Optical Coherence Tomography Angiography (OCTA): Article review

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Fluorescein angiography (FA) and optical coherence tomography (OCT) are commonly used imaging techniques in diabetic retinopathy (DR). The first report describing FA to visualize the retinal vasculature was in 1930 by Kikai. However, the disadvantages of FA became apparent soon. FA photographs can visualize only large superficial retinal vessels located within the nerve fiber layer and the ganglion cell layer, and perfusion of deeper retinal vasculature was not visible. As it is an invasive imaging technique, FA has been associated with rare but life-threatening complications such as anaphylaxis and cardiac arrest (XU et al., 2015). Optical coherence tomography (OCT), which was introduced to the scientific community in 1991 has become one of important imaging modalities. Optical coherence tomography angiography (OCTA) was demonstrated in 2015 by Spaide et al., could image all layers of the retinal vasculature, including the deep layers, in contrast to FA imaging (Freiberg et al., 2016).

OCTA is a relatively new, non-invasive tool that allows simultaneous visualization of the retinal vasculature and microstructure in a three- dimensional, depth-resolved fashion without dye injection, and give high resolution volumetric angiograms allowing the superficial and deep capillary plexuses to be studied separately (Spaide et al., 2015). Technology: In 2012, Jia et al., introduced an intensity-based technique to visualize the retinal and choroidal microvascular called split-spectrum amplitude decorrelation angiography (SSADA) algorithm. The SSADA algorithm divides the OCT spectrum into narrower bands and then averages the intensity decorrelation detected in each band (Hagag et al., 2017). Currently, there are several different OCTA processing methods being used by different companies. These include phase-based techniques (Doppler shift or variance), magnitude-based techniques or intense-based (speckle variance or decorrelation), or a combination of both. Each method utilizes a different part of the OCT signal to obtain flow information, but the goal of visualizing vasculature is the same, and the resulting images are similar (Zhang et al., 2015). The phase-based technique works by assessing changes in the phase of reflected light waves over time. The other technique works by mapping erythrocyte movement through the decorrelation signal between sequential OCT B-scans at the same cross section (De Carlo et al., 2015). OCTA works by scanning the same location on the retina multiple times consecutively. As the scanning laser beam enter the eye, areas with no movement will reflect light by the same way.

But, moving structures will reflect light differently between each B-scan in the amplitude or the phase. After eliminating the effects of bulk motion such as head movements or saccades, these B-scans are compared and any differences between the scans are due to blood flow, and hence indicate the location of a perfused blood vessel. Areas with blood flow appear bright, whereas dark areas indicate no flow. By combining the flow information in all B-scans, an en face image of the microvascular circulation can be formed (OCT Angiogram). These OCTA images can achieve an axial resolution of approximately 5 µm, which gives detailed views of fine capillaries (Spaide et al., 2015).

Currently all available OCTA devices are spectral domain devices (SD- OCT) except Topcon DRI triton devices which are swept source (SS- OCT). Hardware of SS-OCT differs from SD-OCT in several ways including light source, bulk optics, components and photodetection devices. SS- OCT devices uses longer wavelength centered at 1mm and sweeps across a band of

wavelengths. This longer wavelength gives better visualization of choroid. SS-OCT also use a point photodetector while SD OCT use a spectrometer (Choma et al., 2003).

Advantages of OCTA: One of the greatest advantages of OCTA is its ability to provide a three-dimensional, depth-encoded information about retinal vasculature (Jia et al., 2012). Because it is an OCT-based scan, the data obtained consists of multiple B-scans which are combined into a cube. By segmenting the cube into different slabs, OCTA is able to isolate blood flow information at a specific retinal depth. (Matsunaga et al., 2014). OCTA is non-invasive technique with no need for dye injection and Image formation usually takes seconds so it is easy for patients to tolerate and can be performed several times. This suitable for follow the patient more closely, and potentially detect changes earlier. All of these features make OCTA a promising tool for diagnosing and managing disease (Koustenis et al., 2017). Another advantage of OCTA is its resolution. OCTA can achieve an axial resolution of approximately 5 μm, which permits high definition imaging and clear visualization of microvascular capillaries that are difficult to view with current imaging methods. Finally, Automatic quantification of vessel density may be useful in monitoring diseases such as diabetes and glaucoma (Jia et al., 2012).

LIMITATIONS:

- limitations referred to patient:

Ocular: Because OCTA images are derived from OCT data, any media opacity that blocks light from reaching the retina will cause the OCTA image to appear dark. Media opacities include cataracts, floaters, and even dry eyes.

General: OCTA examination is motion-sensitive and requires patient cooperation, which may be difficult in visually impaired patients. -limitations in the machine: Projection artifacts are resulting from fluctuating shadows by blood flow in superficial blood vessels of the retina onto deeper layers. These artifacts will have the same vessel pattern as the superficial layer. Projection artifacts typi-cally occur in reflective retinal layers, which appear bright on the structural B-scan, most strongly in the retinal pigment epithelium (RPE) (Spaide et al., 2015). When evaluating deeper retinal layers, it is important to rule out projection artifacts. Currently, OCTA software has post-processing methods to reduce or eliminate these artifacts (projection-resolving algorithm OCTA-PRA). (Jia et al., 2012).

Another one is segmentation errors which can be a source of artifacts. To avoid that in some cases it is important to manually edit layers for a correct interpretation (Chen et al., 2016). Due to the fast scanning speed of OCT (7000 scan /sec), any flow that is slower than the detection threshold of OCTA will not be shown and will appear dark. Examples of areas with slow flow include intraretinal fluid, some micro-aneurysms, and hemorrhages. However, many of these areas can be visualized on the B-scan (Ishibazawa et al., 2015). As OCT-A detects "motion", and thus very low amounts of blood flow near the device threshold may be undetected (Kuehlewein, et al., 2015). Finally, imaging the peripheral retina is important in many cases, for both diagnosis and treatment. As such, the limited area of visualization of OCTA ($3mm^2$ to $12mm^2$) is a current limitation (De Oliveira et al., 2017).

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