Importance of subfoveal fluid height on visual outcome in macula-off retinal detachments

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ABSTRACT

Aims To investigate the effect of subfoveal fluid height (SFFH) on visual outcome after macula-off retinal detachment (RD) repair.

Methods Prospective interventional case series of consecutive patients undergoing pars plana vitrectomy with gas tamponade (PPV) for primary macula-off RD with duration of symptomatic loss of central vision (LCV) of ≤1 week. Preoperative SFFH was measured on two occasions an hour apart using optical coherence tomography (OCT) by two independent observers. Postoperative best corrected visual acuity (BCVA) was measured at 3 months.

Results Sixty-one patients were included. All patients were pseudophakic after RD repair. The mean preoperative and postoperative BCVA (logarithm of the minimum angle of resolution) at 3 months was 1.41 (±0.71) and 0.15 (±0.12, range 0.00–0.70). Twenty-six patients with SFFH of ≤1500 µm were available for repeat OCT measurements. The variation in SFFH was proportional to the SFFH and showed a logarithmic (base 2) association (r=0.50, p=0.01). Patients were therefore grouped according to their SFFH as group 1: 1–100 µm, group 2: 101–300 µm, group 3: 301–700 µm, group 4: 701–1500 µm and group 5: 1501–3100 µm. BCVA at 3 months significantly reduced with increasing SFFH from 0.04 (±0.03) in group 1 to 0.28 (±0.15) in group 5 (p<0.001) but was not associated with age (p=0.77), preoperative BCVA (p=0.39), duration of LCV (p=0.63) or use of perfluorocarbon liquids (p=0.88). Forty-five patients had SFFH ≤1500 µm and achieved 0.10 (±0.07, range 0.00–0.30) logMAR.

Conclusion Visual acuity following PPV for macula-off RD is related to preoperative SFFH regardless of the duration of symptomatic LCV within the first week.

Key messages

What is already known on this topic

⇒ Visual outcome after macula-off retinal detachment repair depends on duration and submacular fluid height.

What this study adds

⇒ For macula-off retinal detachments within 1 week of duration of symptomatic loss of central vision, postoperative visual acuity at 3 months after vitrectomy and gas tamponade is related to the preoperative subfoveal fluid height (SFFH) measured on optical coherence tomography, but not to the duration of symptomatic loss of central vision.

How this study might affect research, practice or policy

⇒ Since an increase in SFFH is associated with a worse visual outcome, and a clinician cannot know to what extent the preoperative SFFH will increase further and over what period, it would seem sensible to operate as soon as feasible, before there is further increase in SFFH.

Although the visual prognosis for macula-on (fovea-sparing) retinal detachments (RDs) is good, it is less predictable in macula-off (fovea-involving) RDs. The preoperative status of the macula, therefore, has become the main factor upon which the urgency of required RD surgery is currently based, with macula-off RDs and their less favourable visual prognosis being classified as less urgent than macula-on RDs.

Factors reported to be associated with functional recovery after macula-off RD include preoperative visual acuity, duration and height of macular detachment and age.[1–16] Confounding factors include inaccuracy regarding the duration of symptomatic loss of central vision (LCV) particularly in retrospective case series, measurement of subfoveal fluid height (SFFH), surgical technique and lens status. Surgery has either been done with scleral buckling (SB),[1] where residual postoperative blebs of submacular fluid may prolong macular detachment with an uncertain effect on visual outcome, or the cases were mixed with pars plana vitrectomy (PPV),[8 10 11 14] and various proportions of phakic patients with an unclear degree of postoperative cataract formation were included.[1 7–10 15] Only few studies have measured the height of macular detachment, mostly by B-scan ultrasound,[11 13] which would not have been able to detect the precise location of the fovea. While some studies suggest that visual outcome is better for duration of macular elevation ≤3 days,[1 8 15] others have not found any difference for those operated within a week.[7 9 10]

The aim of this prospective study, therefore, was to investigate the effect of SFFH and duration of symptomatic LCV within 1 week on visual outcome following RD repair with PPV and gas tamponade.

METHODS

Patients

Consecutive patients undergoing primary PPV with gas tamponade for macula-off RD at the Technical University of Munich, Ophthalmology

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Department, Hospital rechts der Isar, Germany between October 2019 and September 2021 were enrolled in the study. Inclusion criteria were primary macula-off RD undergoing PPV with gas tamponade in one eye, with pre-existing intraocular lens implant in the capsular bag or in an eye that underwent combined cataract extraction and PPV (CE/PPV) with phacoemulsification and intraocular lens implantation into the capsular bag at the time of RD repair. Only patients were included with a history of duration of symptomatic LCV ≤7 days before surgery. Exclusion criteria were previous RD surgery or any other previous ocular surgery apart from cataract surgery, pre-existing visually relevant co-pathology including epiretinal membranes and other retinal pathology, proliferative vitreoretinopathy, a history of more than −8 D myopia prior to cataract surgery, a history of trauma or amblyopia, inability to determine the time point of LCV and an unclear status of the fovea hidden behind a bullous retinal detachment.

All patients underwent full ophthalmological examination preoperatively, including best spectacle corrected visual acuity (BCVA) measured with a decimal chart, and optical coherence tomography (OCT) scanning of the macula on the day of surgery. Duration of macular detachment was defined as the interval between the onset of symptomatic LCV and surgery, according to the patient's history. Follow-up with repeat examinations including BCVA with refraction and OCT scan were scheduled 3 months after surgery.

Optical coherence tomography

A standard linear macular volume OCT scan (19 horizontal lines with 240 µm spacing; Spectralis OCT, Heidelberg Engineering, Germany) was performed while the patient was asked to fixate a target light presented to the unaffected eye. The SFFH was defined as the distance between the outer surface of the detached neurosensory retina at the central fovea and the inner surface of the perpendicularly underlying retinal pigment epithelium (RPE). The SFFH was measured by two independent vitreoretinal surgeons using the built-in OCT software calliper tool (online supplemental figure 1). To measure the preoperative variation in the SFFH, patients who had not already proceeded to further investigations or surgery had a repeat OCT scan after 1 hour while remaining in the upright position. In patients in whom the RPE and the elevated fovea could not be fully captured on one OCT image because the height of the foveal detachment exceeded the OCT imaging range, the postoperative distance between the reattached fovea and the margin of the optic disc (along a line connecting the fovea with the disc centre) was measured to calculate the theoretical maximum possible SFFH.

Surgery

All patients underwent primary standard 23-gauge PPV (EVA, DORC International, Zuidland, the Netherlands) by three vitreoretinal surgeons. Retinal tears were treated by endolaser and/or cryoretinopexy, and adjunctive perfluorocarbon liquids (PFCLs) were used or a posterior retinotomy was performed to flatten the retina in some cases. Fluid–air–gas exchange was performed using either 20% sulfur hexafluoride (SF_6), 16% perfluoroethane (C_2F_6) or 12% perfluoropropane (C_3F_8) as tamponade. All patients were asked to posture face down for 24 hours after surgery and then to posture according to the location of retinal breaks.

Statistical analysis

Patient data analysed included age, duration of symptomatic LCV, preoperative BCVA, SFFH, type of gas, use of PFCL, combined cataract surgery and postoperative BCVA at 3 months. BCVA collected as decimal visual acuities was converted to the logarithm of the minimum angle of resolution (logMAR) with non-numerical values count fingers=1.88 logMAR and hand movement=2.30 logMAR.[17] Values were reported as mean (±SD) and median (quartiles) for non-parametric data. All statistical analyses were performed using SPSS statistical software (V.27). Non-parametric tests were used for categorical variables and parametric for continuous variables that were normally distributed. A general linear model was used to test for significant associations between BCVA at 3 months and preoperative BCVA, age, duration of symptomatic LCV, SFFH, and the use of PFCL and combined phacoemulsification as covariates and factors. A Bonferroni correction was made for multiple tests.

RESULTS

Seventy-three patients were recruited for the study, of whom nine patients were excluded due to failure of primary surgery, and three patients due to lack of 3-month follow-up. Sixty-one eyes of 61 patients were included in the analysis (44 men and 17 women) with a mean age of 63.8 (±9.1) years. Thirty-seven patients reported ≤3 days and 24 patients 4–7 days symptomatic LCV. Forty-two patients were already pseudophakic and 19 underwent combined CE/PPV. All patients were left pseudophakic with an intraocular lens implant in the capsular bag. In 30 patients, PFCL was used intraoperatively to flatten the retina. At the end of the procedure, 20% SF_6 was used as tamponade in 2 patients, 16% C_2F_6 in 26 patients and 12% C_3F_8 in 33 patients. No intraoperative complications were reported. One patient had residual small PFCL bubbles in the anterior chamber without any signs of inflammation and clear optical media, three patients developed a mild epiretinal membrane and two patients developed mild cystoid macular oedema that responded to anti-inflammatory eye drops.

The mean preoperative and postoperative BCVA at 3 months was 1.41 (±0.71) and 0.15 (±0.12) logMAR. For the measurement of SFFH, the intraobserver correlation coefficient was 0.99 for both observers, and the interobserver correlation coefficient for the same scan was 0.98 at baseline and 0.99 at 1 hour. The first measurements of observer one were used for the analysis. There was no significant association between BCVA at 3 months and the duration of symptomatic LCV (p=0.52) (figure 1). There were no significant differences in preoperative BCVA (p=0.22), SFFH (p=0.61), age (p=0.23), use of PFCL (p=0.70), combined phacoemulsification (p=0.77) and postoperative BCVA at 3 months (p=0.79) between patients with duration of symptomatic LCV of ≤3 days compared with those with 4–7 days.

Repeat OCT measurements after 1 hour to assess variation of the SFFH measurements

Forty-five patients had SFFH ≤1500 µm measurable on OCT, of whom 26 were available for repeat OCT measurements after 1 hour with the patient remaining in the upright position. The mean absolute change in SFFH was 62.31 (±45.34) µm. This change in SFFH varied according to the SFFH (figure 2A) with a logarithmic (base 2) association (r=0.50, p=0.01) (figure 2B).

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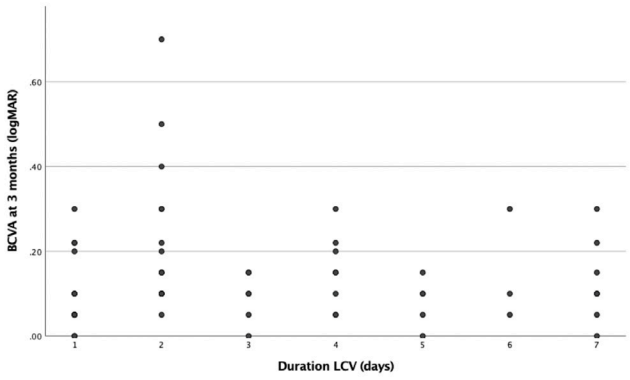

Figure 1 There was no significant association between BCVA at 3 months and the duration of LCV (p=0.52). BCVA, best corrected visual acuity; LCV, loss of central vision; logMAR, logarithm of the minimum angle of resolution.

Analysis of visual outcome based on groups of increasing SFFHs

Based on the logarithmic (base 2) association between the variation in SFFH and the SFFH, patients were grouped with consecutive doubling of the group bin widths as follows: group 1: 1–100 µm (n=4), group 2: 101–300 µm (n=7), group 3: 301–700 µm (n=17), group 4: 701–1500 µm (n=17) and group 5: 1500–3100 µm (n=16). The mean postoperative fovea-to-disc margin distance in group 5 was 3524 (±386) µm, which would constitute the theoretical maximum possible SFFH. Since the detached retina is not only fixated at the optic disc but also 360° at the ora serrata and variably at areas where the retina remains attached, the true SFFH would be less than 3524 µm. Therefore, the calculated upper limit of group 5 with 3100 µm is the best estimate available.

There were no significant differences in the duration of symptomatic LCV between the five SFFH groups (p=0.39). There was a significant association between the BCVA at 3 months and SFFH group (p<0.001). BCVA at 3 months reduced between groups 1 and 5 with 0.04 (±0.03) in group 1, 0.05 (±0.05) in group 2, 0.09 (±0.04) in group 3, 0.14 (±0.07) in group 4 and 0.28 (±0.15) in group 5 (p<0.001) (figure 3).

Post-hoc analysis with a Bonferroni correction showed significant differences in BCVA at 3 months between groups 1 and 4 (p=0.017) and 5 (p<0.001), groups 2 and 4 (p=0.021) and 5 (p<0.001), groups 3 and 5 (p<0.001) and between groups 4 and 5 (p=0.003) but not between groups 1 and 3 (p=0.16). BCVA at 3 months was significantly associated with the SFFH group (p=0.002) but not age (p=0.77), preoperative BCVA (p=0.39), duration of symptomatic LCV (p=0.63), combined phacoemulsification (p=0.95) or use of PFCL (p=0.88).

Subanalysis of visual outcome based on SFFH measurements ≤1500 µm as a continuous variable

Forty-five patients had an SFFH ≤1500 µm measurable on OCT. Mean postoperative BCVA at 3 months was 0.10 (±0.07, range 0.00–0.30). There were significant linear associations between the SFFH and preoperative BCVA (R^2=0.45, p<0.001), and between the SFFH and BCVA at 3 months whether for patients with duration of symptomatic LCV of ≤3 days (R^2=0.69, p<0.001) or 4–7 days (R^2=0.85, p<0.001). There was no association between SFFH and duration of symptomatic LCV (R^2=0.015, p=0.43), and no significant correlation between

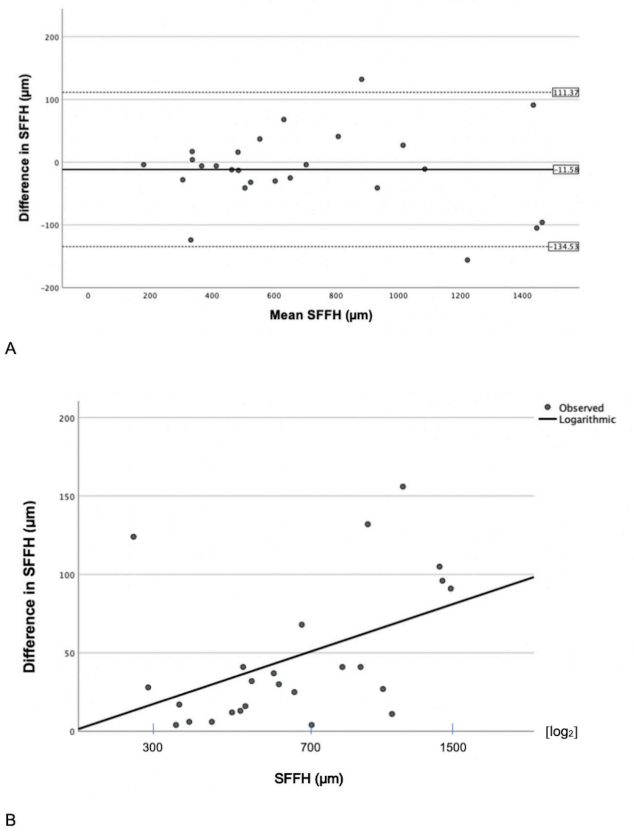

Figure 2 (A) The difference in SFFH measurements between baseline and after 1 hour (y-axis) against the mean of the two measurements (x-axis). Note that as the SFFH increases, the spread of the SFFH measurements after 1 hour around the mean increases, too (the continuous line marks the mean, the dashed lines the upper and lower limits of the 95% CI). (B) The absolute change in SFFH after 1 hour against the SFFH at baseline following a linear increase with the logarithm (base 2) of the SFFH (r=0.50, p=0.01). SFFH, subfoveal fluid height.

symptomatic LCV and postoperative BCVA (R^2=0.07, p=0.07). There were significant univariate correlations between preoperative and postoperative BCVA (R^2=0.30, p<0.01), and age and postoperative BCVA (R^2=0.09, p=0.04); but when other factors were included in the multivariable model, these were no longer significant.

In the multivariable model, postoperative BCVA at 3 months was significantly associated with the SFFH (p=0.005) (figure 4) but not age (p=0.80), preoperative BCVA (p=0.35), duration of symptomatic LCV (p=0.16), combined phacoemulsification (p=0.68) or use of PFCL (p=0.52).

DISCUSSION

The outer layers of the retina obtain their nutrition from the choriocapillaris.[18] Retinal detachment disrupts the contact between the RPE and the photoreceptor outer segments. This reduces the diffusion of oxygen and other metabolites, leading to photoreceptor cell damage and reduced visual outcomes despite the successful surgical repair of macula-off RDs. It is likely, therefore, that the greater the distance between the RPE and the photoreceptors, the less diffusion is possible.

The association between visual outcome and preoperative submacular fluid height using OCT has been described but with

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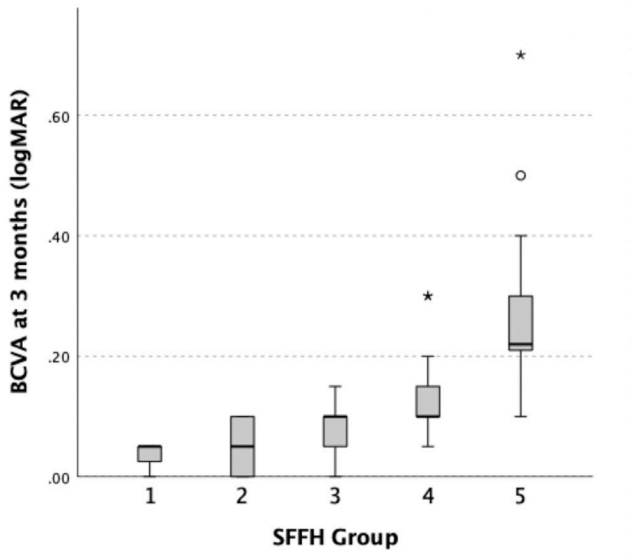

Figure 3 Mean BCVA at 3 months reduced between groups 1 and 5 (p<0.001, ° and * indicate outliers). BCVA, best corrected visual acuity; logMAR, logarithm of the minimum angle of resolution; SFFH, subfoveal fluid height.

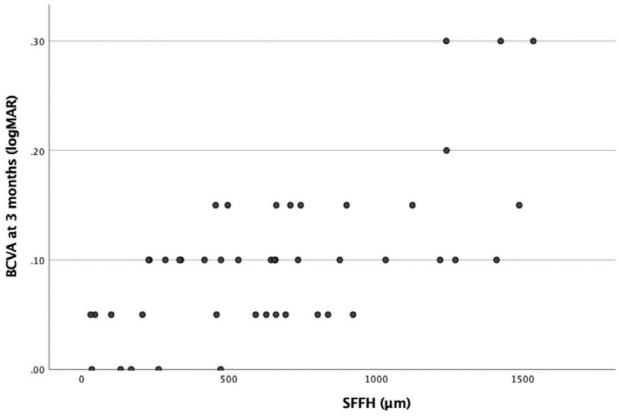

Figure 4 For patients with SFFH ≤1500 µm, BCVA at 3 months was associated with the SFFH as continuous parameter (p=0.005). BCVA, best corrected visual acuity; logMAR, logarithm of the minimum angle of resolution; SFFH, subfoveal fluid height.

limitations, because for patients with higher SFFHs, the SFFH exceeds the conventional OCT imaging range, and the SFFH for those patients has either been measured from the outer surface of the detached fovea to the bottom of the OCT imaging area, which would have underestimated the SFFH,[12] or patients were divided into groups of arbitrarily chosen cut-offs with <1000 µm vs ≥1000 µm SFFH[14] or ≤250 µm vs >250 µm and unmeasurable.[16] Some studies measured the submacular detachment height by B-scan ultrasonography in eyes with duration of symptomatic LCV ≤7 days and found the macular height to be the most important predictive factor for visual outcome and either found no impact of duration[11] or did not stratify for it.[13] However, localisation of the fovea on ultrasound is difficult, and therefore the measurement of SFFH was less precise than using OCT.

We found significant variation in SFFH in some of the patients which may depend on various factors such as the patient's head and eye movements between scans, mobility of the detached retina, the viscosity of the subretinal fluid and the vitreous state. This variation, however, was proportional to the logarithm of the height of fluid and therefore formed the basis for using above SFFH groups. We found that BCVA at 3 months progressively declined with increasing SFFH, independent of the duration of symptomatic LCV.

In most previous studies, patients have been treated by SB and PPV.[11–14] Persistent subretinal fluid blebs at the macula are seen in 27%–78% of patients successfully treated by SB surgery, which may[5 14 19] or may not[2–4] have a deleterious effect on visual outcome. They are, however, much less frequent after PPV.[6] This suggests that full macular reattachment is achieved faster and therefore the duration of foveal elevation is more clearly defined following PPV compared with SB. Therefore, we only included eyes following PPV and none of our patients demonstrated persistent subfoveal fluid on their first postoperative OCT at 1 month. Furthermore, previous studies have included phakic patients at final follow-up and the degree of cataract formation is unclear, which may have affected the measured visual acuity. In our study, all patients were pseudophakic after RD repair.

Yorston *et al*[15] recently presented the results of the largest analysis to date, evaluating 2074 eyes with macula-off RD treated by PPV and gas tamponade; only a minority had silicone oil as tamponade or combined SB surgery. Visual acuity outcome was defined as success if ≤0.3 logMAR at ≥2 months and this was achieved in pseudophakic patients without any other co-pathologies depending on the duration of symptomatic LCV in 83.5% for LCV of ≤2 days, 76.1% for 3–4 days and 68.7% for 5–7 days; however, the preoperative height of macular detachment was not considered. We did not find any significant association between visual acuity outcome and duration of symptomatic LCV (≤3 days and 4–7 days) when SFFH was included; however, all 45 patients with SFFH ≤1500 µm achieved ≤0.3 logMAR at 3 months with a mean of 0.10 (±0.07).

We are aware that our study has limitations. The duration is based on the history of symptoms of LCV the patient provided and is not objective although the same applies to other studies. The number of patients included in this study is not very high and we had fewer patients with SFFH measurements in groups 1 and 2 than groups 3–5. Despite this, there was a consistent association between SFFH group and visual outcome. The follow-up period of 3 months is relatively short, and it may take longer, maybe even years to reach the final visual outcome. The relatively good BCVA at 3 months, however, is encouraging. Contrary to the symptomatic duration of LCV, which is an unreliable measure, SFFH is a more objective predictor of visual outcome. Measurement of and variation in SFFH are, however, an issue for higher SFFHs. We accommodated for this variation by increasing the group bin widths for increasing SFFH measurements which also enabled inclusion of patients with SFFH >1500 µm. There was a clear and significant association between visual outcome and SFFH, whether the SFFH measurements were grouped across the entire possible range or analysed as continuous parameter for values ≤1500 µm.

A larger number of patients is required to evaluate if there are distinct levels of SFFH that are particularly associated with different levels of visual outcome, that is, if there is a kind of threshold effect at which point the distance between the photoreceptors and the RPE is too big for metabolic exchange, and irreversible damage occurs.

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For all RDs, whether macula on or off, there will be an initial time-dependent increase in subretinal fluid and consecutively in the SFFH.[20–22] The increase in and the maximum of subretinal and SFFH will depend on factors such as type, size and location of retinal breaks, extent of the RD, traction on the retina, the status of the vitreous and positioning of the patient. It is difficult, however, to know if SFFH will increase further and over what period. Considering that an increase in SFFH is associated with a worse visual outcome, it would seem sensible to operate as soon as feasible, before there is further increase in SFFH.

Contributors The study was designed by CB and SK. Data were collected and validated by NJ-M, AA, MM and CB. Analysis of the data was performed by CB and SK. The manuscript was drafted by CB and reviewed by SK. All authors have commented on previous versions and read and agreed to the published version of the manuscript. CB accepts full responsibility for the finished work and the conduct of the study, had access to the data, and controlled the decision to publish.

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Patient consent for publication Obtained.

Ethics approval This study involves human participants and was approved by the Ethics Committee of the Technical University of Munich (ID:391/19S). Participants gave informed consent to participate in the study before taking part. The study adhered to the tenets of the Declaration of Helsinki.

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Data are available upon reasonable request.

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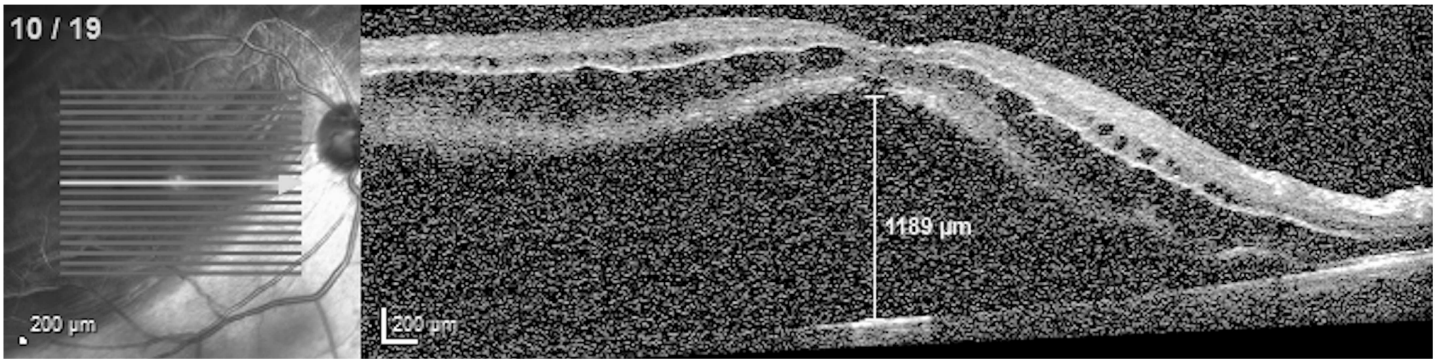
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