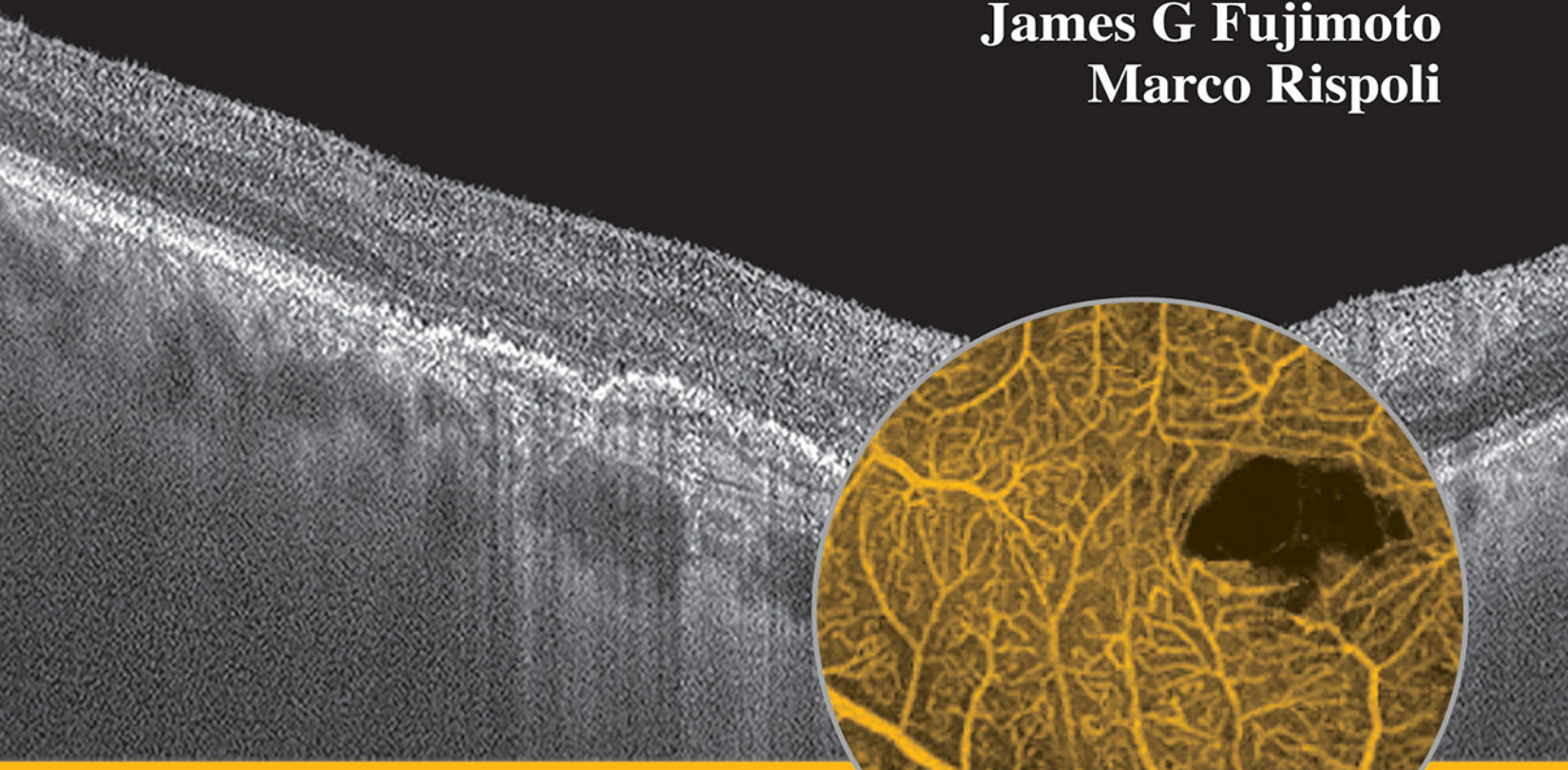
sit our website www.jaypeebrothers.com, for detailed information on ophthalmology books, visit our website www.jaypeebrothers.com

Bruno Lumbroso
David Huang
Yali Jia
James G Fujimoto
Marco Rispoli



Clinical Guide to Angio-OCT

Non Invasive, Dyeless OCT Angiography

Contents

1. Principles of Optical Coherence Tomography-Angiography **1**
Bruno Lumbroso, Marco Rispoli
Limitations of Optical Coherence Tomography-Angiography *2*
Limitations of Optical Coherence Tomography *2*
Retinal Fluorangiography and Optical Coherence Tomography-Angiography *3*

2. Optical Coherence Tomography-Angiography: New Clinical Terminology **5**
James G Fujimoto, Bruno Lumbroso, Marco Rispoli
Angio-OCT Clinical Terminology *5*

3. Split-Spectrum Amplitude-Decorrelation Angiography **8**
David Huang, Yali Jia

4. Solving the Practical Problems of Optical Coherence Tomography-Angiography **10**
Marco Rispoli, Bruno Lumbroso
Mistakes to be Avoided *10*

5. Optical Coherence Tomography-Angiography of a Normal Retina: The Anatomy of Blood Supply in the Retina **12**
Maria Cristina Savastano, Bruno Lumbroso, Marco Rispoli
Posterior Pole *12*
Macular Area *12*
Arteries and Retinal Veins *12*

6. Analysis and Synthesis: Analysis and Interpretation of a Pathological Optical Coherence Tomography-Angiography **16**
Bruno Lumbroso, Marco Rispoli
Analytic Steps *16*
Analysis of Neovascular Membranes *21*
Synthesis *22*

7.1 Clinical Applications: Aspects of OCT SSADA Angiography in Eye Disorders **23**
Bruno Lumbroso, Marco Rispoli, Maria Cristina Savastano, Adil El Maftouhi, Leonardo Mastropasqua, Luca Di Antonio, Giovanni Staurenghi
Age-Related Retinal Anomalies *23*
Retinal Anomalies and Coat's Disease *23*
Retinal Anomalies in Angiomatosis *24*
Retinal Superficial Anomalies in Macular Pucker *25*
Macroaneurysm *25*

Diabetic Patients without Retinopathy *30*
Branch Retinal Vein Occlusions *30*
Recent or Long-Lasting Retinal Ischemias *32*
Diabetic Retinopathy *35*
Proliferative Diabetic Retinopathy *45*
CNV: Neovascular Membranes in ARMD *47*
Neovascular Membranes in Myopic Eyes *48*
Idiopathic Polypoidal Choroidal Vasculopathy *49*
Geographic or Atrophic Macular Degeneration *59*
Optic Disk Disorders *59*

7.2 Clinical Applications: Optical Coherence Tomography-Angiography of Choroidal Neovascularization in Age-Related Macular Degeneration **60**
Yali Jia, David Huang

8. Optical Coherence Tomography-Angiography of Optic Disk and Peripapillary Retinal Perfusion in Glaucoma **64**
Yali Jia, David Huang

9. Fluorescein Angiography and Optical Coherence Tomography-Angiography: Advantages and Disadvantages **68**
Bruno Lumbroso, Marco Rispoli
General Fluorangiography Advantages *68*
General Fluorangiography Disadvantages *68*
Fluorangiography Imaging Advantages *68*
General Angio-OCT Disadvantages *69*
General Advantages of Angio-OCT Imaging *69*
Angio-OCT Imaging Advantages *69*
Angio-OCT Disadvantages *69*
Other Non Invasive Techniques *70*

10. Reporting an Optical Coherence Tomography-Angiography **71**
Marco Rispoli
Analytic Steps *71*
Case Reports *71*

11. Future Ultrahigh Speed Swept-Source OCT Technology and OCT-Angiography **75**
Nadia K Waheed, Woo Jhon Choi, Jay S Duker, James G Fujimoto
Swept-Source Optical Coherence Tomography for Ultrahigh Speeds *75*
Optical Coherence Tomography-Angiography *77*
Imaging the Choriocapillaris *77*
Optical Coherence Tomography-Angiography in Diabetes *79*
Optical Coherence Tomography-Angiography in Dry Age-Related Macular Degeneration *81*

Index *85*

CHAPTER

2

Optical Coherence Tomography-Angiography: New Clinical Terminology

James G Fujimoto, Bruno Lumbroso, Marco Rispoli

JAYPEE BROTHERS

INTRODUCTION

The first two generations optical coherence tomography (OCT), time-domain OCT and spectral domain OCT/Fourier-domain OCT, are structural OCT.

The third-generation OCT, OCT-angiography (Angio-OCT), is a functional OCT which will generate Angio-OCT. So the system we use in this handbook, XR-Avanti Optovue, is an Angio-OCT which uses the split-spectrum amplitude-decorrelation angiography (SSADA) algorithm to produce Angio-OCT. We have to use a new terminology to describe the techniques and the images that Angio-OCT offers. In the analytic description of an Angio-OCT report, both technical and clinical aspects must be taken into account.

ANGIO-OCT CLINICAL TERMINOLOGY

- Level (depth)
- Reflectance
- Flow, blood cell motion signal and decorrelation signal
- Morphology and architecture
- Texture

Level (Depth)

An essential element is the location of the Angio-OCT image and its relative depth in retina and choroid. The offset indicates level or depth. The segmentation levels are generally located at the inner limiting membrane (ILM), the inner plexiform layer (IPL) and the ideal pigmented epithelium [retinal pigment epithelium (RPE) ref section], or better still Bruch's membrane (BM).

While referencing to the exact level is easy for the healthy eye, in clinical practice the IPL is frequently deformed, thickened, or unrecognizable. The reference levels are usually the ILM, the ideal position of pigmented epithelium profile (RPEref), or BM.

Caution: Unambiguous interpretation of en-face OCT and Angio-OCT images at a given level may require a careful, comprehensive and global examination. Retinal pathology can cause displacement of retinal layers from their normal levels. In addition, when retinal pathology is present, image processing software errors, segmentation errors, can incorrectly identify reference retinal layers, so it may be necessary to manually correct the segmentation in order to use correct reference boundaries.

Correct interpretation may require examination of en-face images at multiple depth levels and cross-sectional images through the region of pathology in order to confirm clinical interpretation of an en-face image at a specific level.

Reflectance

Reflectance is the contrast for structural OCT. In structural OCT, tissue density is shown by variation in reflectance.

Flow, Blood Cell Motion Signal, and Decorrelation Signal

Flow or blood cell motion creates contrast in Angio-OCT, and this motion contrast is different from reflectance as seen in structural OCT. Motion contrast is measured by the decorrelation signal.

This is another new and fundamental concept in the description of Angio-OCT. Angio-OCT generates motion contrast by performing repeated B-scans at the same retinal position. Volumetric three-dimensional Angio-OCT data is then generated by performing many such repeated B-scans covering an area of the fundus. Angio-OCT requires larger numbers of B-scans than structural OCT, therefore the scan time is longer or retinal area imaged is smaller. The repeated B-scans are compared numerically and a decorrelation signal is calculated which shows how much structures change between the repeated B-scans. Flow or blood cell motion causes changes between B-scans, and the decorrelation signal measures this motion contrast.

Optical coherence tomography-angiography has the advantage that it can visualize blood vessels and blood flow which may be transverse or perpendicular to the OCT beam. Doppler OCT cannot visualize perpendicular blood flow.

Vascular decorrelation signal: Flow or blood cell motion generates a decorrelation signal which produces contrast and enables visualization of three-dimensional retinal and choroidal vasculature.

Nonvascular decorrelation signal: Decorrelation signals can be generated by structures which are not moving blood. There are conditions where the decorrelation signal shows nonvascular reflecting structures that are present in the corresponding en-face structural imaging, for instance, hard exudates, pigment accumulation, thrombosed aneurysms and retinal hemorrhages. The decorrelation signals are associated with pathology that has very fine or inhomogeneous internal structure, as in the examples described.

This may be the result of very small eye motions or OCT scanning changes which cause these small structures to change in repeated B-scan images and generate a decorrelation signal. Larger or more homogenous structures must move much more in order to generate a decorrelation signal.

Flow velocity and decorrelation signal: The decorrelation signal has a *limited dynamic range* response to flow. Therefore, one must be careful interpreting the decorrelation signal directly as a flow velocity.

There is a *sensitivity limit* for the slowest flow that can be detected which is determined by the time between repeated B-scans. If the time between B-scans is increased, then the decorrelation signal becomes more sensitive to slower flows. However, increasing the time between B-scans also means the decorrelation signal and OCT-angiogram becomes more sensitive to eye motion and has more noise.

There is also a *saturation limit* where the decorrelation signal cannot differentiate faster flows, because any flow which is faster will produce the same decorrelation signal. This means that the decorrelation signal does not respond to changing flow velocity above this *saturation limit*.

For larger vessels, the flows are always fast and generate the same decorrelation signal or OCT angiogram. In other words, the flow is faster than the *saturation limit* and decorrelation signal is saturated.

However, for small vessels such as capillaries or the choriocapillaris, the flow may be too slow and below the *sensitivity limit*. The small vessel with slow flow may not generate a decorrelation signal and may be invisible on the OCT-angiogram, even though the vessel is present.

Therefore, if vascular features are not visible on Angio-OCT, it may mean that there is dropout or atrophy of the vasculature or reduced/impaired flow.

Morphology and Network Architecture

Shape and course of the vessels of the vascular networks: Vessel shape and vessel course are two other parameters to be assessed in Angio-OCT. Shape may be regular or irregular, while course may be regularly winding, stretched out, distorted and contorted. These features may coexist in various combinations in the various pathological presentations.

We should study vascular networks in Angio-OCT separately according to retinal layers.

A very important feature not detectable in traditional angiography is the presence of normal anastomoses between superficial vascular plexus and deep vascular plexus, defined as connections. There may also be anomalous pathological connections between superficial plexus and deep vascular plexus: we define them as shunts.

When studying the architecture, we evaluate the shape of the vessels that may be regular or irregular, and the density of the capillaries that may be sparse or dense. The cross-section of the capillaries shows their diameter that may be thin, large, regular or irregular. The architecture of the vascular network may be regular or irregular.

JAYPEE BROTHERS

Architecture and Density of the Network

The *architecture* of the Angio-OCT in each retinal layer is assessed separately.

The caliber of the vessels is evaluated. It may be large or thin, irregular, and with or without dilatations.

The vascular network may be dense, sparse, widened, dilated, rarefied, weak, dense and tangled. The mesh may be sharp, distinct or indistinct.

Texture

Texture is a new concept in the description of Angio-OCT. Texture may be coarse, granulated, fine, faint, speckled and grayish. Texture is a very interesting concept. However, we should be careful assessing, because texture can change with image averaging. For example, fine texture in retinal layers changes depending on the amount of image averaging. Coarse texture is less sensitive to averaging effects. Since different softwares or instruments in the future may use different amounts of averaging, texture should be defined so that it works with future instruments (i.e. use features that are not so sensitive to image averaging).

- *Ischemia* shows a total disappearance of the capillaries, the area has a grayish aspect and the texture is more or less fine or finely granulated. The density of the collateral branches depends on the extent of the ischemia. Connections (shunts) between the retinal vascular superficial and deep plexuses are almost invisible in normal conditions. They are instead, extremely frequent and evident in the vascular pathology of the retina.
- *Edema* texture is a grayish area related to the widening of the vascular network meshes and rarefaction of the finer capillaries.

The texture should be assessed layer-by-layer and is related to the presence or absence of the vascular plexus that may be altered or absent.

Optical Coherence Tomography-angiography Terminology for Neovascular Membranes

Location (depth, offset): Location is the first point that needs to process because it is necessary to pinpoint the position of the neovascular membrane in the preretinal, intraretinal or subretinal, macular, or parapapillary context. It needs to be located with respect to BM. Age-related macular degeneration: in this disorder new vessels are detected mainly just below the pigmented epithelium, above BM (type I) and in fewer cases above RPE (type II).

Profile: The next step is assessing the profile of the membrane in order to decide on the best segmentation. The correct segmentation of a neovascular membrane does not always coincide with a correct segmentation of the surrounding retina.

Segmentation thickness: It is a necessary feature for assessing the planes of the neovascular membrane. The new vessels may vary considerably in thickness because they develop in a random manner and not within the normal retinal layers.

The *thickness of the segmentation* is of great importance in relation to the average size of the new vessels. If the new vessels are rather thin, a thick segmentation could produce a confused image of the flows on several planes. If the new vessels are rather thick, a thin segmentation will produce a wrong image of the choroidal neovascularization (CNV) flows.

Choroidal neovascularization morphology: In naïve patients, new vessels appear in the form of branched structures with evidence of a main afferent trunk, or they may have a roundish aspect, like a bicycle wheel. Peripheral anastomoses are evident, and they constitute an important parameter to check in the follow up.

These flows have a clear and evident aspect, and it is possible to follow the course of the main and secondary branches. The neovascular membranes flow appears to be more evident than normal adjacent flows.

In case of neovascular membranes treated with anti-vascular endothelial growth factor (VEGF), CNV network appears smaller, with less anastomoses, but above all, after treatment the changes in the flow produce a *fragmented* aspect of the network. It is disaggregated, making it difficult to follow the smaller branches course. The secondary branches decrease or disappear immediately after injection and reappear after 2 or 3 weeks.

JAYPEE BROTHERS

detailed information on ophthalmology books, visit our website www.jaypeebrothers.com, for detailed information on ophthalmology bo

Clinical Guide to Angio-OCT

Non Invasive, Dyeless OCT Angiography

Angio-OCT (Dyeless OCT Angiography) is a new technology that gives already useful results, that can be applied to day-to-day clinical ophthalmology. Several different OCT Angiography prototypes are developing, but only XR-Avanti Optovue with split-spectrum amplitude-decorrelation angiography (SSADA) algorithm is available clinically. Dyeless OCT Angiography is fast, easy, non invasive.

The aim of *Clinical Guide to Angio-OCT (Non Invasive, Dyeless OCT Angiography)* is to show everyday OCT user the clinical utility of OCT angiography. David Huang and Yali Jia present the SSADA algorithm and its applications in choroidal neovascularization (CNV), optic disk disorders and glaucoma. James G Fujimoto and Bruno Lumbroso propose the new terminology necessary to study this new technology. Clinical ophthalmologists, technicians and optometrists will find an OCT angiography atlas of the general syndromes and clinical signs. Then we present technological or scientific Angio-OCT progresses and its clinical applications.

The book discusses the clinical possibilities of OCT Angiography. It will guide the basic ophthalmologists or technicians to understand the new imaging typical and atypical aspects. The book will support to develop interest in using Angio-OCT in normal clinical work, to show Angio-OCT users the practical clinical interest in everyday ophthalmology, help users in understanding Angio-OCT. Most imaging (77 figures) has been performed with XR-Avanti Optovue SD-OCT device using SSADA algorithm.



Bruno Lumbroso MD is the Director, Centro Oftalmologico Mediterraneo for Retinal Diseases, Rome, Italy. He has been the Head and Director, Department of Ophthalmology, Rome Eye Hospital and Professor, Libero Docente of Clinical Ophthalmology in the University of Rome La Sapienza for more than 35 years and General Secretary of the Italian Laser Society. He has written handbooks on Retinal Imaging in Fluorescein Angiography, Indocyanine Green Angiography, Microperimetry, Time Domain OCT, Spectral Domain OCT, and En Face OCT. His main interests are in logical methods of retinal imaging analysis and interpretation, and in clinical applications of OCT technology for retinal disorders.



David Huang MD PhD is Professor, Department of Ophthalmology, Casey Eye Institute, Oregon Health and Science University, Portland, Oregon, USA. He co-invented OCT when he was a PhD student with Professor James G Fujimoto at the Massachusetts Institute of Technology, Cambridge, USA. He heads the Center for Ophthalmic Optic and Lasers, a group that pioneered corneal and anterior segment OCT and developed the split-spectrum amplitude-decorrelation angiography (SSADA) algorithm for OCT angiography. He led the Advanced Imaging for Glaucoma Bioengineering Partnership which developed OCT ganglion cell complex mapping and retinal blood flow measurement. He is a recipient of the Champalimaud Vision Award and the Association for Research in Vision and Ophthalmology (ARVO) Friedenwald Award.



Yali Jia PhD is Research Assistant Professor, Department of Ophthalmology, Casey Eye Institute, Oregon Health and Science University, Portland, Oregon, USA. She was involved in the development of optical micro-angiography during her doctoral studies. Recently, she worked with Dr David Huang and developed a new OCT angiography algorithm—split-spectrum amplitude-decorrelation angiography (SSADA). Now she has become focused on the improvement of SSADA and its clinical applications in patients with microvascular abnormalities.



James G Fujimoto PhD is Elihu Thomson Professor of Electrical Engineering and Computer Science, Massachusetts Institute of Technology, Cambridge, USA. His group and collaborators are responsible for the invention and development of OCT. He is a Member of the National Academy of Sciences, National Academy of Engineering and American Academy of Arts and Sciences, USA.



Marco Rispoli MD is Staff Ophthalmologist, Department of Ophthalmology, Ospedale Nuovo Regina Margherita, and Centro Oftalmologico Mediterraneo for Retinal Diseases, Rome, Italy. He is interested in developing ocular imaging. He has written handbooks on Retinal Imaging Interpretation of Time Domain OCT, Spectral Domain OCT and En Face OCT.

JAYPEE PROOFS

Available at all medical book stores
or buy directly from Jaypee Brothers through online shopping
at www.jaypeebrothers.com

JAYPEE BROTHERS
Medical Publishers (P) Ltd.
www.jaypeebrothers.com

Join us on facebook.com/jaypeebrothers

Shelving Recommendation
OPHTHALMOLOGY

ISBN 978-93-5152-399-4