

Optical coherence tomography angiography in chorioretinal disorders

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ABSTRACT • RÉSUMÉ

Optical coherence tomography angiography (OCTA) is a novel imaging modality that incorporates blood motion contrast to create angiograms of the retinal vasculature in a noninvasive manner, without the use of dye. It is a safe procedure and can be repeated as frequently as desired. The use of OCTA for delineation of choroidal neovascular membranes, for the study of microvascular abnormalities in diabetic patients, to assess nonperfused areas in retinal occlusions and vascular changes in macular telangiectasia are some of the potential OCTA applications. However, it is not free of drawbacks. Major limitations include the small field of view and its great sensitivity to movement. As a result, it is prone to motion artifacts, leading to poor-quality images. The scope of the body literature regarding this new modality rapidly increases as we learn how to better use this technology. Our objective is to point overall aspects of OCTA, including its limitations and review some of its initial reports on chorioretinal diseases.

L'angiographie par cohérence optique (ACTO) est une nouvelle technique d'imagerie qui utilise le contraste du mouvement sanguin pour créer des angiogrammes du système vasculaire rétinien de manière non invasive, sans injection de produit colorant. C'est une intervention sûre qui peut être répétée aussi souvent que désiré. La délimitation des membranes néovasculaires choroïdiennes, l'étude des anomalies microvasculaires chez les patients diabétiques afin d'évaluer les zones de non-perfusion dans les cas d'occlusion rétinienne et les changements vasculaires dans les cas de télangiectasie maculaire sont quelques-unes des applications potentielles de l'ACTO. Cependant, cette technique n'est pas sans inconvénients. Les principales limites incluent le petit champ de vision et sa grande sensibilité au mouvement. Par conséquent, l'ACTO est sujette à des artefacts de mouvement se traduisant par des images de mauvaise qualité. La portée du corpus de littérature en ce qui concerne cette nouvelle modalité augmente rapidement à mesure que nous apprenons à mieux utiliser cette technologie. Notre objectif est de souligner les aspects généraux de l'ACTO, y compris ses limites, et de revoir certains de ses rapports initiaux sur les maladies choriorétiniennes.

In 1961 Novotny and Alvis published the first article on retinal fluorescein angiography (FA) in human subjects.¹ Since then, the study of retinal diseases changed from predominantly histological information to clinical assessment.² Fifty-four years later, FA remains the gold-standard examination for evaluating vascular retinal disorders.³ The procedure can provide dynamic information about the retinal anatomy and conclusions are made considering the pattern of dye distribution along the vessels, intraretinal, subretinal and choroidal spaces. However, it is a time-consuming, invasive procedure, with risk of adverse reactions, ranging from nausea to anaphylaxis.⁴⁻⁶

A new imaging modality, optical coherence tomography (OCT) angiography (OCTA), has arrived and provides the dyeless study of the chorioretinal vasculature. This is a fast, safe, noninvasive procedure to assess the chorioretinal vessels in real time and could be repeated as frequently as desired. The number of studies regarding this novel modality increases as we learn how to better use this technology.

HOW DOES IT WORK?

OCTA works by measuring the differences in the signal intensity (amplitude) between sequential OCT B-scans

from a determined area. Although static tissue will show only little changes, moving structures, such as blood cells, will present variations from one image to another, acting as blood motion contrast and generating fundus angiograms.

Another method for detecting blood motion, as mentioned by Spaide et al.,⁷ is called "phase variance," which captures variations in the phase of the reflected light waves under successive acquired B-scans. Blood cells may produce a higher variation over time, which differs from less-mobile regions. The combination of the 2 methods (amplitude and phase variance) may help to better characterize flow, although studies are still needed to confirm this concept.^{7,8}

For the purposes of this review, the figure examples along the article are from the AngioVue software of the RTVue XR Avanti spectral-domain OCT (Optovue, Fremont, California, USA). It uses a split-spectrum amplitude decorrelation angiography (SSADA) algorithm, which detects blood motion contrast by comparing the reflected OCT signal amplitude between consecutive cross-sectional B-scans at the exactly same place.⁹⁻¹³ The system operates at 70,000 A-scans per second to obtain OCTA volumes of 304 × 304 A-scans in approximately

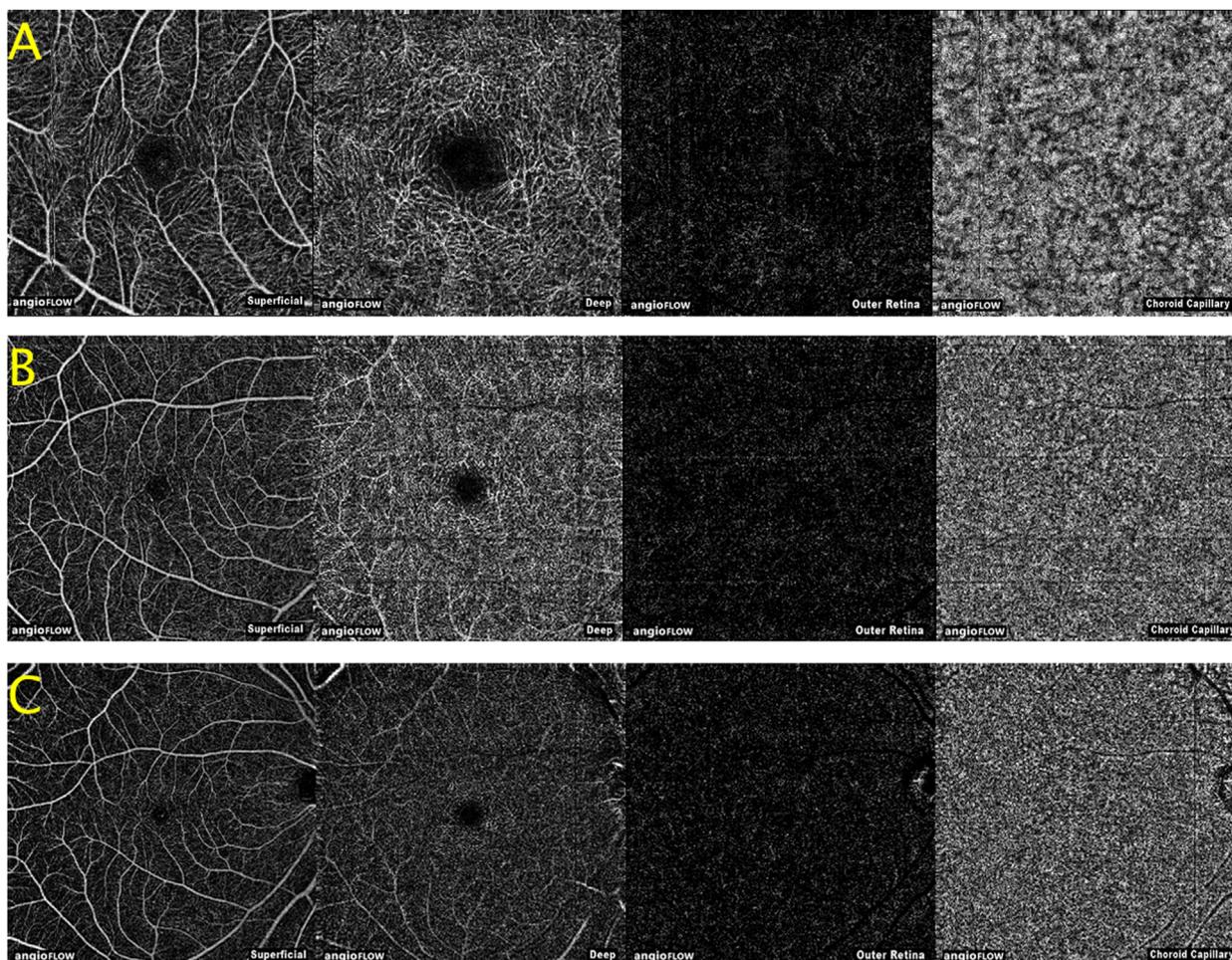


Fig. 1—Angioflow images of a 32-year-old healthy male patient, centred at the macula, showing the 4 “slabs” (from left to right: superficial plexus, deep plexus, outer retina, and choriocapillaris) in 3 different fields of view: 3 × 3 mm (A), 6 × 6 mm (B), and 8 × 8 mm (C). Notice that because the number of scans taken is always the same, as the field of view increases the resolution of the images decreases.

2.6 seconds, with a light source of 840 nm wavelength, resulting in a cube. The cube is then divided into 4 angioflow slabs, representing different segments of the retina: the superficial vascular plexus, the deep vascular plexus, the outer retina and the choriocapillaris. The superficial plexus corresponds to the vessels normally seen in a routine FA examination, present in the ganglion cell layer and in the retinal nerve fiber layer. The deep vascular plexus presents the vascular network right below the superficial layer, consisting of 2 plexuses located on the inside of the nuclear layer and on the outside of the outer plexiform layer.¹⁴ This deep plexus was not previously appreciated in FA examinations and, as described by Bonnin et al.,¹⁵ consists of a radial convergence of capillaries toward an epicentre in the OCTA examination. The outer retina normally does not contain vessels and the angioflow signal is absent. Finally, the choriocapillaris angioflow shows the superficial choroidal vasculature, below the Bruch’s membrane (BM). All of the slabs are evaluated en-face and autosegmented by the software. However, this autosegmentation may be manually

modified to evaluate different areas of interest. Furthermore, they can be correlated to the correspondent OCT B-scan image, allowing both functional and anatomical study at once.¹⁶ The currently available fields of view are 2 × 2 mm, 3 × 3 mm, 6 × 6 mm, and 8 × 8 mm (Fig. 1). Because the number of scans is the same, a gradual loss of resolution and details occurs when going from 2 × 2 mm to 8 × 8 mm.

OCTA IN CHOROIDAL NEOVASCULAR MEMBRANES

Choroidal neovascular membranes (CNVM) are characterized by the development of a neovascular complex that could originate from the choroidal space, breach into the BM, and extend between the BM and retinal pigment epithelium (type 1), or into the subretinal space, above the retinal pigment epithelium (type 2). The neovascular network could also be located in the intraretinal space, also known as retinal angiomatous proliferation (type 3).^{17–19}

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