Intraoperative OCT and Vitreoretinal Surgery

This technology has the potential to improve clinical outcomes and enhance understanding of the pathophysiology of a wide variety of surgical vitreoretinal diseases.

BY JUSTIS P. EHLERS, MD

Intraoperative optical coherence tomography (OCT) is an emerging diagnostic imaging modality with significant potential to benefit surgeons and patients undergoing vitreoretinal surgery. The initial report of intraoperative SD-OCT came from clinicians at Duke University, led by Cynthia Toth, MD, who performed intraoperative imaging using a handheld spectral-domain OCT (SD-OCT) system (Bioptigen Spectral Domain Ophthalmic Imaging System; Bioptigen, Inc., Research Triangle Park, NC).1,2 Sunil Srivastava, MD, first reported utilizing a microscope-mounted handheld system to enhance image acquisition through improved stability and control of the device.3 Currently, at the Cole Eye Institute, we use two different prototype microscope mount systems (Figure 1). The first (Figure 1A) fixes the handheld system to the objective lens of the microscope and allows the surgeon to use an undraped microscope. The second (Figure 1B) utilizes a modified plate to position the OCT probe to the side of the scope, allowing complete draping of the entire system.

CROSS-SECTIONAL ANATOMIC INFORMATION

The high-resolution cross-sectional anatomic information obtained from SD-OCT is a perfect complement to the 3D aspects of vitreoretinal surgery. It provides detailed anatomic views from a cross-sectional perspective that are not possible intraoperatively through the microscope. Utilizing this information, intraoperative OCT may further our understanding of vitreoretinal pathophysiology, assist in surgical decision-making, refine surgical techniques, and improve patient outcomes.

IMPROVED UNDERSTANDING OF PATHOPHYSIOLOGY

Numerous gaps exist in our understanding of the pathophysiology of many vitreoretinal diseases. For example, the source of fluid for optic pit-related maculopathy has been largely unknown. It is also unclear whether a connection exists across the optic pit between the vitreous cavity and the intraretinal fluid. Multiple surgical techniques have been suggested with varying levels of success. Intraoperative OCT has allowed a new level of understanding of the pathophysiology of optic pit-related maculopathy. During vitrectomy, an air-fluid exchange was performed with prolonged aspiration over the area of the optic pit. Intraoperative OCT during the vitrectomy showed significant collapse of the area of fluid adjacent to the optic pit, strongly suggesting a connection.
between the vitreous cavity and the intraretinal space.\(^4\) Twenty-four hours following surgery, the distribution of the intraretinal fluid had shifted to a new equilibrium. Without intraoperative OCT, the direct effect of aspiration would not have been appreciated.

**Figure 2.** Intraoperative OCT of full-thickness macular hole prior to internal limiting membrane peeling. Small area of subretinal hyporeflectivity (red arrows; A). Intraoperative OCT following internal limiting membrane removal with architectural alterations including increased height (white arrow) and increased width (blue arrow) of subretinal hyporeflectivity (B). Optimized postoperative day 1 OCT through gas bubble showing closed macular hole (C).

**UNCOVERING NEW FINDINGS**

Intraoperative OCT can also change our impression of the effects of our surgical maneuvers on the microarchitecture of the retina and surrounding tissues. In epiretinal membrane (ERM) and macular hole surgery, increased subretinal hyporeflectivity has been noted following surgical intervention using intraoperative OCT.\(^{3,5}\) Progressive increases in subretinal hyporeflectivity have been noted following peeling of successive layers (eg, ERM and internal limiting membrane [ILM]). The significance of this finding for visual outcomes is unclear. The possibility exists that this may represent photoreceptor trauma, and

**Figure 3.** Intraoperative OCT of bullous macula-involving retinal detachment (red arrow; A). Intraoperative OCT during retinal detachment repair following perfluorocarbon liquid tamponade showing subclinical persistent subretinal fluid (blue arrow; B) and perfluorocarbon liquid interface (yellow arrow; B).
refinement of surgical techniques to minimize this disruption may improve visual outcomes.

Visual recovery following macula-involving retinal detachments (RD) is difficult to predict. Intraoperative OCT during RD repair has shown numerous novel findings, including persistent subclinical subretinal fluid and significant alterations to the foveal architecture. Intraoperative OCT findings such as height of residual fluid following drainage and repair may prove useful in prognosticating visual recovery.

Case Sample: Full-thickness Macular Hole

Figure 2 documents intraoperative OCT findings during macular hole surgery. A small area of subretinal hyporeflectivity is noted prior to peeling the ILM. After ILM removal, intraoperative OCT reveals architectural alterations including increased height and increased width of subretinal hyporeflectivity. One day following surgery, OCT optimized through gas, shows that the macular hole has already closed.

INTRAOPERATIVE FEEDBACK FOLLOWING SURGICAL MANEUVERS

Intraoperative OCT can be particularly helpful in providing immediate feedback to surgeons following surgical manipulations. In complex cases, such as tractional retinal detachments and proliferative diabetic retinopathy, it can be difficult to determine whether complete membrane removal has been achieved. Following ERM surgery, intraoperative OCT can provide high-resolution visualization of any residual membranes and help to identify whether the traction has been relieved. This immediate feedback can help to minimize unnecessary surgical maneuvers if total removal has been accomplished, improving surgical feedback. Additionally, if subclinical residual membranes are present, intraoperative OCT may reduce the need for additional surgery by allowing additional removal during the initial procedure.

Case Sample: ERM Removal

Intraoperative OCT during vitrectomy for ERM removal identifies inner retinal striae with a prominent ERM (Figure 4). The posterior hyaloid can be seen above the retinal surface. After core vitrectomy and combined ERM/ILM peeling, intraoperative OCT confirms complete membrane removal except for a minimal extrafoveal membrane noted nasally.

Case Sample: Proliferative Diabetic Retinopathy with Posterior Hyaloidal Traction

Membrane removal and hyaloid elevation can be complex in proliferative diabetic retinopathy. In this case, preoperatively there appeared to be posterior hyaloidal traction with an underlying ERM (Figure 5). During the surgical procedure, as the hyaloid was...
elevated there appeared to be significant vitreoschisis. Following elevation of the hyaloid, intraoperative OCT confirmed complete removal of all membranes confirming vitreoschisis without an underlying ERM. Utilizing intraoperative OCT, additional membrane peeling was minimized by confirming complete removal prior to additional maneuvers.

**TIME WILL TELL**

Intraoperative OCT is still in its infancy, and current systems have significant limitations. Handheld or modified tabletop units require the surgical procedure to be stopped, resulting in time delays. Additionally, this prevents true real-time evaluation of surgical maneuvers. True microscope integration of the OCT device is needed to provide a seamless system for real-time intraoperative OCT. At Duke University, Dr. Toth has developed a microscope-integrated prototype. This system allows simultaneous surgical maneuvers and OCT scanning. Additionally, Susanne Binder, MD, along with colleagues in Vienna, has described a microscope-integrated Cirrus OCT (Carl Zeiss Meditec, Germany) prototype for intraoperative use.

Significant advances are needed in multiple areas to bring OCT into mainstream use in the OR. Surgical instrumentation will need refinements to achieve OCT compatibility. Metallic instruments result in severe shadowing and limited visualization during intraoperative maneuvers. We are currently testing numerous materials to identify those compatible with OCT visualization. Simultaneous display of OCT imaging and the surgical field are necessary for successful integration. Rapid aiming mechanisms to guide the OCT to the area of interest will be needed to optimize efficiency during intraoperative use. Advances in software analysis packages are needed to provide real-time analysis of OCT data to give key data to the surgeon without information overload.

In the past few years, significant progress has been made in the field of intraoperative OCT. Although numerous hurdles remain, the future is promising for true integration of OCT into the art of vitreoretinal surgery. In clinical practice, OCT has revealed things we never expected and has allowed us to be better physicians. With the anatomic information OCT provides, this technology is a natural complement to the OR and will hopefully allow us to become better surgeons as well.

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**Figure 5. Intraoperative OCT of posterior hyaloidal traction with appearance of partially separated posterior hyaloid (blue arrow) and underlying epiretinal membrane (red arrow; A and B). Intraoperative OCT following posterior hyaloid elevation without membrane peeling (C and D). Intraoperative OCT identifies complete removal of membranes (yellow arrow; C and D) following hyaloid elevation confirming vitreoschisis and limiting unnecessary additional membrane peeling procedures.**