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Original Article

Optical coherence tomography assessment for attached posterior vitreous in eyes with macular holes and epiretinal membranes

Petros Aristodemou[1,2], Marten E. Brelen[1,3], Nishant Kumar[1,4], Richard Markham[1], Richard J. Haynes[1], Andrew Dick[1]

[1]Department of Vitreoretinal, The Academic Unit of Ophthalmology, University of Bristol, Bristol Eye Hospital, Lower Maudlin Street, Bristol, UK, [2]Vitreous Retina Macula Clinic, Ygeia Hospital, Limassol, Cyprus, [3]Department of Ophthalmology and Visual Sciences, The Chinese University of Hong Kong, Hong Kong Eye Hospital, Hong Kong SAR, China, [4]P D Hinduja Hospital, and Hinduja Healthcare Surgical, Mumbai, Maharashtra, India

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Address for correspondence:
Dr. Marten E. Brelen, Department of Ophthalmology and Visual Sciences, The Chinese University of Hong Kong, Hong Kong Eye Hospital, Hong Kong SAR, China.
Phone: +852 3943 5806.
Fax.: +852 2715 9490.
E-mail: marten.brelen@cuhk.edu.hk

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Abstract

Purpose: The purpose of this study was to assess the reliability of spectral-domain optical coherence tomography (OCT) as a diagnostic tool in the detection of an attached posterior vitreous.
Methods: A double-blind comparison of the vitreous imaged by OCT acquired on the day of surgery with the status of the posterior vitreous assessed at the time of surgery.
Results: A total of 103 patients were recruited to the study, 67 of whom had complete data and were included in the analysis. 37 eyes had macular holes (MHs), 23 eyes had epiretinal membranes (ERM), and the remaining 7 eyes had other macular pathology, including vitreomacular traction syndrome and lamellar holes. The overall sensitivity of OCT in detecting an attached posterior vitreous was 80% and the specificity was 56%. For MH, this was 88% and 60%, respectively, whereas for ERM, it was only 45% and 50%.
Conclusions: The assessment of attachments of the posterior hyaloid membrane on OCT can reliably predict attached posterior vitreous in MH but not in ERM.

Introduction

For a number of macular pathologies such as macular holes (MHs) and epiretinal membranes (ERM), vitreoretinal surgery is required to restore or preserve central vision. An important part of surgery is to detect any attachments of the posterior vitreous and induce a posterior vitreous detachment (PVD) before peeling any macular membranes. The pre-operative diagnosis of attached posterior vitreous is not always reliable and many times the true state of posterior vitreous attachments is found at surgery.

A number of imaging modalities have so far been reported as diagnostic tools for assessing the posterior vitreous. These include the scanning laser ophthalmoscope, B-scan ultrasound, time-domain, and spectral-domain OCT.[1] Kičová *et al.* found that B-scan ultrasonography and examination of the patient with slit lamp biomicroscopy were more reliable than OCT alone in diagnosing a PVD.[2] The authors showed that only a proportion of patients (30%) can have their posterior hyaloid imaged using OCT, with a poor correlation between pre-operative assessment of the posterior hyaloid and intraoperative findings during vitrectomy.[2] However, their study was based on a small sample of only 30 eyes in 30 patients. Other studies have contradicted the findings by Kičová *et al.* demonstrating a high correlation between pre-operative OCT imaging and intraoperative findings of the status of the PVD ($\kappa = 0.947$).[3] In this latter study, there was also 100% agreement between the two observers of the OCT findings preoperatively. Gallemore *et al.* reviewed OCT images of 139 eyes retrospectively and showed that OCT was better able to identify vitreoretinal adhesion than B-scan ultrasonography. This suggests that OCT is more accurate in determining the status of the posterior hyaloid.[4] OCT has also been used to subclassify the progressive stages of a partial PVD developing into a complete PVD.[5] In a study by Uchino *et al.*, eyes with fully detached vitreous slit lamp examination had no identifiable vitreous signal on OCT because the posterior hyaloid was at a greater distance from the retinal surface than the OCT was able to detect within its scan range.

The aim of this study was to further explore the ability of OCT to detect the status of the posterior hyaloid preoperatively in patients undergoing vitrectomy and to define OCT diagnostic criteria for predicting an attached posterior hyaloid at surgery. The sensitivity and specificity of OCT in pre-operative prediction of the posterior hyaloid status was compared to intraoperative findings during vitrectomy.

Methods

This is a prospective cross-sectional study conducted at the Bristol Eye Hospital, Bristol, UK. The study complies with the Declaration of Helsinki, and ethical approval was obtained from the local ethics review board (Ref OP/2008/2994, Central Bristol Research Ethics Committee). All patients gave written informed consent before taking part in the study.

An initial pilot study was performed to define OCT diagnostic criteria for attached posterior vitreous and PVD. 19 patients underwent full biomicroscopic slit lamp examinations and OCT scanning of the macula. Patients were scanned by a masked investigator using the Topcon three-dimensional (3D) OCT 1000 (Topcon Corporation, Japan). The cube protocol at four positions at the posterior fundus was implemented: The macula, the disk, the superior-temporal, and the inferior-temporal vascular arcades. Each cube scan consisted of single parallel OCT scans, with no averaging, forming a 6/6 mm area. The OCT scan was assessed for the presence of a vitreous signal, using the 3D mode; where the vitreous signal is more visible since OCT signals from adjacent line scans are used to build a three-dimensional structure. Following the OCT scanning, the patient was assessed at the slit lamp by a masked physician and the agreement between the slit lamp examination and the OCT was thereafter assessed.

For the second part of the study, patients with macular pathology requiring vitrectomy were recruited. The inclusion criteria for the study were as follows: (1) Listing for macular surgery, (2) clear optical media, (3) refractive error <6 diopters, (4) no previous retinal surgery, (5) no proliferative diabetic retinopathy, and (6) no retinal detachment. The exclusion criteria were as follows: (1) No OCT scan performed on the day of surgery, (2) missing data on the operative form, (3) <21 years of age, and (4) unable to give informed consent. On the day of surgery, patients had a pre-operative OCT scan with the same protocol as the pilot study detailed above. During the vitrectomy, the surgeon, who was masked to the study OCT scan, assessed the following surgical signs: The presence of a visibly detached posterior hyaloid membrane attaching to the vitreous base and the presence of a fish-strike sign using a Flynn flute flexible silicone-tipped cannula and the induction of a PVD during surgery. OCT scans were assessed by a separate clinician who was masked to the surgical findings. OCT scans were assessed for the signs defined by the pilot study. The 3D mode was chosen to visualize the presence of any vitreous signal within the scan volume. The macular diagnosis for each case was based on the OCT findings for this study.

Data processing and statistical analysis

Data were treated statistically with excel spreadsheets (Excel 2010, Microsoft Corporation). Two-tailed Fisher's exact test was performed using an online calculator (http://research.microsoft.com/en-s/um/redmond/projects/mscompbio/fisherexacttest/).

Results

In the pilot study, 11 of 19 patients were found not to have a PVD and for 10 of these patients, the OCT found evidence of an attached vitreous. The remaining eight patients were found to have a PVD, and for seven of these, there was no evidence of attached vitreous on OCT. This gave a 91% (10/11) sensitivity of the OCT detecting an attached posterior vitreous and 88% (8/9) specificity.

In the pilot study, a number of OCT signs were found which supported the finding of an attached posterior vitreous including the visualization of an attached posterior hyaloid face or vitreous strands to the disk with or without attachments to the retina or blood vessels [Figure 1]. The absence of any vitreous signal within the scan volume was an indication of a PVD [Figure 2].

In total, 103 patients were recruited. 53 patients were subsequently excluded: 14 patients were found not to meet the study inclusion criteria, while 10 patients had no OCT scan performed on the day of surgery, and 26 patients had missing data on the operative form.

Of the 67 patients who completed the study, 37 patients had a full thickness MH (FTMH), while 23 had ERM, 4 had vitreomacular traction syndrome, and 2 had lamellar MH associated with an ERM, and one case had macular edema without an apparent ERM. Of the 23 ERM seen, 13 extended beyond the temporal vascular arcades as seen on OCT, while 10 appeared to remain confined within the arcade vessels.

Of the 67 recruited patients, 49 eyes were found to have an attached posterior vitreous at surgery and the remaining 18 had a PVD present. The OCT analysis showed 42 eyes had evidence of an attached posterior vitreous and 14 eyes had no evidence of attached posterior vitreous. In 11 eyes, there were no OCT diagnostic criteria met as the OCT could not detect the posterior hyaloid membrane, but there was possible vitreous signal within the scan area. These results are summarized in Chart 1.

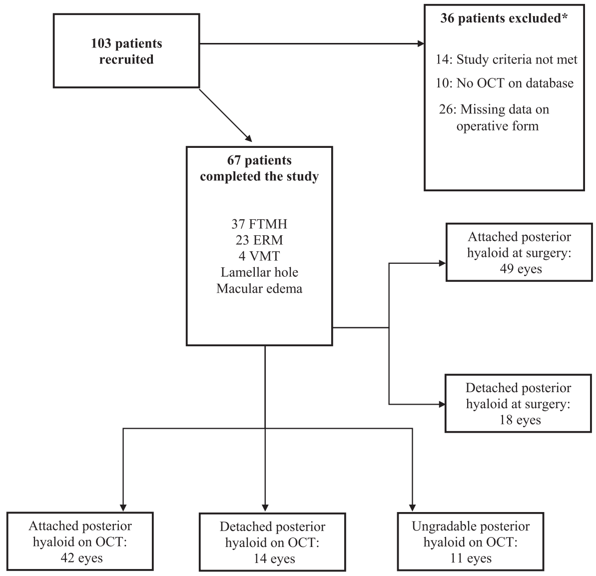

Chart 1: Patient numbers and results of operative and OCT findings. *Patients may have more than one reason for exclusion. FTMH: Full-thickness macular hole, ERM: Epiretinal membrane, VMT: Vitreomacular traction syndrome

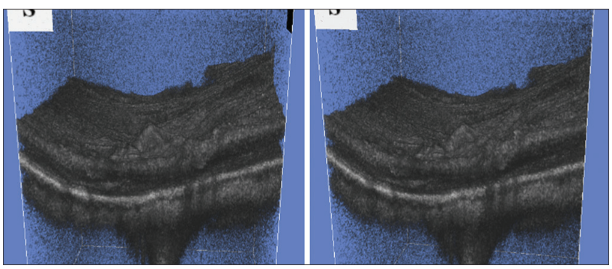

Figure 1: Optical coherence tomography showing no vitreous signal anterior to the retina and disk

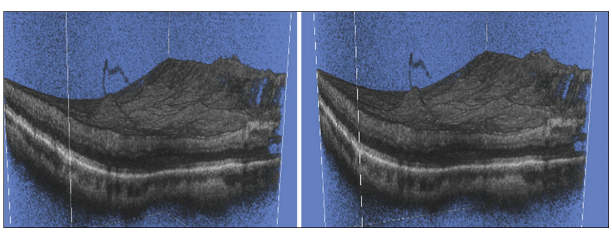

Figure 2: Optical coherence tomography showing an attached vitreous to the disk

For all pathologies, 49 of 67 eyes had attached posterior vitreous at surgery. Including equivocal results, the OCT had 80% sensitivity and 56% specificity in detecting attached posterior vitreous, which gave a 93% positive predictive value and 71% negative predictive value. Excluding ungradable results, sensitivity rose to 91% and specificity was 71% [Table 1].

For FTMH, 32 of 37 eyes had attached posterior vitreous at surgery. 11 eyes (26%) had an equivocal OCT result. OCT including equivocal OCT results had 88% sensitivity and 60% specificity in detecting attached posterior vitreous, which gave a 93% positive predictive value and 75% negative predictive value. Excluding ungradable OCTs sensitivity rose to 97% and specificity was 60% [Table 2].

For patients with ERM, 11 of 23 eyes had attached posterior vitreous at surgery. Eight eyes (35%) had an equivocal OCT result. OCT including equivocal OCT results had 45% sensitivity and 50% specificity in detecting attached posterior vitreous, which gave an 83% positive predictive value and 33% negative predictive value. Excluding equivocal results, sensitivity rose to 63% and specificity was 86% [Table 3]. Figure 3 shows a false-positive case and Figure 4 a false-negative case.

Cases of FTMH were more likely to have an OCT meeting grading criteria, compared to ERM (Table 4, Fisher's exact test: $P = 0.0153$ [two-tailed], statistically significant association).

Optical coherence tomography (OCT) data were obtained from the four locations on the optic disk, macula, superior temporal, and inferior temporal vascular arcade. For patients with confirmed attachments of the posterior vitreous at surgery, only the MH group had enough number of eyes for analysis. All patients with no PVD had on OCT the vitreous visibly attached to the optic disk (which was the OCT definition of attached posterior vitreous). Half of cases had detached posterior hyaloid from the macular surface and slightly more than that had detached posterior hyaloid from the retina around the temporal vascular arcades. Table 5 summarizes these results.

Discussion

For MH, there was a good agreement between surgical findings and the OCT interpretation of the posterior hyaloid. The diagnostic ability of spectral-domain OCT mainly relies on the detection of a partially detached posterior hyaloid membrane as this serves as the primary interface where signal is detected. The pathology of an FTMH depends at least on a partial separation of the posterior hyaloid membrane from the surface of the macula. Detecting the attachment of the posterior hyaloid membrane to the disk with OCT is a sensitive sign of an attached posterior vitreous. The attachments of the posterior vitreous to the posterior retina were variable in cases of FTMH. In around half of the cases, the only attachment of the vitreous to the posterior pole was at the optic disc, and not at the macula or temporal vascular arcades. This finding is in keeping with previous studies on the evolution of PVD both in normal eyes[5] and fellow eyes of patients with a preexisting unilateral MH.[6]

The difference in sensitivity and specificity of OCT as a diagnostic tool for attached posterior vitreous differs greatly between cases of FTMH and cases of ERM. For the former, OCT carries a good diagnostic sensitivity of predicting an attached vitreous at surgery, if the vitreous signal is detected on OCT. OCT diagnostic criteria were met in the vast majority of

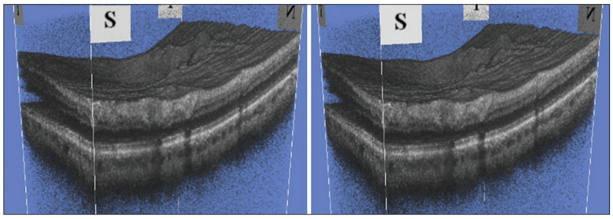

Figure 3: An example of a false-positive case in an epiretinal membranes patient. No obvious vitreous signal anterior to the retina on OCT but attached posterior vitreous found at surgery

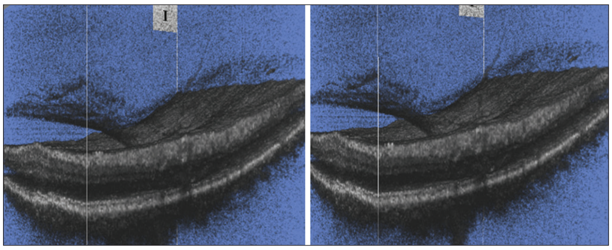

Figure 4: An example of a false-negative case in an epiretinal membranes patient. Obvious vitreous signal anterior to the retina on OCT but detached posterior vitreous found at surgery

Table 1: OCT versus surgery: Results for all pathologies

All pathologies	Surgery no PVD	Surgery PVD	Total
OCT no PVD	39	3	42
OCT PVD	4	10	14
OCT ungradable	6	5	11
Total (OCT criteria met)	43	13	56
Total	49	18	67

PVD: Posterior vitreous detachment, OCT: Optical coherence tomography

Table 2: OCT versus surgery: Results for FTMH

FTMH	Surgery no PVD	Surgery PVD	Total
OCT no PVD	28	2	30
OCT PVD	1	3	4
OCT Ungradable	3	0	3
Total (OCT criteria met)	29	5	34
Total	32	5	37

MH: Macular holes, PVD: Posterior vitreous detachment, OCT: Optical coherence tomography, FTMH: Full-thickness macular hole

Table 3: OCT versus surgery: Results for ERM

ERM	Surgery no PVD	Surgery PVD	Total
OCT no PVD	5	1	6
OCT PVD	3	6	9
OCT Ungradable	3	5	8
Total (OCT criteria met)	8	7	15
Total	11	12	23

ERM: Epiretinal membranes, PVD: Posterior vitreous detachment, OCT: Optical coherence tomography

Table 4: OCT criteria versus macular pathology

Pathology	OCT criteria met	OCT criteria not met
FTMH	34	3
ERM	15	8

FTMH: Full-thickness macular hole, ERM: Epiretinal membranes, OCT: Optical coherence tomography

Table 5: Vitreous attachments visualized on OCT in cases with attached posterior vitreous confirmed on surgery

OCT attachments	FTMH
Disk	28/28
Macula	14/28
Superior retina	10/28
Inferior retina	11/28
Total	28

OCT: Optical coherence tomography

FTMH cases (34 of 37 eyes). On the other hand, OCT could not predict the state of posterior vitreous attachment for ERM, with many examples of apparent vitreous signal and a PVD observed at surgery and vice versa, no OCT signal seen with attached posterior vitreous. There were cases where the posterior vitreous was completely attached with no separation of the posterior hyaloid membrane from the retinal surface. The OCT did not have enough definition to distinguish between cortical vitreous and a posterior vitreous cavity free from vitreous. Moreover, undulations of the ERM were mistaken for the posterior hyaloid membrane and attached vitreous was predicted in cases where a full PVD was found at surgery. Therefore, the detection of an apparent posterior hyaloid membrane is not a reliable sign in predicting attached vitreous in ERM.

The anatomic detail visible with spectral-domain OCT appears to be a limiting factor with respect to its ability to visualize the vitreous. The posterior hyaloid membrane was clearly seen in many eyes, mainly with FTMH, but in eyes with ERM, the OCT would not reliably detect vitreous cortex if the hyaloid membrane was not partly detached from the retinal surface. This was more common in cases of ERM. The OCT machine used in this study uses single OCT line scans without averaging. OCT platforms from other manufacturers are able to average a number of line scans to improve anatomic definition and reduce noise. This may improve the diagnostic sensitivity of the OCT. Swept source OCT (ss-OCT) is now providing even better imaging capabilities of the posterior segment. The visualization of the vitreoretinal interface appears to be very good although ss machines use longer wavelengths to image structures deeper to the retina, which limits the amount of anatomic detail visible at the level of the posterior vitreous and retina.[7] Indeed, as many as 25.6% of patients can still not have the status of the PVD graded on ss-OCT.[8] Until validation studies are carried out using these new OCT techniques on cases with ERM, we advise caution in interpreting posterior vitreous attachments. Indeed, spectral-domain OCT is currently the most widely used OCT technology, and this study confirms its use in predicting the state of posterior vitreous attachment in MH. However, it also highlights its limitations in determining the vitreous state in cases of ERM.

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