OCT Angiography : Basic Concepts

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Abstract :

Optical Coherence Tomography Angiography (OCTA) is a non-invasive dye-free imaging technology that creates high resolution depth resolved angiographic images of vascular flow in retina. It is based on the principle of split spectrum amplitude decorrelation angiography algorithm. OCTA gives segmentation of layers as superficial capillary plexus, deep capillary plexus, outer retinal layer, outer retina to choriocapillaris, choriocapillaris layer and choroid layer.OCTA is also useful for visualization of choroidal neovascularization and the monitoring of age-related macular degeneration (AMD) by observing the morphologic changes of choroidal vessels. It is an efficient tool to keep evidence of regression and progression of the disease in follow up cases of AMD patients on anti-VEGF treatment. OCTA plays an important role in the diagnosis of early and advanced changes in diabetic retinopathy (DR). It has the advantage to examine the superficial and deep capillary plexuses separately. The segmentation of layers in OCTA in a case of DR is important in the micro evaluation of the status of the retinal vasculature and for prognostication. Disadvantages of OCTA are that images do not show leakage, dye pooling and tissue staining. It has limited field of view, artifacts, and limited choroidal penetration. OCTA is a useful tool to be used in correlation with structural cross-sectional scans in determining treatment decisions.

INTRODUCTION:

The risingcall towards non-invasive methodsof retinal imaging led to the development of the imaging modality in 2015 called theoptical coherence tomography angiography (OCTA).

OCTA providesmany advantages over conventional angiography in terms of both patient comfort as well as technical superiority. Patient comfort is in the form of shorter acquisition time and in being non-invasive. Thus, it is free of the associated systemic adverse effects and anaphylactic reactions.

OCT ANGIOGRAPHY:

OCTA is a non-invasivedye-free imaging technology that creates high resolution and depth resolved angiographic images of vascular flow in retina. It is able to do so in a span of few minutes by using motion contrast. [1-3]

Unlike fundus fluorescein angiography (FFA),which is an invasive dye based procedure, OCTA is a non-invasive procedure free from complications.This investigative technique provides the advantage ofvisualizing deep capillary vessels while FFA depicts mainly superficial capillary vessels.

PRINCIPLE OF OCTA:

OCTA is based upon the principle of the split spectrum amplitude decorrelation angiography (SSADA) algorithm. It applies highspeed OCT scanning to detect blood flow. It carries out signal decorrelation between scans and analyses it to differentiate the flow of blood vessels from the other surrounding non-vascular tissue.[4-7]

SEGMENTATION OF LAYERS SEEN ON OCT ANGIOGRAPHY :

Segmentation of layers can be performed on OCTA

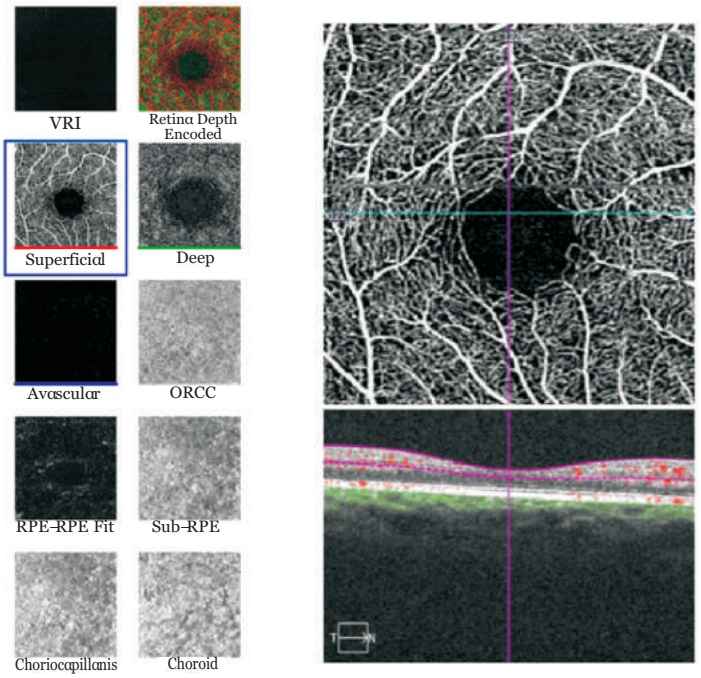

Figure 1: OCT-A showing the segmentation of layers of the retina

1. Superficial Capillary Plexus:

It is in form of continuous perifoveal arcade with regular meshes arranged in centripetal pattern around foveal avascular zone. It lies about 3µm from the internal limiting membrane (ILM). It supplies the retinal nerve fibre layer, ganglion cell layer and superficial part of inner plexiform layer. Its thickness is approximately 10µm. [8-9]

2. Deep Capillary Plexus:

It is in form of close knit pattern of vessels around the avascular zone. Its thickness is approximately 60µm. It lies around 15µm from the Inner Plexiform Layer. It supplies the deep part of inner plexiform layer, inner nuclear layer, outer plexiform layer and superficial part of outer nuclear layer. [8-9]

3. Outer Retinal Layer:

It is an avascular layer, does not show any vascular plexus normally. Any vascularity seen in this layer can be pathological neovascularisation arising from beneath. It ranges from deep outer nuclear layer to external limiting membrane. It is nearly 30 µm away from retinal pigment epithelium (RPE) and its thickness is approximately 30µm. [8-9]

4. Outer Retina to Choriocapillaris (ORCC):

It is present between the outer boundary of outer plexiform to 8µ below Bruch's membrane. It is used to detect progression of choroidal neovascularisation for the determination of the type of wet age related macular degeneration (AMD) as well as to monitor the response of therapy. [10]

5. Choriocapillaris layer:

It is imaged 10µ beneath the Bruch's membrane. The angiogram ofthis layer is generally homogenous. There is presence of black shadowing of vessels in this layer. [11]

6. Choroid layer:

OCTA gives us the advantage to visualize choroid vasculature in depth. Changes in the choroidal vessels can be picked up in early course of disease. However, OCTA has limited choroidal penetration. [11]

ROLE OF OCT-A IN WET AGE-RELATED MACULAR DEGENERATION (AMD)

One of the most important clinical applications of OCTA is supposed to be the visualization and monitoring of choroidalneovascularization (Figure 2). It has been seen that

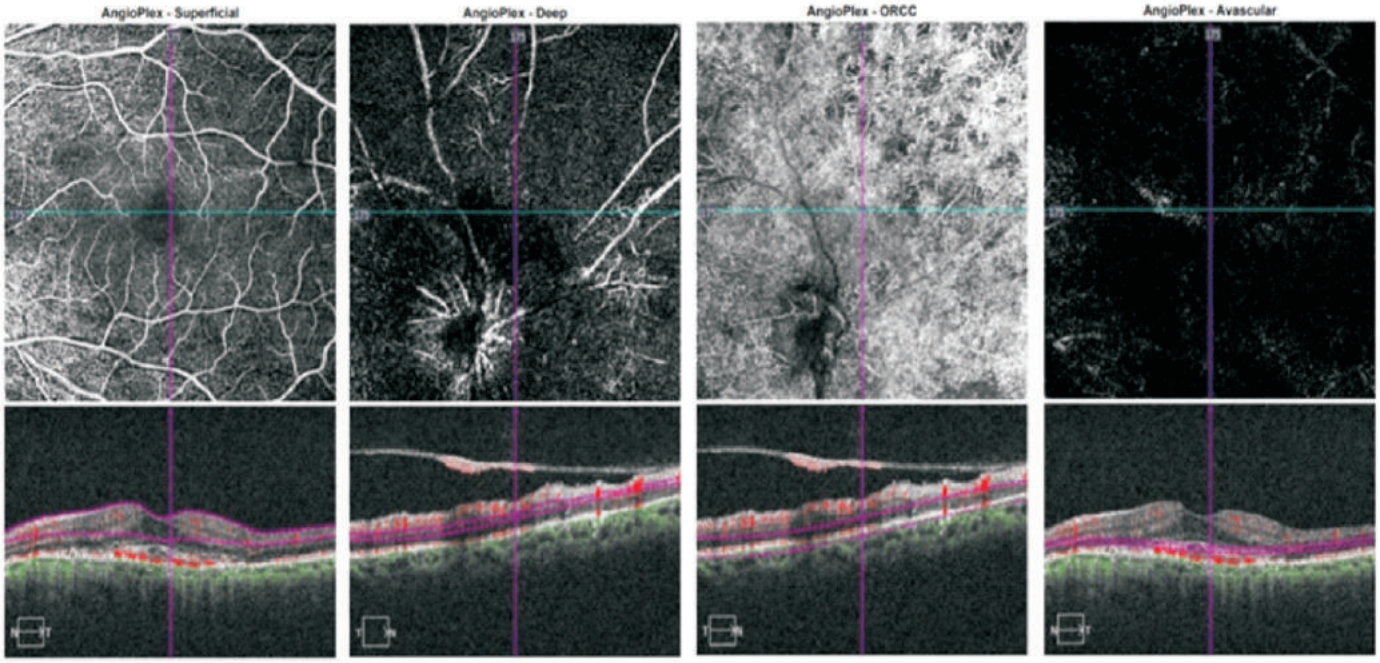

Figure 2: OCT-A of a case of wet AMD showing superficial, deep, ORCC and avascular layers respectively.

with the use of OCTA early choroidalneovascular membrane (CNVM) can be detected earlier than FFA, in which it is generally difficult to detect. [12]

The neovascularcomplex of retinal angiomatousproliferans (RAP) appears as a small tuft of bright high-flowtiny vessels with curvilinear morphology located in the outerretinal layers with a feeder vessel communicating with the inner retinal blood vessels detecting CNV. [13-14] OCTA is able to identify a distinct neovascular complex in these RAP lesions.

Intravitreal injection of anti-vascular endothelial growth factor (anti-VEGF) is the mainstay of therapy for the management of CNVM in wet AMD today. [14-15] OCTA is also useful for the

monitoring of AMD by observing the morphologic changes of CNV vessels over weeks after treatment with intravitrealanti–VEGF. It is an efficient tool to keep evidence of regression and progression of the disease in follow up cases of AMD patients on anti–VEGF treatment.

ROLE OF OCTA IN DIABETIC RETINOPATHY

OCTA plays an important role in the diagnosisof early and advanced changes in diabetic retinopathy (DR). In patients with DR, OCTA reveals retinal changeslike capillary dropout in the superficial and deepplexuses, foveal avascular zone (FAZ) enlargement and the presence of microaneurysms.OCTA has the advantage to examine the superficial and deepcapillary plexuses separately which helps us to outline retinalinvolvement in different diabetic lesions. Increase in the size of theFAZ has a correlation with severity of disease and is best seen in the superficial plexus, whereas capillarydropout and microaneurysms are best visualized in thedeep plexus.[16] However, microaneurysms are visible on OCTAonly in the presence of intravascular flow; therefore in cases of decreased flow or thrombosis they will remain undetected. Thedetection of preretinal and pre-papillary neovascularizationcan be done with the help of OCTA as new vessels do not blurby leakage as seen in conventional dye-based angiography.

The segmentation of layers in OCTA in a case of DR is important in the micro-evaluation of the status of the retinal vasculature and for prognostication (Figure 3).

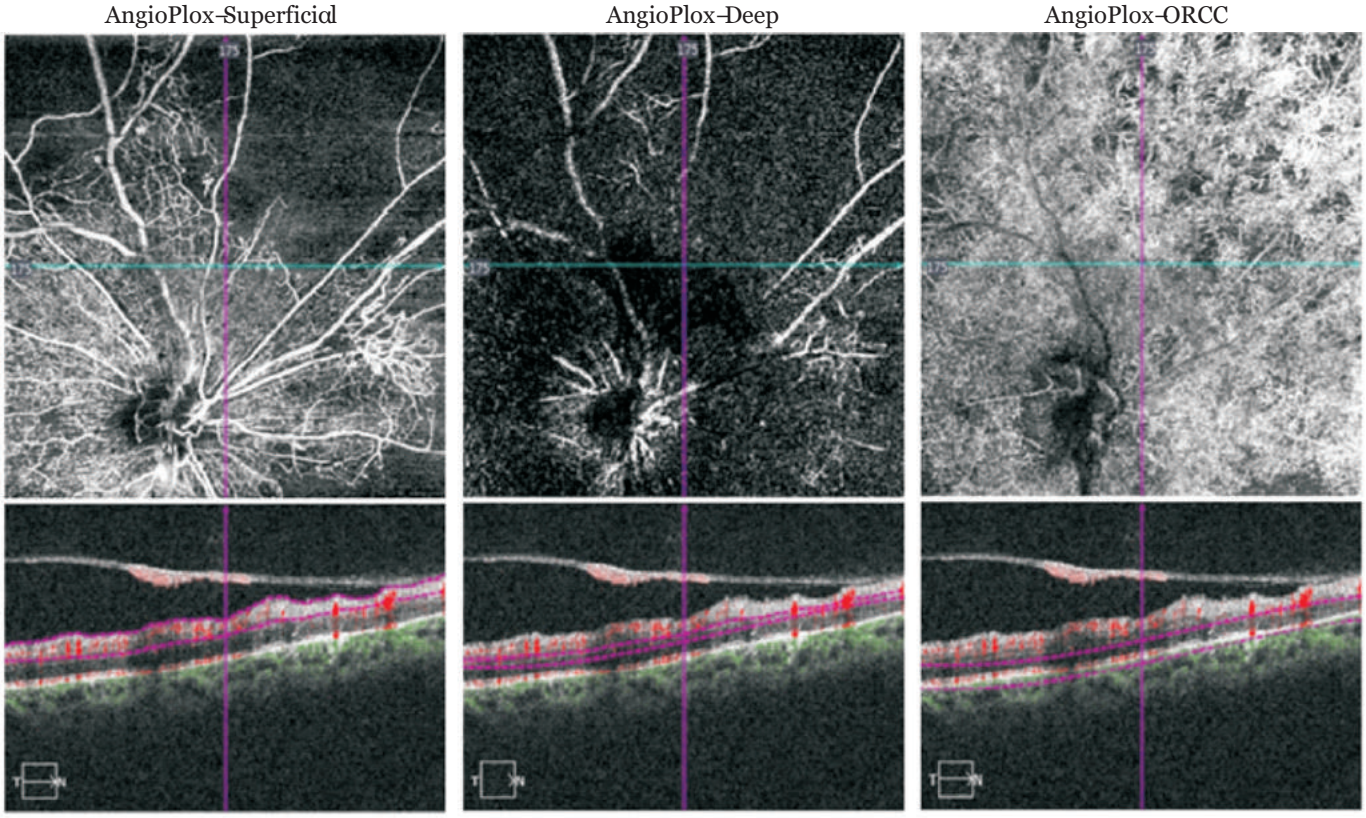

Figure 3: OCT-A of a case of proliferative diabetic retinopathy showing neovascularization elsewhere in superficial, deep and ORCC layer respectively.

Using SD-OCT and OCTA, NVEs have been proposed to develop in 3 stages: I—disruption of ILM; II—horizontal growth along ILM and III—multiple breach of posterior hyaloid (PH) and linear growth.[17,18] According to their morphology they have been classified by Vaz-Pereira et al as (1) flat, when confined to the PH face; (2) forward when lesions showed PH traversal and (3) tabletop when neovascular complexes (NVCs) were displaced anteriorly by vitreous traction but tethered to the retina. NVEs were also classified according to location in (1) above the ILM and (2) below the ILM types based on their intraretinal component.[17,18]

ARTIFACTS AND LIMITATIONS OF OCTA

Despite improvements in softwares in many models of OCTA, some significant limitations are still present and require further refinements of technology. Asit is based on SSADA algorithm that detects blood flow by movement, any movement

by the patient will give rise to a significant artifactand this will cause worsening of image quality.

Projection artifact also known as the tailing artifact,is the transit of blood cells in a superficial blood vessel that casts flickering shadows on the deeper tissue layer. This makes it difficult to distinguish from blood flow in deeper layer, causing duplication of vessels. This makes it difficult to differentiate normal physiological vessels from pathological vessels. The software provides a function to remove projection artifacts, but this can cause some loss of signal of pathological blood vessels.[19]

Segmentation artifact occurs in conditions that alter the anatomy of retinal architecture. OCTA allows us to have segmental visualization of superficial capillary plexus and the deep capillary plexus and the choriocapillaris. In pathological conditions where the retinal architecture is altered, it can give an incorrect segment interpretation of these layers and blood vessels in it.

Motion artifact can be seen with eye movements and blinking. Motion correction technology is provided that helps reduce decorrelation and gaps in the image it createsby identifying changes in consecutive images of the same location.[20]

As OCT angiography is dye-free, images do not show leakage, dye pooling and tissue staining, which are important features of certain disorders of inflammation and diabetic retinopathy. These need to be correlated simultaneously with structural cross sectional OCT scan.

OCTA technology has limitations in the form of limited field of view, artifacts, and limited choroidal penetration.[20,21]

The limited field of view has been improved with the introduction of widefield OCTA, which used montaging algorithms to provide a larger field of view.[22]

The artifacts in OCTA images such as blink, motion, projection and segmentation errors lead to difficulty in interpretation of the images.[21]

Thus, OCTA should not be used asan exclusive diagnostic modality and always needs to be used in correlation with structural cross-sectional scans in determining treatment decisions. Improvements in the form of software updates, scan acquisition rate with automated artifact removal and adaptation will be of help to further the role of OCTA in the management ofchorio-retinal pathologies in a much more advanced way.

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