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Optical Coherence Tomography Angiography

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This issue of the journal *RETINA* is devoted to the use of optical coherence tomography (OCT) in creation of a new form of angiography, known as OCT angiography. Optical coherence tomography produces depth-resolved evaluation of the reflectance data from tissue. A three-dimensional volume of tissue being evaluated gives rise to a three-dimensional volume of information. Optical coherence tomography angiography visualizes vasculature using motion contrast. Stationary tissue produces a nearly constant reflection or scattering whereas moving tissue produces OCT signals that change over time. Optical coherence tomography information can be compared from one time instance to the next by repeatedly scanning the same region of tissue. Optical coherence tomography angiography operates under the basic assumption, which is an over simplification, that the only moving thing in the retina is blood flow. Pixels from individual areas in repeated OCT images are compared over time, and those pixels which show changes or fluctuations are displayed as bright, whereas pixels from areas with little or no change are displayed as black. There are many different algorithms or methods for detection motion contrast. Some involve using OCT signal amplitude, phase, or a combination of the two. There are also different statistical techniques for assessing changes. However, all of these methods essentially visualize vasculature by detecting motion.

This means that slow flows may not be detected, and flow sensitivity is limited by parasitic eye motion, scan intervals, processing techniques, and the threshold set for what is considered to be flow. Furthermore, since the same area of tissue must be scanned multiple times, OCT angiography has slower imaging speeds and more limited retinal coverage than structural OCT. On the positive side, OCT angiography has the advantage that there is no dye injection required. Imaging can be performed in situations when conventional angiography is not indicated, repeated on every patient visit, and dynamic changes can be assessed. Optical coherence tomography angiography cannot assess vascular permeability as one would with fluorescein or indocyanine green. Leakage as detected during angiography is a diffusion process, not a bulk flow phenomenon. The presence of leakage gives us physiologic information that is helpful in disease analysis. However, images obtained by OCT angiography are not obscured by leakage and therefore clearly show involved vessels. In addition, since OCT angiography is obtained from structural OCT data, it enables three-

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dimensional volumetric imaging of the retinal and choroidal vasculature. However, because of its inherent complexity, OCT angiography can have artifacts and requires careful interpretation.

The images produced from the inner plexus of retinal vessels are remarkably similar to those seen in early phases of fluorescein angiography. The retina also has a deeper plexus, which is not visualized in fluorescein angiography, but is seen readily in OCT angiography because specific vascular layers can be selected in the depth resolved OCT volume and because the presence of overlying vessels does not mask the underlying vessels. Fluorescein angiography formed the basis of medical retina, particularly with the landmark work of Gass. The framework established with fluorescein angiography provided many answers about disease processes, but left many questions as well. One possible explanation for this is that fluorescein angiography provides an incomplete view of the retinal perfusion as it does not show the deep vascular plexus. Thus, OCT angiography offers the opportunity to expand our knowledge of the physiology of the retina in health and disease.

Although it may seem to be a self-evident truth, OCT angiography actually is not a replacement for fluorescein angiography. By analogy, the car was not a replacement for the horse. Imagine a time in the late 19th century when an enterprising family used a horsedrawn cart in New York's Lower East Side to sell pickles. Fast forward to today, do the descendants of the original pickle seller now use a Tesla to pull the pickle cart around the Lower East Side? As automobiles became cheaper, the demand grew, in parallel, the desire to drive on paved roads led to the creation of many roads and highways, particularly after the National Interstate Highways Act in 1956, the largest public works project in the United States up to that time. Larger stores containing thousands of products developed in areas that required automobile travel for access. Along the way, fast-food restaurants popped up to sell fast food to teenagers in particular. This was the start of McDonald's and Burger King. People ate too much of that and other stuff, did not do enough exercise, and now are obese. Because people drive cars too much, there is excessive air pollution including carbon dioxide. To avoid carbon dioxide and to take advantage of subsidies, electric cars such as the Tesla line were developed. The transformation to society caused by automobiles would not have been possible with horses. So the car did not replace the horse. The car contributed to a transformation of our society, and in that new society, the horse is not relevant. In a similar fashion, OCT angiography is likely to transform our understanding of the retina in ways not possible or even foreseen with fluorescein angiography. Considering the opportunities involved, thinking that the future of OCT angiography will be a replacement for fluorescein angiography ignores many of the potentials of the new imaging modality. Optical coherence tomography angiography is in its early developmental stages, and this issue significantly expands the number of published articles using this imaging modality. The range and insight of the articles in this special issue is stunning, and foretells the future of OCT angiography. We are excited about the future of this imaging as it safe, fast, provides a great deal of interesting information, and it can be readily incorporated in clinical instruments.

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