High resolution retinal imaging

CHAPTER 14

IMPACT

This is a golden age in ophthalmic imaging since ophthalmology is among the most technology-driven medical specialities with major advances in imaging techniques, both in hardware and software. They have led to reduction in discomfort of invasive tests and more detailed ocular examination with high-quality images. This results in better understanding of the eye in health and pathology, prognosis and response to therapy. Furthermore, the eye being mostly optically transparent, acts as a window to the cardiovascular and nervous systems.

Right through my internship I felt drawn towards the field of ophthalmology and decided to major in it. During my residency, I met many patients with end stage diabetic retinopathy, advanced age-related macular degeneration and inherited retinal disorders. That is when I decided to work on understanding the pathophysiology of these diseases and finding ways for early diagnosis and timely interventions to prevent irreversible blindness.

While pursuing my fellowship, I was exposed to various imaging technologies, one of them being time domain optical coherence tomography (TD-OCT), which at that time, revolutionised the management of retinal diseases. The beauty of being able to see the individual layers of the in vivo retina was riveting. It changed the way we managed active choroidal neovascular membranes and diabetic macular oedema. Further, it coincided with the initiation of anti-vascular endothelial growth factor therapy. Advances in the technology of OCT led to the era of spectral domain SD-OCT and swept source OCT which resulted in new terminology for different layers being formulated.

It was 2012 when I attended the ARVO meeting at Fort Lauderdale, and, I first saw the adaptive optics (AO) technology and the work being done with it. By compensating for the aberrations caused by irregularities of the optics of the eye, resolution to the order of 2 μm could be achieved, thereby allowing, for the visualization of individual cone photoreceptors. Intrigued by this, we visited the Imagine eye office at Paris, France, and some of their users in Rome, Italy. We soon acquired the machine and started working with it. As we understood the clinical application and the possibilities of the machine, we wrote a review on it (Chapter 1). We then established a normative baseline for emmetropes (Chapter 2) and myopes (Chapter 3) in our clinic. As a clinician, our interest is always on the functional outcomes. Whether they are patients with maculopathy or retinal detachment, our aim is always to improve their vision through intervention. Hence establishing a structure-function correlation becomes vital. This was the basis of

our study (Chapter 4). We had an interesting patient with minimal clinical features, but adaptive optics and electrophysiology clinched the diagnosis of melanoma associated retinopathy and helped in assessing the extent of pathology (Chapter 5). This leads to the use of adaptive optics in many different diseases, like hydroxychloroquine toxicity, serpiginous choroiditis and inherited retinal disorders. A baseline image of the patient would be established and then subsequent scans done to show progression, if any, to either stop the toxic medicines or in cases of inherited retinal disorders, the patients were explained the progressive nature of the disease, the rate of progression and its possible implication with regard to lifestyles and rehabilitation.

We went on many international podiums like Asia ARVO, 2013, World Ophthalmic Congress, 2014, to organise special interest groups and presented at multiple national podiums. Since Narayana Nethralaya, Bangalore, was the first hospital in India to work with a commercially available adaptive optics machine, it became our responsibility to discuss results with all our Indian colleagues. There had been no literature published thus far from the Indian population and our work helped in the development of a normative database in emmetropic subjects. This now allows us to understand early pathology at the cellular level and intervene. Newer therapeutic modalities that are targeted at the cellular level like micro-pulse laser, stem cells, gene therapy etc. are also better monitored in terms of safety and efficacy. These therapies are designed to cause early and subtle changes in the photoreceptors as a response rather than showing any gross changes in the SD-OCT.

Optical coherence tomography angiography (OCTA) is a new non-invasive imaging technique that employs motion contrast imaging to high-resolution volumetric blood flow information generating ocular angiographic images in a matter of seconds. It helps understand the vascular pattern of the different layers in the eye. OCTA was used to study the architecture of the vascular tree in an isolated racemose angioma (Chapter 6). In the retina clinic, most patients with macular edema are either with diabetic retinopathy (Chapter 7) or post cataract surgery (Chapter 9). We started doing OCTA to understand the pathogenesis of why some patients develop it and some do not.

We analysed the vascular parameters and the foveal avascular zone in diabetics and realised the circularity gets affected initially. These may be the patients who later go on to develop macular edema. These subtle changes can be diagnosed early in the course of diabetes, followed-up closely, allowing early intervention. The response to antivascular endothelial growth factor treatment is variable in diabetic macular edema. Understanding the vascular biomarkers is critical to individualize the standard of care and predict the response to treatment.

OCTA scans have now become a standard baseline investigation for all patients with choroidal neovascular membranes. But we realized that automated segmentation was missing many of the membrane complexes unless it was manually corrected (Chapter 8). I am now a part of a group that collects and analyses data for machine learning with the help of AI, the machine itself decides when manual or automated segmentation is preferable.

This made me realise that the serious limitations of the current OCTA machines is in the analysis software. It is time consuming and varies with every OCTA machine. Hence, I am now working with my colleagues on analysis tools with quantitative indices that help in establishing a baseline in pathology.

The remarkable advances in ophthalmic imaging have transformed simple photographic documentation into powerful investigative methods enabling clinicians to make objective measurements and assessments of retinal structures in detail. The future would be to have a unified software platform with integrated investigations such that for every patient at a given retinal location, the cellular details (AO), tomography (SD OCT) and vascular details (OCTA) along with the functional tests of the retina (MAIA, electrophysiology) can be documented. This will give a holistic view of the retina and help in early detection and treatment of pathology.