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Optical Coherence Tomography Angiography (OCTA) in Ophthalmology; Technology, Pros, Cons and Commercial Prototypes

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Abstract

The OCTA is a novel evolving imaging technology which utilizes motion contrast to visualize retinal and choroidal vessels. It showed promises to be used in predicting, grading, guiding and following treatment of important ocular vascular diseases. The main advantages of the OCTA are being non-invasive; being blue light and dye free and providing high quality images in a relatively short time. It has alleviated important limitations of Fluorescein Angiography (FA), but still it is not considered as a complete substitute of FA, by experts. The Combined FA/ICGA and OCTA imaging systems are introduced to the market. It may have the advantages of the both systems, while having the least limitations. Resolution of images, field of view, depth of images and scan speed are important factors when choosing a device. But one should also take into account that higher image quality needs more time to be acquisitioned. It could be challenging in busy clinics. In this article we compared FA and OCTA and also compared widely available commercial prototype of OCTA devices.

Introduction

Optical Coherence Tomography Angiography (OCTA) is a novel imaging technology which has considerable advantages over older angiograms token by Fluorescein Angiography (FA) or Indocyanine Green Angiogarphy (ICGA). On top of them, one may list advantages like being non-invasive; no needs for dye; high resolution simultaneous visualization of the both retinal and choroidal vasculatures; simultaneous 3 dimensional (3D) visualization of retinal and choroidal structure; and possibility of segmentation of retinal layers and capillary plexuses in 3 layers including Superficial (SCP), Middle (MCP) and Deep (DCP) [1]. One of the promising features of this technology is that beside qualitative data, it provides quantitative data regarding retinal and choroidal structural and vascular indices like Vascular Density (VD), Foveal Avascular Zone (FAZ), etc. Feasible Quantitative data provided by OCTA; may revolutionize current ophthalmic practice in regards of predicting [2,3], grading [4,5], following up treatment in patients with important vascular diseases like diabetic retinopathy, retinal vein obstruction, choroidal neovascularization, etc. [6-10]. However, currently the quantitative data are mostly used for researches, But it seems that in the future when some cut off points are available by large scale studies. Then, these data could be used for everyday clinical practices. For an instance, quantitative assessment of Foveal Avascular Zone (FAZ) could be useful in optimal selection of therapy in patients with Diabetic Macular Edema (DME) [11] or even grading the severity of Diabetic Retinopathy (DR) [5,12]. It has also shown that FAZ metrics could change in response to treatment [6] so it could be used in following up patients. But a recent study has challenged these changes [13]. It should be emphasized that FA could also provide data regarding FAZ, but OCTA is more reliable, precise and also much more feasible. In FA, frequently dye leakage or DCP and SCP overlaps may influence the FAZ measurement [14]. Hereby, the OCTA technology, advantages, disadvantages and some commercial prototypes are discussed.

Optical Coherence Tomography Angiography Technology

The principal of this imaging system is detecting motion contrasts. This device record and compare multiple fast B-Scans of each vascular layer of retina. It simply presumes that the only motion inside retina is related to red blood cells (RBC) within vasculatures. These decorrelation signals are mapped in an OCT angiogram. Lastly, OCT B-Scan and OCT angiogram join together to visualize the both histological and vascular structures at the same time [15].

Optical Coherence Tomography Angiography vs. Fluorescein Angiography

Currently, FA and ICGA are gold standard in assessment of retinal and choroidal vasculatures. But the FA has considerable shortages like being invasive; being dye dependent; putting patients at possible dye mortal side effects (however, rare); clinical contraindications of dye; putting retina at risk of blue light toxicity; relative long picture acquisition time (some 15 minutes); disability in assessing deeper retinal or choroidal layers; disability in providing 3D pictures, disability in providing structural details of retina and choroid; and not providing quantitative data. It seems that OCTA has alleviated all above FA's limitations. However, as any other device, it has inherited some technical limitations [16,17]. One may count: more limited field of view; not providing functional data regarding vessels like not showing leakages; being more sensitive to small eye movements; needs for more patients' cooperation and ability to maintain proper fixation [18]. This later may make the acquisition time in real practice much longer than official announcements by manufacturers. Different commercial devices utilize various technologies to improve quality of picture by reducing motion artifacts [19]; through special algorithms (amplitude decorrelation algorithm, OCT-based or optical microangiography (OMAG) [20], split-spectrum amplitude decorrelation angiography (SSADA), etc.) [21]; and also improving the field and depth of pictures [22]. In this technology, we encounter day to day evolution of imaging system in terms of eye tracking systems; speed of picture acquisition; artifact reduction solutions [23]; field and depth of images [22]. Table 1 compares FA and OCTA. The invention of the combined imaging systems which provide a hybrid FA/ICGA and OCTA images may have the least limitations.

Table 1: Optical coherence tomography angiography and fluorescein angiography comparison

Features	OCTA	FA
Invasiveness	No	Yes
Dye dependence	No	Yes
Fluorescein side effect	No	Yes
Blue light toxicity possibility	No	Yes
Image dimensions	3 Dimensional	2 Dimensional
Field of view (at most)	12×12mm	Wider field is available
Acquisition time [28]	<5 minute	15 minute
Time sequence of circulation events (important in delays or fast wash out)	NO	Yes
Segmentation of layers	Yes	No
Functional data like vascular leakage	No	Yes
Qualitative and quantitative assessment of FAZ [29]	Affected by shadows from hemorrhage and macular edema	Affected by leakages and overlaps
Distinguishing IRMA from neovascular tufts [30]	Yes	No
Detecting Veins from arteries [31]	Not directly	Yes
Direct visualization of depth of lesions	Yes	No
Feasible measurement of vascular lesions like CNV	Yes	No

FA: Fluorescein Angiography; FAZ: Foveal Avascular Zone; OCTA: Optical Coherence.

Tomography Angiography; IRMA: Intraretinal Microvascular Abnormalities

Is it possible to Upgrade SD-OCT Devices to OCTA Device?

The SD-OCT devices can do 26 to 40 thousands scans per seconds while commercial OCTA's scan speed is some two-fold of this. The resolution of images (indirectly, as resolution is dependent on number of scan per section which is limited by fixed scan speed and acquisition time) and their sensitivity to motion artifacts is particularly dependent on this. So the SD-OCT can not be utilized to obtain angiogram as images would be small and clinically useless. Fortunately, some manufacturers supplied their previous SD-OCT users with a two-step SD-OCT to OCTA upgrade. Firstly, they upgrade the hardware of device to higher frequency scan device, then they install OCTA software module on the device.

Commercial Prototypes Comparison

Most commonly used device in clinical centers, is AngioVue (Opto Vue, Inc., Fremont, Calif., USA) [10]. Recently, Heidelberg

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Engineering has released its OCTA modules. AngioPlex (Zeiss Meditec, Inc., Dublin, Calif., USA) is also an other widely available device in market. Table 2 compare features of these brands, provided by their manufacturer.

Table 2: Comparison of widely commercially available optical coherence tomography angiography devices.

Features	Heidelberg, Spectralis® OCTA	Optovue, AngioVue™	ZEISS, Angio Plex™
Scan speed (per second)	85,000	70,000	68,000
Field	Up to 55 (16mm)	8×8mm	6×6mm
Depth of imaging (mm)	1.8	3	2
Acquisition time (seconds)	Not available	3	3
Axial resolution (micron)	3.9	5	5
Transverse resolution (micron)	14	15	15
Image resolution (pixels)	512×512	304×304	304×304
Focus range	-12 to+12	-15 to+20	-20 to+20
Combination with FA/ICGA	Possible	No	No
Tracking system	True-Track™	Real time tracking	Fast Track™
Algorithm	amplitude decorrelation algorithm	SSADA	OMAG

All the values are retrived from official websites of manufacturers.

While choosing a device one should consider following issues. The higher the scan speed is, the lower the effect of motion artifact would be. And also the resolution of images depends on number of scans per section. As the scan speed and scan acquisition time are limited, so it should be taken in to account that the high resolution of image translate to more acquisition time which is challenging in busy clinics. It is the reason why some manufacturer has not announced their device acquisition time, officially. And also some have reduced their image quality. As the OCTA is not substitute of FA in expert opinions; and also it is considerably expensive technology; moreover, many clinics has physical space limitation; so devices that provide hybrid FA/ICGA and OCTA, could be an all-in-one reasonable option.

Future of Optical Coherence Tomography Angiography

Currently, the clinical use of OCTA is limited by its' expensiveness; small field of imaging; slow acquisition time; quality of images; lack of cut off points for quantitative data; lack of defined clinical significance of enormous data provided.

While developers are trying to invent faster swept source devices; smarter eye tracking systems; and also reducing artifacts that could provide wider higher quality views in matter of seconds, clinicians should utilize massive data provided by this technology in their everyday clinical practice by investigating the clinical relevance of findings. As we are on the edge of new robotic era, there are promises that images of retina could be efficiently processed by computers to diagnosis and grade diseases [24] and also conjunction of surgical or laser devices with imaging system could revolutionize both the diagnosis and treatment of ocular diseases [25-31].

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