduces OCT axial resolution and consequently reduces its susceptibility to axial motion noise. These changes result in improved detection of the flow signal, which in the ocular fundus is predominantly in the transverse dimension.

It can evaluate blood flow and volume of retinal and choroidal vasculature, highlight vessels where the flow is present and evaluate abnormalities in retinal and choroidal vasculature.

Conclusion

En-face imaging has the advantage that ophthalmologists are more familiar with the interpretation of transversal images since they are of similar orientation as those found in fundus cameras. It allows point-to-point correspondence between images of the retinal surface and at various depths. Information may be essential when evaluating conditions that emerge from the choroidal tissue such as in AMD, providing the clinician a more complete and interactive tool.

In conclusion, en-face OCT imaging approach provides a better overview of the whole area of interest, allowing identification of microstructural information, focal changes as well as their distribution throughout the scanned area not available with standard scans. It also allows identifications subclinical changes, which may be early markers for the progression of the disease.

REFERENCES


