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Accuracy of Spectral Domain Optical Coherence Tomography of the Macula for Detection of Complete Posterior Vitreous Detachment

Eileen S. Hwang, MD, PhD[1], **Jessica A. Kraker, BS, MS**[1], **Kim J. Griffin, BA**[1], **J. Sebag, MD**[2,3], **David V. Weinberg, MD**[1], **Judy E. Kim, MD**[1]

[1]Medical College of Wisconsin / Froedtert Eye Institute, Milwaukee, Wisconsin, United States

[2]VMR Institute for Vitreous Macula Retina Huntington Beach, California, United States

[3]Doheny Eye Institute/UCLA, Los Angeles, California, United States

Abstract

Purpose: To assess the accuracy of macular spectral domain optical coherence tomography (OCT) in detecting complete posterior vitreous detachment (PVD).

Design: Evaluation of diagnostic test or technology using a retrospective comparative study.

Subjects: 175 eyes in 175 patients (111 female, 64 male; mean age = 65 years) with pre-operative OCT within 90 days of vitrectomy.

Methods: PVD status on preoperative macular OCT was compared to PVD determination during vitrectomy. Attached vitreous was identified on OCT by visualizing the posterior vitreous cortex or the premacular bursa. Complete PVD was identified by the absence of these findings, and was considered a positive outcome for the purpose of analysis.

Main Outcome Measures: Sensitivity, specificity, positive predictive value, and negative predictive value of macular OCT for detection of complete PVD compared to findings at surgery.

Results: Of the 38 eyes graded as complete PVD on OCT, 20 eyes were found to have pre-existing PVD at the time of surgery (true positives), and 18 eyes were found to have attached vitreous at the time of surgery (false positives). Of the 137 eyes graded as attached vitreous on OCT, 129 eyes had attached vitreous at the time of surgery (true negatives), and 8 eyes had pre-existing PVD at the time of surgery (false negatives). The sensitivity of OCT for detecting complete PVD was 71% and the specificity was 88%. In the study population, the positive predictive value of an OCT scan showing complete PVD was 53% while the negative predictive value of an OCT scan showing attached vitreous was 94%.

Corresponding Author / Address for Reprints: Eileen S. Hwang, MD, PhD, Medical College of Wisconsin / Froedtert Eye Institute, 925 N 87th Street, Milwaukee, Wisconsin, 53226 United States, eileenhwang@yahoo.com, phone: 414-955-2020 fax: 414-955-6300.

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Conclusions: If the premacular bursa or posterior vitreous cortex are visualized on macular OCT, an accurate determination of attached vitreous can be made. The diagnosis of complete PVD by macular OCT is less accurate and requires ultrasound.

Introduction:

Posterior vitreous detachment (PVD) is the age-related separation of vitreous from retina.[1] At birth, the vitreous body is firmly attached to the retina and there is no PVD. Age-related vitreous liquefaction and weakening of vitreoretinal adhesion lead at first to partial PVD, and later to complete PVD. Optical coherence tomography can be used to detect eyes with no PVD by visualization of the premacular bursa, and partial PVD by visualization of the posterior vitreous cortex as initially described by Uchino and refined by Johnson.[2,3]

PVD status may be assessed by physical exam, ultrasonography, or OCT, with varying degrees of accuracy. PVD status, specifically vitreomacular adhesion, has been correlated with disease prognosis and response to anti-VEGF treatment in diabetic retinopathy, exudative age-related macular degeneration, and retinal vein occlusion.[4–9] Although some studies used ultrasound to diagnose PVD,[7,8] many of these studies relied on OCT to assess PVD status despite the scarcity of studies validating the use of OCT in this context. Nonetheless, OCT is commonly obtained during pre-operative evaluation of macular and retinal diseases and can potentially provide information about PVD status and guide pre-surgical planning and counseling. For example, pre-operative PVD status may affect the choice between pneumatic retinopexy, scleral buckle, or vitrectomy to repair a retinal detachment,[10] and a patient with a pre-existing PVD may have a lower risk for iatrogenic tear during macular surgery.[11] Thus, the accuracy of PVD diagnosis by OCT is an important area for investigation.

In this study, we evaluated the accuracy of pre-operative spectral domain OCT of the macula for determining PVD status in comparison to intraoperative findings during vitrectomy.

Methods:

Medical College of Wisconsin Institutional Review Board approval was obtained with a waiver of informed consent (study number PRO00031324). The study conformed to HIPAA regulations and was performed in accordance with the Declaration of Helsinki. A retrospective chart review was conducted comparing PVD status on operative notes compared to pre-operative OCT scans. A total of 552 retina clinic patients over 18 years of age who underwent primary vitrectomy at the Froedtert & the Medical College of Wisconsin Eye Institute between the dates of 01/01/09 and 12/31/17 were screened. Operative notes lacking clear descriptions of posterior vitreous status were excluded, as were eyes that had previously undergone vitrectomy. Operative notes were classified as either attached vitreous or pre-existing complete PVD. If a patient had two eyes that underwent vitrectomy during this time period that met eligibility criteria, one eye was randomly selected. Of the initial 552 patients, 248 were included for OCT review and correlation with surgical findings.

Spectral domain OCTs were obtained using the Heidelberg Spectralis with 15 scans averaged (Heidelberg Engineering, Heidelberg, Germany), Topcon 3DOCT (Topcon, Tokyo,

Japan), and Cirrus 5000 (Carl Zeiss Meditec, Inc., Dublin, CA). Of the total 175 eyes, 164 were imaged with Spectralis, 8 with Topcon, and 3 with Cirrus. Repeating the analysis with only the 164 eyes imaged with Spectralis did not significantly affect the results. Twelve 6-mm radial fovea-centered scans were obtained up to 90 days before surgery. A power calculation indicated that review of 176 OCT scans would provide 95% power with an alpha of 0.001 for a Fisher's exact test assuming 20% prevalence of stage 4 PVD by one method and a difference in rates of 37% between the two methods.

Two masked ophthalmologists (ESH and DVW) independently graded PVD status according to a decision tree (see Supplemental Figure 1, available at https://www.ophthalmologyretina.org/). Disagreement regarding stage was resolved by joint review of the OCT scans. Although the decision tree was used to classify each eye according to PVD stages 0, 1, 2, 3, 4, and abnormal, for purposes of comparison with intra-operative findings, stage 0, 1, 2, 3, and abnormal were categorized together as attached vitreous and stage 4 was categorized separately as complete PVD. Of the eyes with attached vitreous, there were 3 eyes in stage 0, 24 eyes in stage 1, 44 eyes in stage 2, 51 eyes in stage 3, and 15 eyes with abnormal PVD.

The decision tree was based on a previously published OCT staging system which utilizes a 9 mm OCT scan length that includes the optic nerve.[12] Our retrospective study utilized a 6 mm OCT scan length, which does not include the optic nerve. To assess the potential impact of this, we performed a limited study of 63 eyes that underwent 6 mm and 16.5 mm OCT scans.[13] The results of this study supported our assumption that if the posterior vitreous cortex is visible on the 6 mm scan, it is attached to the optic nerve (stage 3), and that if it is not visible on the 6 mm scan and the premacular bursa is not visible, the vitreous is separated from the optic nerve (stage 4).

Scans without visible posterior vitreous cortex or premacular bursa of Worst were classified as stage 4 if the scan position and quality were adequate to rule out the presence of the premacular bursa (as would be seen in a stage 0 eye). Eyes were judged to have an acceptable scan position if the top of the scan was at least three "retina thicknesses" above the retinal pigment epithelium at the foveal center. This criterion was selected to capture the anterior edge of the premacular bursa, which was reported to be approximately 708 um over the retina at the foveal center,[14] based on a nasal retinal thickness on the Spectralis of 344 um.[15] Retina thickness was measured at the nasal edge of the horizontal scan for each eye unless this retina was pathologically thickened or thinned, in which case a temporal edge was selected. Eyes without any scans that met the position requirement were excluded as short ("s"). Eyes with grainy appearing vitreous on all 12 scans were excluded as poor quality ("q"). Scan position and quality were only assessed in eyes in which the premacular bursa and posterior vitreous cortex were not visible.

Results:

Two ophthalmologists independently graded pre-operative spectral domain macular OCT scans of patients undergoing vitrectomy surgery (Figure 1). OCT scans of 247 eyes were evaluated, and 72 eyes without visible posterior vitreous cortex or premacular bursa were

excluded due to inadequate OCT image quality or scan position. 175 eyes of 175 patients (111 female, 64 male) with an average age of 65 years were included in the analysis for comparison against intraoperative findings (Table 1). The kappa statistic was 0.57, indicating moderate agreement between graders. A major source of disagreement was the scan position and quality criteria.

Attached vitreous was identified on OCT by visualizing the posterior vitreous cortex or the premacular bursa. Complete PVD was identified by the absence of these findings, and was considered a positive outcome for the purpose of the analysis.

By OCT, we graded 137 eyes as attached vitreous and 38 eyes as complete PVD. PVD stage on OCT was compared to the surgeon's description of vitreous status in the operative note (Table 2). The operative notes were categorized in a binary fashion as describing either attached vitreous or detached posterior vitreous. Eyes with operative notes lacking a description of the vitreous status were excluded. At surgery in the entire group, 28 eyes had pre-existing PVD and 147 eyes had attached vitreous.

Of the 38 eyes graded as complete PVD on OCT, 20 eyes were found to have pre-existing PVD at the time of surgery (true positives), and 18 eyes were found to have attached vitreous at the time of surgery (false positives). Of the 137 eyes graded as attached vitreous on OCT, 129 eyes had attached vitreous at the time of surgery (true negatives), and 8 eyes had pre-existing PVD at the time of surgery (false negatives). The sensitivity of OCT for detecting complete PVD was 71% and the specificity was 88%. In the study population, the positive predictive value was 53% and the negative predictive value was 94%.

The most common diagnosis was macular hole (53%), followed by premacular membrane with pucker (21%) and proliferative diabetic retinopathy (13%). 13% of eyes had miscellaneous diagnoses (age-related macular degeneration, cataract, glaucoma, retinal detachment, vitreous hemorrhage, vitreomacular traction, and vitreous opacities). Eyes undergoing vitrectomy for macular hole and premacular membrane with pucker were compared. Attached vitreous was found significantly more frequently in eyes with macular hole (90%) compared to eyes with premacular membrane with pucker (73%) ($p<0.0001$ by Fisher's exact test). In eyes with macular hole, the sensitivity of pre-operative OCT in correctly diagnosing PVD was 67%, specificity was 88%, positive predictive value was 38% and negative predictive value was 96%. In eyes with premacular membrane with pucker, sensitivity was 20%, specificity was 85%, positive predictive value was 33% and negative predictive value was 74%.

Discussion

We compared PVD staging on spectral domain OCT of the macula to intraoperative findings. Since our study is retrospective, the OCT scans were not obtained with the enhanced vitreous imaging technique.[16–18] This technique is optimum for visualization of vitreous structures, but our findings using regular OCTs are more applicable to images obtained in routine clinical practice. We classified OCT scans of adequate scan height and image quality as consistent with complete PVD when neither the premacular bursa nor the

posterior vitreous cortex were visualized. Using this strategy, we found poor sensitivity (71%) for detection of complete PVD, indicating that ultrasound is necessary to accurately identify complete PVD, confirming previous findings.[19] On the other hand, we found a specificity of 88% in ruling out PVD, indicating that when the posterior vitreous cortex or premacular bursa are visualized on OCT, attached vitreous will likely be encountered during vitrectomy Seeing an early stage PVD on OCT may guide a surgeon away from pneumatic retinopexy toward a scleral buckle for retinal detachment repair, or may suggest that a patient is at higher risk for developing an intraoperative tear during vitrectomy for macular pathology. However, if neither the premacular bursa nor the posterior vitreous cortex are visualized, spectral domain OCT has poor predictive value.

Using Ovid MEDLINE, we searched the terms “vitreous detachment”, “pre-operative”, “OCT”, and “macular hole”, and found one other publication that made this comparison. Kicova et al. compared spectral domain OCT of the macula to intraoperative findings.[20] They observed the posterior vitreous cortex without attachment to the retina in eight eyes, which they interpreted as a complete PVD. In seven of eight eyes, they found the vitreous to be attached during vitrectomy and concluded that OCT was inaccurate. In contrast, we interpreted the presence of the posterior vitreous cortex in the scan area without visible attachment as evidence for vitreous attached only to the optic nerve (i.e. stage 3 partial PVD) and found better correlation with intraoperative findings. Our comparison of 6-mm scan length to 16.5-mm scans supported our ability to distinguish stage 3 from stage 4 PVD without visualizing the optic nerve. Kicova et al. also compared intraoperative findings to pre-operative ultrasound and biomicroscopy and found that ultrasound was more accurate, although the correlation was imperfect. Thus, in patients not undergoing surgery, ultrasound is the gold standard to detect complete PVD in clinic.

Rahman et al. published a prospective study that showed good correlation of PVD status on three-dimensional OCT of the optic nerve head to intraoperative findings.[21] This methodology is likely limited in its ability to distinguish an early stage of PVD (stage 0 or stage 1) from complete PVD (stage 4), since in both cases, the posterior vitreous cortex would not be seen inserting into the optic disc. The greatest challenge for OCT is to distinguish between stage 0 (completely attached vitreous) and stage 4 (complete PVD). Our strategy was to classify an eye as stage 0 if the premacular bursa was visible but the posterior vitreous cortex was not. If neither the premacular bursa nor the posterior vitreous cortex were visible, we assessed whether the scan was of adequate position and quality to be able to exclude the presence of the premacular bursa. However, very few eyes in this study were in stage 0, which limits our ability to assess the accuracy of visualization of this classification method, but reflects the advanced age and high prevalence of at least partial PVD in the population undergoing vitrectomy. Further work should be done to determine under which circumstances the premacular bursa can and cannot be visualized, perhaps with swept source OCT.

One potential cause of discordance between OCT and surgical findings could be interval development of complete PVD between the date of the OCT and the date of surgery. The mean time between OCT and surgery was 31 +/− 19 days. In the subgroup with attached

vitreous on OCT and complete PVD at surgery, the mean time was similar (33 +/− 8 days), suggesting that this was not a significant confounder.

Splits within the posterior vitreous cortex (vitreoschisis) contribute to the pathogenesis of vitreomacular diseases and may confound assessment of PVD status both intraoperatively and by OCT.[22–24] Intraoperatively, there can be a layer of vitreous cortex remaining after an apparent complete PVD, which may only be detected when chromodissection with a dye or steroid is used.[25] Steroids were used intraoperatively in 72% of the vitrectomies included in this study. Vitreoschisis may also be apparent on OCT, but there may also be times when it is present but undetected.[26]

Another limitation of this study was our reliance on surgeon description of vitreous status in the operative note. The accuracy of surgeon notes could be affected by faulty assessment of vitreous status when steroids are not used, by the vitreous becoming detached in the very early part of the vitrectomy, or by errors in dictation. During the screening process, 43% of eyes were excluded due lack of surgeon description of vitreous status, which may have resulted in a bias in which more eyes with attached vitreous were included since presumably surgeons were more likely to comment on the vitreous status if they found it to be attached and had to lift it off the retina. In addition, eyes were excluded on the basis of scan position or quality only when the scan appeared consistent with stage 4 complete PVD, which may have also led to overrepresentation of eyes with attached vitreous.

At surgery, we found attached vitreous in 90% of the eyes with macular holes, consistent with the reports by others of attached vitreous (macular hole stages 1–3) in 79% of eyes by OCT,[27] and 88% of eyes by ultrasound.[28] At surgery, we found attached vitreous in 61% of eyes with premacular membrane and pucker, which was more than Koizumi et al. who found attached vitreous in 17% of eyes with premacular membrane and pucker by OCT,[29] and Sebag's group who by ultrasound found no PVD in only 7% of eyes with premacular membrane and pucker.[28] A high prevalence of vitreoschisis in eyes with premacular membrane and pucker could contribute to these discrepancies.[21, 22] In our study, the prevalence of pre-existing complete PVD, and therefore the positive and negative predictive values, may not reflect the population of patients undergoing vitrectomy in clinical practice.

The depth of field of OCT is a significant limitation since following complete PVD, the vitreous cortex may be located a significant distance anterior to the retina. We relied upon the absence of the premacular bursa and posterior vitreous cortex to classify OCTs as complete PVD, but found that this method has poor sensitivity for detection of complete PVD. In contrast, we found a high specificity, suggesting that most eyes with attached vitreous will have an OCT demonstrating the premacular bursa or posterior vitreous cortex. Ultrasound has a better depth of field and the capability to evaluate movement, which facilitate assessment of vitreoretinal adhesion and separation.[30] Swept source OCT has a greater anterior depth of field and may have an improved ability to visualize the vitreous compared to spectral domain OCT,[17,18] but the accuracy of swept source OCT for detection of complete PVD will need to be tested against ultrasound or intra-operative findings.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Abbreviations:

OCT	ocular coherence tomography
PVD	vitreous detachment

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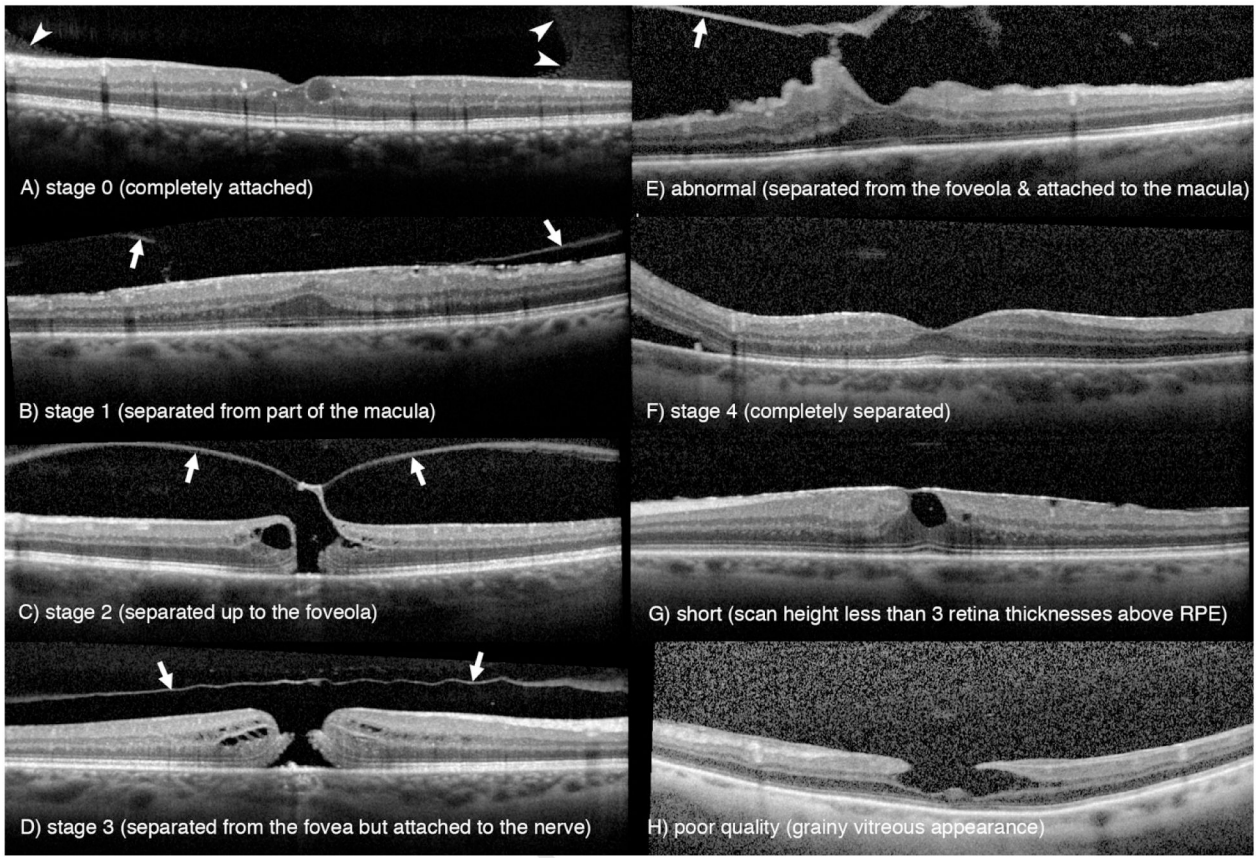

FIGURE 1.

Example 6 mm optical coherence tomography scans demonstrating posterior vitreous detachment classification. Attached vitreous includes stage 0 (A), stage 1 (B), stage 2 (C), stage 3 (D), and abnormal stage (E) and was identified by either the premacular bursa (arrowheads) or posterior vitreous cortex (arrows). Complete posterior vitreous detachment is represented by stage 4 (F), in which neither the premacular bursa nor the posterior vitreous cortex were visualized. Scans were excluded if they had insufficient scan height (G) or insufficient scan quality (H). Image brightness has been adjusted to maintain quality during printing. Staging system modified from Ma et al.[12]

Table 1.

Characteristics of eyes included in comparison between optical coherence tomography (OCT) and surgery

Age in years (mean +/− SD)	65 +/− 12
Sex (n, %)	
female	111, 63%
male	64, 37%
Race (n, %)	
Caucasian	141, 81%
African American	27, 15%
Hispanic	4, 2%
Asian	3, 2%
Eye (n, %)	
right	79, 45%
left	96, 55%
Refractive error (n, %)	
High Myopia < −6 D	6, 3%
Low Myopia < −1 and >= −6 D	36, 20%
Emmetropia < +1 and >= −1 D	31, 18%
Hyperopia >= +1 D	34, 19%
Not Available	69, 39%
Days between OCT and surgery (mean +/− SD)	30 +/− 19
Intraoperative steroids used (n, %)	126, 72%
Diagnoses (n, %)	
macular hole	93, 53%
epimacular membrane with pucker	37, 21%
proliferative diabetic retinopathy	23, 13%
other	22, 13%
Previous intravitreal injections (n, %)	
none	164, 93.5%
anti-vascular endothelial growth factor	8, 4.5%
ocriplasmin	3, 2%
Previous retinal laser (n, %)	
none	154, 88%
pan-retinal photocoagulation	15, 9%
other retinal laser	6, 3%

Other diagnoses include age-related macular degeneration, cataract, glaucoma, retinal detachment, vitreous hemorrhage, vitreomacular traction, and vitreous opacities Other lasers include focal/grid, photodynamic therapy, and laser retinopexy

Table 2.

Results of optical coherence tomography (OCT) classification of posterior vitreous detachment (PVD) stage.

attached vitreous by OCT		137 eyes	
attached vitreous at surgery	*129 eyes*	*complete PVD at surgery*	*8 eyes*
OCT stage 0	1 eye	OCT stage 0	2 eyes
OCT stage 1	22 eyes	OCT stage 1	2 eyes
OCT stage 2	43 eyes	OCT stage 2	1 eye
OCT stage 3	50 eyes	OCT stage 3	1 eye
OCT stage a	13 eyes	OCT stage a	2 eyes
complete PVD by OCT		38 eyes	
attached vitreous at surgery		*complete PVD at surgery*	
OCT stage 4	18 eyes	OCT stage 4	20 eyes