



Published in final edited form as:

Ophthalmol Retina. 2020 April ; 4(4): 378–383. doi:10.1016/j.oret.2019.11.002.

Intraoperative OCT-Assisted Retinal Detachment Repair in the DISCOVER Study: Impact and Outcomes

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Abstract

Purpose: The purpose of this study is to evaluate intraoperative OCT (iOCT) utility and outcomes during retinal detachment (RD) repair.

Design: The DISCOVER intraoperative OCT study is a prospective IRB-approved study.

Subjects: Subjects in the DISCOVER study undergoing surgical repair for RD.

Methods: This was a post-hoc analysis of eyes in the DISCOVER study undergoing surgical repair for retinal detachments. Inclusion criteria included iOCT following perfluorocarbon liquid (PFO) placement and at least 6 months follow-up. Exclusion criteria included severe retinal pathology unrelated to RD. Surgeons completed standardized questionnaires after each case evaluating the iOCT instrument's utility. Functional and surgical outcome data was collected at the latest available time point between 6 or 12 months. Outcomes were evaluated in 2 groups: uncomplicated primary and complex cases.

Main Outcome Measures: Intraoperative OCT utility, single-surgery success, visual acuity outcomes

Results: One hundred three eyes were included in this study, 51 primary and 52 complex cases. Intraoperative OCT provided valuable information in 36% of cases. In 12% of cases, iOCT data directly altered surgical decision making. There was a significantly higher rate of valuable iOCT feedback in complex cases compared to primary cases (50% vs 22%, $p < 0.01$). Among primary cases, 48 (94%) had successful single surgery repair with a mean postoperative visual acuity of

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Disclosures: Dr. Srivastava is a consultant for Bausch and Lomb, Carl Zeiss Meditec, and Leica; a researcher for Allergan and Bausch and Lomb; and has a patent licensed to Leica. Dr. Sharma is a consultant for Eyepoint. Dr. Rachitskaya is a consultant for Allergan, Alcon, and Zeiss; and is a speaker for Novartis. Dr. Ehlers is a consultant for Alcon, Allergan, Leica, Santen, Thrombogenics, Genentech, Novartis, Aerpio, Allegro, Regeneron, Roche, and Zeiss; has intellectual property licensed to Leica; and receives research support from Alcon, Genentech, Regeneron, Boehringer-Ingelheim, Novartis, Aerpio, and Thrombogenics. The following authors have no financial disclosures: Joseph Abraham, Thuy Le and Jamie Reese.

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20/47 compared to the complex group's 75% single surgery success (n=39) and mean postoperative visual acuity of 20/92.

Conclusions: This study affirms the potential impact of iOCT in assisting select cases of RD repair, particularly with complex pathology. The single surgery success rate was good with over 80% of cases successfully repaired with one surgery.

Précis:

Intraoperative OCT demonstrates significant value for surgical decision-making during retinal detachment repair, particularly with complex cases. Single surgery success was high with intraoperative OCT-assisted surgical repair.

Keywords

Intraoperative OCT; retinal detachment; optical coherence tomography

Introduction

Successful anatomic and functional outcome for retinal detachment repair remains challenging to predict. In particular, long-term visual prognosis following anatomically successful repair of retinal detachments remains elusive.^{1,2} However, some factors have correlated with outcomes: age, preoperative vision, duration of detachment, and height of macular detachment.^{3,4} Optical coherence tomography (OCT) imaging has become integrated into routine clinical care with enhanced visualization of retinal structures, permitting beneficial modifications to surgical planning especially for more complex cases.^{5,6} Findings from OCT imaging studies have emphasized that disruption to the outer retina such as ellipsoid zone disruption and presence of retinal corrugations correlate with visual outcomes.⁷

Intraoperative OCT (iOCT) permits real-time retinal visualization during surgery offering additional operative information to surgeons.⁸ The technique has been found in prior studies to benefit surgical decision making in both anterior and posterior segment cases.⁹⁻¹³ iOCT during retinal detachment repair has been demonstrated to be feasible.^{12,14,15} Similar to the OCT in clinic, iOCT has provided unique insights into intraoperative anatomic dynamics. In particular, studies have reported altered foveal configurations, such as occult full-thickness macular holes, and persistent submacular fluid following perfluorocarbon liquid tamponade.^{12,15} To date, few studies have examined the impact of iOCT on surgical decision-making in RD repair.

The purpose of this study is to evaluate the utility iOCT in retinal detachment surgery for retinal detachments in the DISCOVER study and to assess surgical outcomes.

Methods

The DISCOVER study is an IRB-approved prospective, single-center, multi-surgeon consecutive case series evaluating the potential role of microscope-integrated iOCT during ophthalmic surgery. This study adhered to the tenets of the Declaration of Helsinki and

complied with HIPAA regulations. Written informed consent was obtained from each patient. The study design and methods for the DISCOVER study have been described previously.¹² For this analysis, subjects with retinal detachments from the DISCOVER study were included. Inclusion criteria included surgical repair of retinal detachment with use of iOCT. Exclusion criteria included absence of follow-up data (visual outcomes, surgical complications, reoperations) and severe retinal pathology unrelated to retinal detachment such as retinal vasculitis, retinal tumors, or trauma significant enough to cause globe rupture. Surgical cases were also divided into two groups, (1) uncomplicated primary cases and (2) complex cases. Complex cases were defined as those eyes with notable additional retinal pathology including but not limited to preoperative proliferative vitreoretinopathy (PVR), presence of a giant retinal tear, panuveitis, and recurrent detachments.

Intraoperative Imaging and iOCT Feedback

Briefly, the study involved a prespecified intraoperative protocol for imaging patients during or after surgical milestones, or both, as determined by the operating surgeon. A microscope-integrated OCT system was used for intraoperative imaging [the RESCAN 700 prototype (Carl Zeiss Meditec, Inc., Oberkochen, Germany) or the EnFocus prototype (Biotigen/Leica Microsystems, Wetzlar, Germany)].¹² In the primary scleral buckle cases, a chandelier illumination system with concurrent use of the iOCT-enabled microscope with widefield visualization was used. Intraoperative imaging data were reviewed by the surgeon during surgery and also were reviewed independently after surgery.

Standardized surgeon questionnaires were completed immediately after surgery for all subjects, focusing on several specific areas related to the microscope-integrated system and retinal detachment repair. This included demographic information such as patient age, race, gender, iOCT system, scans obtained, the perceived value of iOCT to the procedure, the specific impact on surgical decision-making, and whether use of iOCT interfered with surgery.

Statistical Analysis

Surgical and functional outcome data were collected at postoperative month 6 and/or year 1. Outcome measures included visual acuity, surgical complications, reoperations, and outer retinal layer architecture changes. Count fingers (CF) and hand motion (HM) visual acuities were estimated as 20/2000 and 20/20000 respectively when included in outcome averages. Functional outcomes between the complex and uncomplicated cases were compared using 2-sample t-tests with LogMAR conversions and iOCT utility evaluated through comparison of two proportions. All statistics were completed in JMP Pro 14.

Results

Patient Demographics and Clinical Characteristics

A total of 103 eyes from 103 patients were identified from the DISCOVER study that had undergone retinal detachment repair for retinal detachments. Of the 103 eyes (Table 1), the mean age was 60.0 ± 13.0 years (mean and SD). There were 67 men (65%) and 36 women (35%). Preoperative mean VA was 20/500 including the 36 CF, HM, and LP cases (range

20/20-LP). Notable comorbidities included proliferative vitreoretinopathy (PVR) (22 eyes, 21%) and FTMH (4 eyes, 4%). Nearly half of the cases were phakic (50 eyes, 48%), while pseudophakic (49 eyes, 48%), and aphakic eyes (4 eyes, 4%) made up the remainder. Sixty-five eyes (63%) were macula-involving detachments. Complex cases comprised 52 of the 103 repairs (50%). Fifty-one cases had vitrectomy (49%), 11 had scleral buckle (11%), and 41 had scleral buckle and vitrectomy (40%).

Intraoperative OCT characteristics and utility

In 37 out of 103 cases (36%), the iOCT provided feedback the surgeons deemed valuable. Specific iOCT findings that were described as valuable included confirmation of vitreous detachment, identification and evaluation of residual fluid post-PFO, confirmation of retinal reattachment, need for retinectomy, occult macular hole, presence of preretinal membrane, and retinal cyst identification. In 13 cases (12%), the use of iOCT specifically altered the surgical procedure (Table 2). Specific surgical tasks that were altered by iOCT included additional subretinal fluid drainage, revision of retinectomy, selecting optimal drainage site, identification of subretinal PFO, and additional membrane peeling. Among uncomplicated primary cases, iOCT provided valuable feedback in 11 of 51 surgeries (22%), while in 4 cases (8%) the instrument modified surgery. In 26 of 52 complex repairs (50%) the surgeon reported useful feedback gained from the iOCT which was significantly higher than in primary repairs ($p < 0.05$). In 9 cases (17%) its imaging output positively altered surgical maneuvering. In 4 cases, the iOCT process interfered with surgery due to delays from software malfunction.

Clinical and Surgical Outcomes Non-Complex Primary Retinal Detachment Repair

In uncomplicated primary retinal detachment repairs, 48 of the 51 eyes (94%) had successful single surgery reattachment. In 3 cases, recurrent or new detachments occurred (6%). Six cases required postoperative surgical intervention for other complications including ERM, macular hole, and vitreous hemorrhage. Nonsurgical complications included cystoid macular edema in (7 eyes, 14%) and epiretinal membrane (6 eyes, 12%). Postoperative mean visual acuity was 20/47 (range 20/20–20/300). Mean follow-up time was 10 months.

Complex cases

In complex retinal detachment repairs, 39 of the 52 eyes (75%) had successful single surgery detachment repair. Thirteen cases (25%) required subsequent repair of a recurrent or new detachment. Three cases required additional surgical intervention for postoperative ERM (2 eyes) and scleral buckle removal due to orbital inflammation (1 eye). The most common nonsurgical complication was ERM (6 eyes, 12%). Final visual acuity was 20/55 (range 20/20–20/400) with an additional 6 cases of HM or CF, while inclusion of these cases resulted in a mean visual acuity of 20/92. This was a significantly lower visual acuity outcome compared to the noncomplex primary cases ($p = 0.01$). Mean follow-up time was 9.6 months.

Discussion

In this study, we report on the outcomes and utility of iOCT in retinal detachment repair and the sequelae of retinal detachment on outer retinal architecture following surgical repair. The use of iOCT was deemed valuable for providing feedback in a large proportion of cases (36%) and altered surgical decision-making in a non-trivial number as well (12%). There was a wide range of reported information that surgeons utilized through iOCT imaging intra-operatively such as diagnosing or confirming retinal pathology such as macular holes to retinal membranes or visualizing pockets of subretinal fluid or subretinal perfluorocarbon liquid. In several cases, this enabled surgeons to have greater understanding of the underlying anatomy and understanding of the achievement of surgical objectives.

Interestingly, iOCT provided useful information in a notably higher percentage of complex cases (50%) than in primary repairs (22%) ($p < 0.05$), while similar results were seen in adjusting surgery based on iOCT in complex cases 17% vs 8%. Our findings thus suggest that iOCT most benefits retinal detachment repairs in higher complexity surgeries where the real-time retinal imaging is more likely to be utilized. Additionally, integrating the workflow of iOCT into the surgical procedure appeared to be well received. Surgeons reported that in the vast majority of cases (96%) the iOCT did not interfere with surgery. Software malfunction resulting in delay to surgical case was the primary issue resulting in interference. In those small number of the total cases where interference was noted, unlikely instrument malfunction such as imaging freezing was culpable.

To date, there had been no study with a significant cohort of patients evaluating functional and surgical outcomes in iOCT-assisted retinal detachment repair. Mean visual acuity among uncomplicated primary repairs showed improved outcomes to the more complex cases (average of 20/47 vs 20/92). This study found among all eyes a high rate of successful single surgery repair (84%) within 12 months of follow-up that remained high with uncomplicated, primary repairs (94%) but dropped when evaluating more complex case outcomes (75%) corresponding to 6% and 25% reoperation rates respectively. The most common causes for reoperation included recurrent detachment, PVR, and ERM. This success rate of primary RD repair was excellent when compared to other studies of primary RD repair.¹⁷⁻²⁴ In one large cohort assessing 6-month outcome data from 5857 primary retinal detachment cases nonstratified for case-complexity, reoperation rates were at 13.9%, close to historically reported figures of 13-17%.^{17,23} Another more recent retrospective cohort analysis similarly yielded a redetachment rate of 14.7% which was notable for only including uncomplicated cases.²¹ Rates of primary repair failure have varied significantly in the literature, however. A nationwide analysis from Denmark reported a 22% reoperation rate from 6522 eyes, while a randomized control trial comparing SB vs PPV for primary RD in medium complexity cases reported an average failure of 36.8%^{19,22}. Several other studies have identified reoperation rates between 20-30%.^{18,20} A number of factors have been reported to account for this wide variation including case complexity, follow-up duration, definition of primary RD failure, and inclusion vs exclusion of silicone oil use.¹⁷

Several factors have been associated with reduced rates of surgical success, particularly related to complexity of surgical case and clinical features. In a recent studies of RD with

PVR at baseline, patients visual acuity at 6 months postoperatively was 20/200 or better in only 24% of patients, while 238 of 555 (43%) required reoperation.²⁵ A small case series looking into retinal detachment repair outcomes in patients with acute retinal necrosis found that 46% required reoperation,²⁶ while in another series giant retinal tears were associated with a 27% reoperation rate post-vitreectomy.²⁷ In this study, only 25% of complex cases required reoperation. The high rate of surgeon-perceived value of iOCT data (50%) suggests that iOCT may have contributed to this relatively low reoperation rate for a complex group. However, as several other factors may contribute to surgical success including variability in surgeon skill, patient postoperative positioning compliance, and complexity of the cases themselves, a randomized comparative prospective trial would be needed to more definitively evaluate the role of iOCT for surgical success.

As with any study, our work has important limitations that must be considered. One significant limitation is the lack of a control group that underwent standard RD repair without iOCT assistance to compare long-term outcomes with the same group of surgeons using a randomized design. The feasibility of a prospective randomized comparative study is currently being evaluated. Relatedly, the reported single surgery success of this study in primary RD repair is comparable to the prior studies with some of the best outcomes; however, it is difficult to determine the true iOCT impact in these cases without a randomized control group. Although the largest study to date, the sample size for the study is still relatively small. This study also did not include comparative evaluation of the different iOCT systems. Given the vast majority of cases were performed on one device, such comparative assessment was not possible. This limitation highlights the need for potential future comparative investigations on comparative iOCT device outcomes. Additional future work will need to assess the cost benefit ratio of implementing iOCT, critical for any new technology with unclear definitive benefit, in a prospective randomized trial. Strengths of the work include its relative novelty, particularly in relation to iOCT utility and outcomes in retinal detachment repair.

In summary, this study affirms iOCT feedback may provide surgeon-perceived valuable feedback and may modify surgical decision-making, particularly in complex cases. Further research may focus on a prospective randomized design to assess iOCT utility, comparatively evaluate iOCT devices, and determine the cost-benefit ratio of iOCT in retinal detachment repair.

Acknowledgments

Funding: National Institutes of Health/National Eye Institute, Bethesda, Maryland, USA, K23-EY022947-01A1 (J.P.E.); Ohio Department of Development, Columbus, Ohio, USA, TECH-13-059 (J.P.E., S.K.S.)

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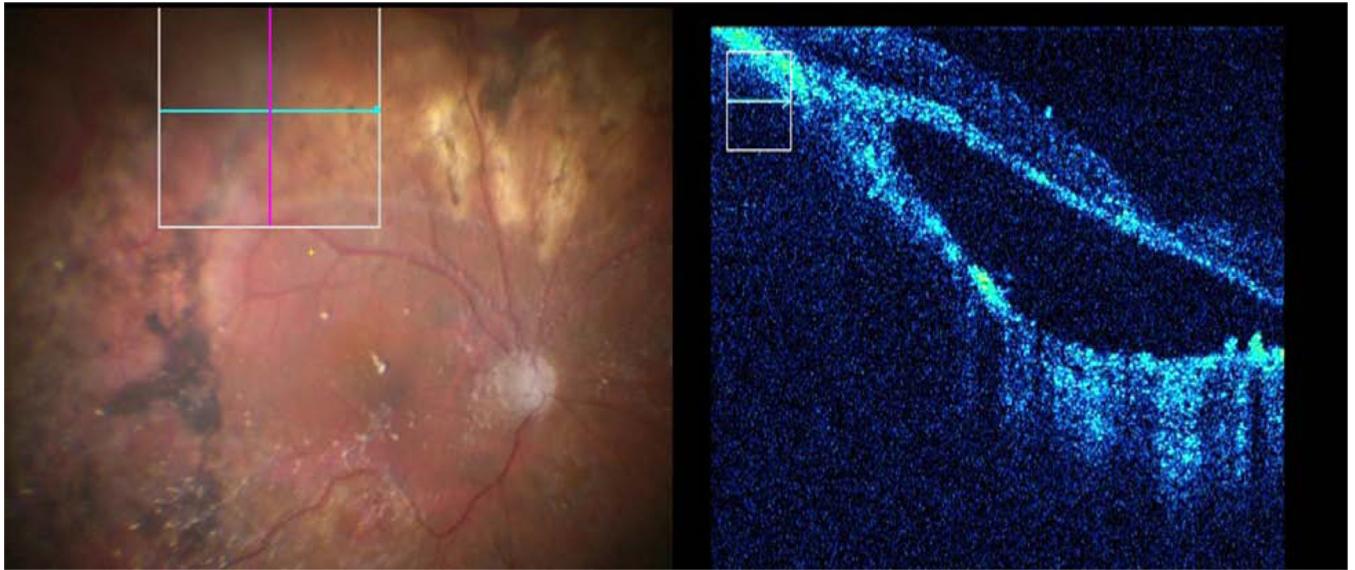


Figure 1. Representative example of iOCT utility showing both surgical visualization and iOCT imaging. iOCT identified definitive hyperreflective subretinal membrane (arrowhead) consistent with PVR that was anatomically significant and required removal.

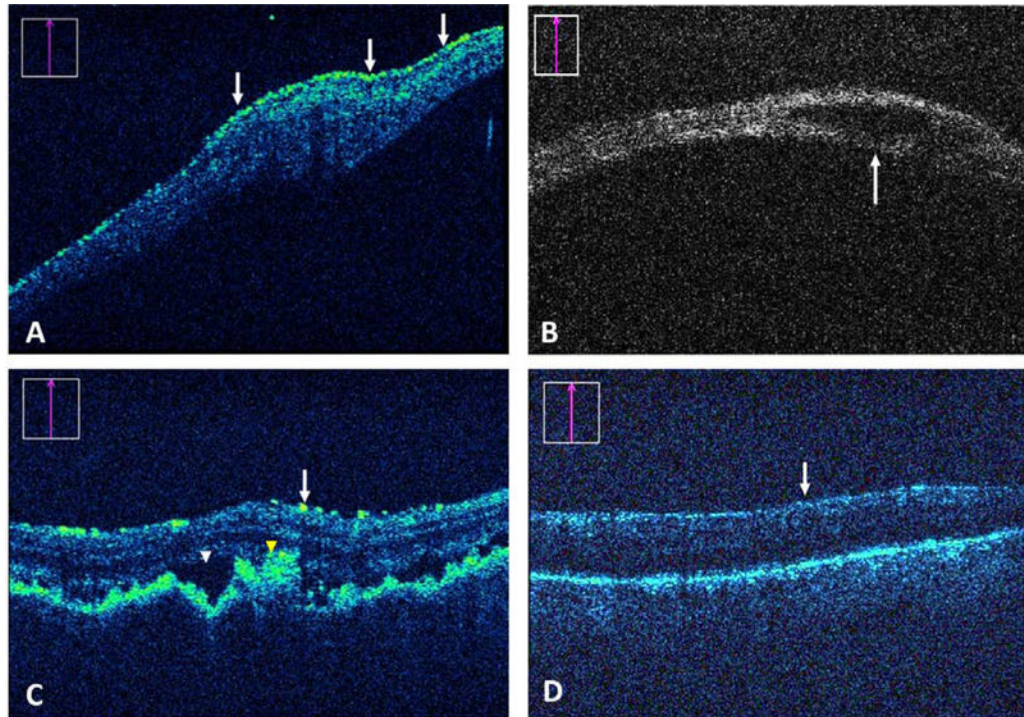


Figure 2.

Impact of iOCT on surgical decision-making. (A) Preretinal membrane (arrows) identification by iOCT that prompted further peeling. (B) iOCT-based identification of a retinal cyst (arrow) confirming no need for additional treatment. (C) A complex combined exudative/rhegmatogenous detachment repair with suspected uveitis and choroidal folds in which SRF (white arrowhead) and abnormal pigment (yellow arrowhead) were identified by iOCT. The feedback resulted in more drainage. (D) In a possible proliferative vitreoretinopathy case, iOCT confirmed lack of preretinal membranes (arrow) that prevented unnecessary staining or membrane peel attempts.

Table 1.

Baseline Demographic and Clinical Characteristics.

	All (n = 103)	Uncomplicated (n = 51)	Complex (n = 52)
Age (mean +SD)	60 ± 13	60 ± 12	60 ± 14
Sex			
Male	67 (65%)	33 (65%)	34 (65%)
Female	36 (35%)	18 (35%)	18 (35%)
Lens status			
Phakic	50 (48%)	29 (57%)	21 (40%)
Pseudophakic	49 (48%)	21 (41%)	28 (54%)
Aphakic	4 (4%)	1 (2%)	3 (6%)
Macula-involving detachments	65 (63%)	38 (75%)	29 (56%)*
PVR	22 (21%)	0	22 (42%)*
FTMH	4 (4%)	0	4 (8%)

PVR = Proliferative vitreoretinopathy, FTMH = Full thickness macular hole,

* = p < 0.05 comparing two proportions between uncomplicated and complex cases.

Table 2.

Feedback that resulted in surgical changes from iOCT in DISCOVER RD

Eye	iOCT feedback	iOCT based procedure changes
1	Identified residual preretinal PFO	Aspirated preretinal PFO
2	Showed no SRF under PFO	No additional maneuvers required
3	No residual SRF on buckle	No additional maneuvers required
4	Identified subretinal PFO	Removed PFO
5	Area of SRF plan for drainage retinotomy	Placement of drain
6	Identified preretinal membrane	Prompted peeling
7	Identified retinal cyst	Confirmed no need for further intervention
8	Identified hole	Additional laser performed
9	Limited retinal flattening	Prompted retinectomy
10	Identified preretinal membrane	Additional peeling
11	Confirmed flat retinectomy edge	No additional maneuvers required
12	SRF and associated pigment	Prompted more drainage
13	No SRF in macula	Posterior retinotomy avoided

Abbreviations: PFO: perfluorocarbon liquid; iOCT: intraoperative optical coherence tomography; SRF: subretinal fluid.