Intraoperative OCT: How Might it Impact Patient Care?

Ongoing research promises to expand the utility and functionality of intraoperative OCT.

BY JUSTIS P. EHLERS, MD

Optical coherence tomography (OCT) has transformed the way retina specialists provide care to patients in the clinic. It has changed how pathologies affecting the retina are diagnosed, and it has improved the ability to follow patients over time and determine their responses to medical therapy. In addition, OCT has become an invaluable tool for formulating a surgical plan preoperatively and determining the success of a procedure postoperatively.

Given its utility in the clinic and before and after surgery, it is possible that OCT technology may also improve the ability to enhance patient care in the OR. This article reviews the current state of technology and the areas of need for continued progress for seamless integration to surgical practice.

PROS AND CONS

Intraoperative OCT has many potential benefits. In essence, it can function as a rapid feedback channel helping to guide the surgeon on the status of the procedural objectives. In addition to increasing the understanding of the pathophysiology of certain vitreoretinal diseases, intraoperative OCT may also facilitate surgeon training and education. Finally, as the technology is refined and improved, it may offer new opportunities in disease management as new surgical techniques based on image-guidance are developed.

However, questions remain about how much intraoperative OCT adds to surgical outcomes in vitreoretinal surgery. It may be the case that current visualization and lighting technology permits sufficient enough understanding of the retinal and macular anatomy to obtain good outcomes. As well, use of intraoperative OCT in its current commercially available iterations in the United States adds time (not to mention cost) to the surgery and, thus, potentially reduces surgical efficiency. Adding yet another piece of equipment to an already crowded OR may also be unnecessary if surgical outcomes are not enhanced with the technology.

There are several hurdles that must be cleared before intraoperative OCT becomes a truly seamless addition to our surgical procedures. Microscope integration is now becoming a reality, but real-time tracking is still at the research and development stage. Perhaps most importantly, commercial software is not available for analyzing the surgical alterations that occur following manipulations that are captured with intraoperative OCT, and, therefore, its clinical applications and direct impact on patient care are still being explored.

With these caveats in mind and based on our experience with intraoperative OCT, it is still my opinion that the technology has the potential to be an important tool in surgery. In its early stages, many clinicians doubted the widespread role for OCT in managing vitreoretinal diseases, but it has now become the mainstay of diagnostic testing in our clinics. In the same way, OCT in the OR may have transformative potential. The immediate feedback it provides will facilitate better understanding of whether preoperative surgical goals have been achieved, such as removal of a membrane. In addition, it will offer the ability to ensure that a maneuver was performed correctly before moving to the next step. It may improve surgical efficiency through confirming completion of surgical objectives when it is unclear to the surgeon, and may guide surgical decision-making based on the visualization of surgery-induced changes to anatomy.

CLINICAL UTILITY: PIONEER STUDY

The PIONEER study was initiated to investigate the feasibility and utility of intraoperative OCT in the surgical management of ophthalmic disease. Initial enrollment for the PIONEER study began in 2011 at the Cole Eye Institute

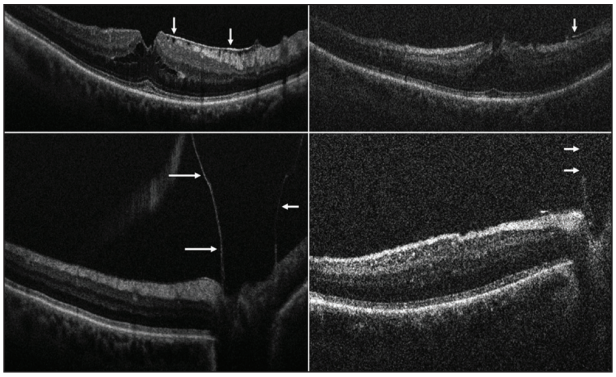

Figure 1. Example of epiretinal membrane as seen on intraoperative OCT. Epiretinal membrane surgery and intraoperative optical coherence tomography. Preincision intraoperative optical coherence tomography (OCT) B-scan reveals epiretinal membrane (ERM, arrows, top left) and attached posterior hyaloid attached (arrows) at the optic nerve (Bottom left). Intraoperative OCT B-scan following membrane peeling and hyaloid elevation identifies residual ERM (arrow, top right) and confirms hyaloid release from the optic nerve with minimal residual hyaloid elements (arrows, bottom right).[1]

at the Cleveland Clinic. At final enrollment, over 700 eyes were included in the study. There are anterior segment and posterior segment arms of the study, and we used a questionnaire to determine how intraoperative OCT affected decision-making during procedures. In the PIONEER study, intraoperative OCT was performed with a microscope-mounted portable OCT system (Bioptigen). This provided foot pedal control of X-Y-Z movement.

Several important findings have come out of the PIONEER study.[1] Various vitreoretinal indications for surgery were included in the study. The majority of cases were macular pathologies, but retinal detachment and vitreous hemorrhage were also common. Alterations to anatomy following surgical maneuvers were commonly identified.

In macular hole cases, geometric changes in hole shape were noted with alterations to the relationship between the photoreceptors and retinal pigment epithelium, as previously described.[2] Early analysis of the architectural alterations seen in macular hole surgery suggest that some of these subclinical changes may have important implications for complete appositional closure, persistent subfoveal fluid, and potential closure rate. Ongoing research will help to identify whether this information may be useful in determining need for postoperative positioning, additional membrane peeling at the time of surgery, and, potentially duration of positioning. These alterations may explain some of the factors involved in successful anatomic outcomes.

Using intraoperative OCT during vitreomacular traction surgery, surgeons were able to verify inner retinal integrity or identify an occult macular hole. These findings may impact surgeon decision-making for internal limiting membrane peeling or gas tamponade.[3] Intraoperative OCT also appeared to be useful in the management of epiretinal membranes. In fact, in about 10% of cases, the use of intraoperative OCT changed the surgical course because of the feedback that it gave to the surgeon, such as confirming completion of peel when the surgeon thought there was more to peel or revealing residual membrane that was not identified through the microscope.

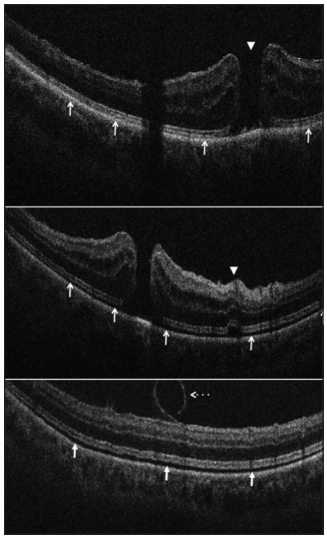

Figure 2. Macular hole surgery and intraoperative optical coherence tomography. Preincision intraoperative optical coherence tomography (OCT) B-scan provides visualization of baseline ellipsoid zone to retinal pigment epithelium (EZ-RPE) distance (solid arrows) and full-thickness macular hole (arrowhead, top). Following internal limiting membrane (ILM) peeling, intraoperative OCT reveals focal full-thickness retinal elevation (arrowhead) and generalized expansion of the EZ-RPE distance (solid arrows, middle). Extrafoveal B-scan in same eye following ILM peeling identifies residual curled ILM (dashed arrow) and similar expansion of the EZ-RPE distance (solid arrow, bottom).[1]

Intraoperative OCT for retinal detachments frequently identified residual subretinal fluid and alterations to the outer retina and foveal architecture. These findings may help to provide better prognostic guides to surgeon for visual outcomes in macula-involving retinal detachments.[4] Proliferative diabetic retinopathy and complex retinal detachments with proliferative vitreoretinopathy may also benefit from intraoperative OCT through the identification of surgical planes, membrane relationships, and the presence of small retinal breaks.

TECHNOLOGY OVERVIEW

A few devices already on the market are suitable for intraoperative imaging, and new systems will be coming to the market soon.

Tabletop Units

Tabletop units, like the ones used in regular clinical applications, can be modified for use as intraoperative devices.

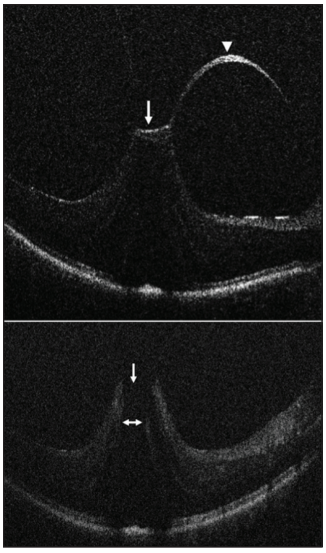

Figure 3. Vitreomacular traction intraoperative optical coherence tomography. Preincision intraoperative optical coherence tomography (OCT) B-scan revealing prominent foveal traction (arrow) and partially separated posterior hyaloid (arrowhead, top). Intraoperative OCT B-scan following hyaloid elevation reveals resolution of the traction with resultant occult full-thickness macular hole (arrows, bottom).[1]

These devices may offer optimal visual quality, but they are not really practical for regular use, as they require a special setup in the OR and do not provide optimal portability.

Handheld Probes

Most of the current literature on clinical use of intraoperative OCT is focused on portable spectral-domain OCT devices. Two manufacturers (Bioptigen and Optovue) have systems that have been described in the literature of intraoperative OCT. These are portable and versatile for imaging in multiple situations. However, these devices have limited scan repeatability because of their variability, and they are user-dependent. These also do not allow for real-time OCT and requiring halting of the surgical procedure.

Microscope-Mounted Devices

To attempt to answer some of the shortcomings of handheld probes, our research team has coupled these probes on the surgical microscope. This allows the user to take advantage of the X-Y-Z translation of the microscope, permitting improved stability and a reduction in the time required to acquire an image. However, this does not negate the need to stop surgery to obtain an image and does not allow for visualization of tissue-instrument interaction.

Microscope-Integrated Systems

Research systems have been described in the literature that have been developed at the Cleveland Clinic, Duke, and at the Medical University in Vienna.[5-7] Microscope integration is a significant iterative advance in the field of intraoperative OCT. It potentially allows for "real-time" visualization of surgical maneuvers, limits disruption of surgery, and provides for more rapid scan localization.

Recently, commercial integrated systems have become more available. Zeiss and Haag-Streit both have microscope integrated OCT systems that are approved in Europe. The Zeiss RESCAN700 is built on the Lumera 700 platform and utilizes the Callisto feedback system.[8] These systems are not currently FDA approved in the United States.

FUTURE DIRECTIONS

Intraoperative OCT is an evolving technology, and there is already work under way on the next generation of devices and integrative solutions. For instance, optimizing heads-up display feedback will be important for surgeon visualization and procedural integration.[9] Work is also ongoing to develop OCT-compatible surgical instruments, automated tracking algorithms, and procedure-specific software that may expand the functionality of intraoperative OCT.[9-11] Further research is needed to continue to understand the role of intraoperative OCT in vitreoretinal surgery and its impact on surgical outcomes. In its present form, intraoperative OCT can be a rapid surgeon feedback tool, giving information on the status of the anatomy and achievement of specific surgical objectives. In the future with advances in integrative technology, intraoperative OCT may transform the field towards image-guided/assisted surgery, opening the doors to new procedures and changing the way we look at vitreoretinal surgery. ■

Figures 1 to 3 are reprinted from American Journal of Ophthalmology; Ehlers et al. The Prospective Intraoperative and Perioperative Ophthalmic ImagiNg with Optical CoherEncE TomogRaphy (PIONEER) Study: 2-year Results. In press. 2014.

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