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Update on retinal imaging: OCT angiography

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Introduction

OCT angiography (OCTA) is a new addition to the armamentarium for retina specialists for the retinal vascular diseases. It is based on generating 3D volumetric data on retinal and choroidal tissue with fast high-definition scanning. In the last couple of years, we have seen an exponential volume of literature on the use of OCTA.

Background

High definition Fourier domain (FD) OCT images provide detailed structural reconstruction in vivo generated from variance in light reflection (back scatter) from retinal tissues that mimic histological appearance of retina when B-scans are aligned. The computing algorithms inherent in commercial OCT systems have auto segmentation facility which allow viewing of the compiled b-scan images en face. Readers are familiar with ocular angiography using injectable dyes – viz. fluorescein angiography (FA) and indocyanine green angiography (ICGA) that provide high-contrast dynamic images of retinal circulation. There are well-known patterns on both FA and ICGA that aid the diagnosis and monitoring of retinal conditions and their management. The smaller molecule of fluorescein allows for identifying areas of leaky blood vessels, while larger molecule of ICG complements this by demonstrating architecture of the retinal and choroidal vessels in vivo.

The OCTA is based on using moving blood cells within retinal vessels (motion contrast) to construct images of retinal microvasculature. It exploits the specific image acquisition techniques of OCT scanners and by employing special image processing technology extracts details of retinal circulation. In general, the OCTA is based on decorrelation of sequential b-scan signals (amplitude or intensity or both) from the same point of tissue scan to construct blood flow pattern creating the angiographic image. It therefore requires multiple OCT (volume) image acquisition at a very fast rate and additional motion correction to compensate for blur induced by saccadic eye movements.

Technology

The basic platform for OCTA is fast HD OCT, that provides rapid successive scanning of retina at a given point of interest, usually in the posterior pole. Current commercially available systems offer small areas of scan 3x3mm to 6x6mm with a newer version offering possibility of 12x12 mm scan for OCTA. The resultant high-definition b scan images are analysed for relative change in tissue reflectivity induced by moving blood cells in retinal and /choroidal vessels. Various computing methods are described as summarised below:

Phase Doppler approach: (DOCTA) is based on calculating Doppler shift e.g. phase contrast, phase variance, phase subtraction. Moving blood cells in vessels lead to phase shift, information of this is insidiously obtained on routine OCT scans but not used conventionally.

Magnitude (amplitude) based approach: correlation mapping OCT (cm OCT,) speckle variance OCT (svOCT), Split –Spectrum Amplitude Decorrelation Angiography (SSADA) are software calculations used to generate angiographic imaging used in various commercially available systems. Optoview for example is an SSADA based system[1], while Topcon uses intensity ratio analysis (OCTARA) without splitting the full spectrum which claims to give better axial resolution.

Combined approach

Combination of both the phase based and magnitude based calculations are exploited in Eigen Decomposition OCT (EDOCTA) as well as in Optical Micro angiography (OMAG). OMAG algorithm combines phase based and magnitude based signals for analysis as utilised by Zeiss.

As the software needs to compare scans of the same location to detect changes in reflectivity, the images need to be from static eye, thus free of micro saccades. Eye tracking therefore is important to reduce the blur induced by eye movements.

Clinical application

The laminar arrangement of the retina and the vascular networks within it offers convenient segmentation in to distinct layers. The ability to represent this anatomy en- face with decorrelation of images facilitates visualisation of retinal vasculature. This provides distinct image for both the superficial and deep retinal capillary network (figure 1 a ,b), unlike conventional FA, where this distinction between the two networks is not readily possible[2,3]. Commercially available system software can generate sets of images of these layers based on auto segmentation as 1) superficial 2) deep retinal networks[4], 3) outer retinal and 4) choriocapillaris based on en face segmentation. Furthermore, computation of perfusion indices - vessel density and flow index - information can further enhance clinical application of OCTA by providing perfusion maps for given layer at given location. (The flow index = average decorrelation values; vessel density = percentage area occupied by vessels in given segmented area[5]).

The retinal pigment epithelium limits imaging of choroid however the Swept Source scanner (SSOCT) and Enhanced Depth Imaging (EDI) scanners have improved choroidal viewing. SS has added the potential advantage of reduced eye movements due to invisible longer wavelength scanning light. In the context of study of choroidal circulation, presently OCTA has been used to auto-segment choriocapillaris layer, as used in cases of AMD and CSCR. The slower blood flow lesions pose additional challenge of detection on OCTA. This can be offset by increasing image acquisition time and using reflectivity subtraction from images taken at relatively longer intervals.

Potential efficacy of OCTA in clinical practice is described in a number of published reports based on cases and case series. It has many potential applications in retina practice, especially for

retinal vascular diseases, studies of choriocapillaris and choriodal circulation[6]. In AMD, it offers potential to identify neovascular complex with details of capillary network[7]. Unlike dye angiography, absence of leakage facilitates delineation of capillary plexus with clarity on OCT. All 3 types - type 1 (occult), type 2 (classic) and type 3 (RAP) CNVs can be identified with OCTA, noted to be specifically useful for type 3 (RAP) lesions[8] due to the capacity of en face presentation with a 3D depth resolution. With increasing pattern recognition it is possible to demonstrate low flow polypoidal lesions too. It may be possible to use OCTA in monitoring treatment response of CNV in AMD[9]. OCTA has also been employed in evaluation of retinal microvasculature for common retinal vascular diseases such as diabetic retinopathy[10], retinal vein occlusions[11], macular telangiectasia[12] and CSCR[13]. OCTA can provide information on integrity of retinal circulation facilitating disease management as in diabetic retinopathy or vein occlusion. As can be seen in figure 1c, OCTA provides details of both superficial and deep retinal capillary network in macula in an acute case of CRVO with macular oedema where conventional FA suffers masking from retinal haemorrhages and leakage (Figure 1d).

Practical points

OCTA is promising new technology as it provides both structural and functional (blood flow) information in non-invasive, quick and reproducible way providing 3D axial representation not obscured by leakage. This makes it an attractive alternative option over dye angiography which is invasive, expensive and relatively less patient friendly due to its invasive nature and potential small risk of side effects. Where repeated and frequent follow-up examinations are needed OCTA would seem more practical.

However, OCTA still is an emerging technology and has its own limitations. It is an 'inference' of retinal circulation at a fixed time point generated by computer software and it does not provide real information as FA. Additionally, information on leakage and source of leakage is not identifiable. As it is dependent on auto segmentation it is prone to artefacts and resultant errors in interpretation. The light penetration in deeper layers is blocked by haemorrhage, thick scar and pigment which are added limitations of OCTA. The motion – e.g. fixation losses- lead to aberrant interpretation of movement similar to 'flow', usually seen as while lines on OCTA; while blocking the light as in blinking creates black lines ('shadow'). Retinal pigment epithelial detachments are described as another source of movement artefact. The ghosting of blood vessels, especially for images of deeper network is generated by unsuppressed superficial network by the algorithm. Due to the fibrosis or slow flow in microaneyrisms or CNV, they may be 'invisible' on OCTA when conventional sampling and analysis is done. **Table 1** summarises the different characteristics of OCTA against FA.

It appears that there is already a vast clinical experience using this technology in various kits using different algorithms. There is now need to validate this technology to define its sensitivity and specificity for standardised clinical application. Similarly cross validation between the systems will be important to ensure the uniformity of identification of retinal blood vessels on each machine.

Conclusions

OCTA is a promising new technology that provides quick structural (OCT) and functional (blood flow) information. Currently it is complementing the gold standard dye angiography (FA/ICG). Despite its known limitations of motion artefact, limited field and lack of dynamic information (leakage), with further refinements and validation studies, OCTA has potential to be established as part of routine retina practice.

Figure 1:

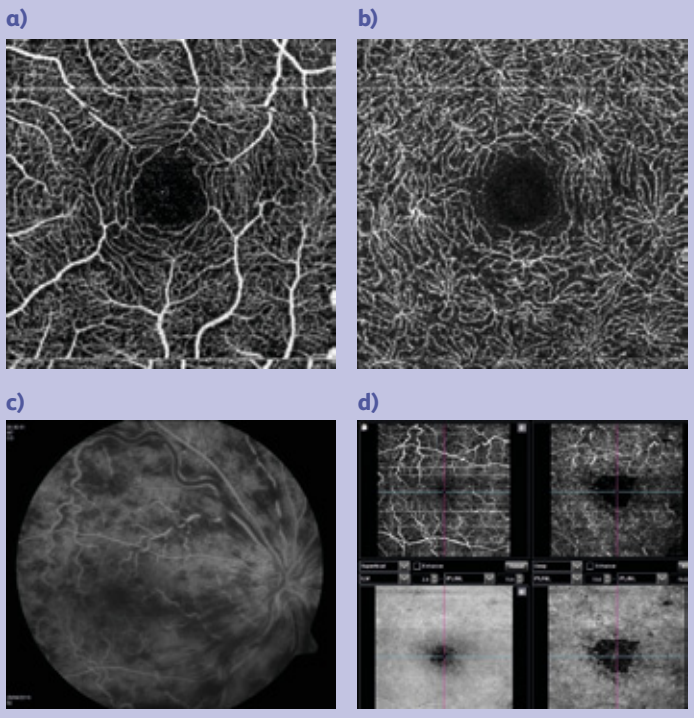

Table 1:

	OCTA	FA
Procedure risks	Non invasive	Invasive - allergy, anaphylaxis
Time and access	Quick on demand	10-30 mins , scheduling
Cost	New kit	Available tool in all ophthalmology departments
	Lower procedure cost	Higher procedure cost
Image quality	Technician dependence	Technician dependence
Field of view	Small	Wide
Angiography image	Virtual	Real
Angiogram pattern	Leakage not demonstrable	Leakage demonstrable
	No staining no Pooling seen	Staining and pooling seen
	Thin 'vessels' as depicts flow only within lumen	Bigger vessels as it shows flow + staining of walls
Angiogram clarity	Movement artefact	Less movement artefact
	3D resolution possible	No 3D view
	Clearer without masking from leakage/ pooling	Masking from leakage/ pooling

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