Posterior Vitreous Detachment in Normal Healthy Subjects Younger Than Age Twenty

Ayumi Hayashi, Yoko Ito, Yuki Takatsudo, Naoto Hara, Peter L. Gehlbach, and Keisuke Mori

1Department of Ophthalmology, International University of Health and Welfare, Nasushiobara-shi, Tochigi, Japan
2Wilmer Eye Institute, Johns Hopkins University School of Medicine, Baltimore, Maryland, United States

Correspondence: Keisuke Mori, Department of Ophthalmology, International University of Health and Welfare, Nasushiobara-shi, Tochigi, Japan; cfh.hra1.arms2@gmail.com, keisuke@ihuw.ac.jp.

Received: July 24, 2021
Accepted: September 27, 2021
Published: October 22, 2021


https://doi.org/10.1167/iovs.21-26877

Purpose. To describe the initiation of posterior vitreous detachment (PVD) in the eyes of normal individuals, under 20 years of age, using wide-angle optical coherence tomography (OCT).

Methods. This is an observational cross-sectional study. Montaged images of horizontal and vertical OCT scans were obtained in 63 healthy eyes of 35 consecutive subjects ranging in age from 4 to 17 years.

Results. Forty-five eyes (71.4%) had obvious PVD, defined as a contiguous line of posterior cortical vitreous separated from the surface of the retina. Eighteen eyes (28.6%) had no PVD. The mean age of the individuals without PVD was significantly younger than those with PVD (P = 0.008). The spatial distribution of PVD initiation was highest in the superior quadrants, with the nasal, inferior, septum papillomaculae, and temporal quadrants following in descending order of frequency (P < 0.001). PVD was observed to begin anterior to the premacular liquefied lacuna, where the vitreous gel directly adheres to the vitreoretinal interface. In the majority of subjects (80.6%), PVD was initiated anterior to the vascular arcades.

Conclusions. PVD can be observed by OCT to begin in the first and second decade of life. It begins in the mid-peripheral vitreous, most frequently in the superior quadrants anterior to the vascular arcades. In this study, all PVDs originated outside of the macular liquefied lacunae, where the vitreous gel adheres directly to the retina.

Keywords: posterior vitreous detachment, juvenile, optical coherence tomography, wide-angle

Posterior vitreous detachment (PVD) is one of the most important age-related events in the human eye. A separation of the posterior cortical vitreous from the internal limiting membrane of the retina is the fundamental change. PVD is considered complete when separation of the vitreous from the retina occurs in all areas posterior to the vitreous base. PVD is now believed to be a progressive process occurring throughout life and usually completes by age twenty.[1] PVD has been studied in autopsy eyes without ocular disorders. In recent studies using ultrasonography and optical coherence tomography (OCT), it has been suggested that PVD begins in the macular region during middle age as a result of progressive vitreous liquefaction.[2–5,14] Although OCT is capable of high-resolution images of the vitreoretinal interface, standard OCT imaging protocols capture only the macular region, within a 9- to 12-mm radius, and thus may miss changes occurring in the mid-peripheral and peripheral fundus. To overcome this limitation, we have developed a wide-angle OCT imaging method that enables observation of the vitreoretinal interface from the macula to approximately the equator.[16–18] The feasibility of this montage imaging technique has now been replicated by other study groups.[19–21] Utilizing this method, we have reported that PVD changes are detectable predominantly in the midperipheral and peripheral regions in more than 90% of eyes in the third decade of life.[7]

In the same report, for subjects older than 20 years old, PVD was classified into the following five stages: stage 0, no PVD present; stage 1, peripheral PVD limited from paramacular to peripheral zone; stage 2, perifoveal PVD expanding to the periphery; stage 3, peripapillary PVD with persistent vitreopapillary adhesion alone; and stage 4, complete PVD. Stage 1 was subdivided into two categories: stage 1a, peripheral PVD with multilayered linear hyperreflective lines or interposed reflective material between retina and vitreous; and stage 1b, peripheral PVD without interposed material between retina and vitreous. Because most subjects in the

Downloaded from arvojournals.org on 12/19/2021
third decade already had associated changes with obvious PVD in the peripheral vitreous, the question was raised as to when, where, and how PVD is initiated. In this study, therefore, we further investigated the very early manifestations of PVD and its evolution by applying wide-angle OCT imaging to healthy eyes in young adults under 20 years of age.

**METHODS**

**Subjects and Study Design**

This was an observational cross-sectional study. A total of 63 eyes of 35 consecutive healthy normal volunteers younger than 20 years of age underwent wide-angle montage of OCT images of their entire viewable vitreoretinal interface at the International University of Health and Welfare between March 2018 and February 2019. The investigation adhered to all of the tenets of the Declaration of Helsinki. This study was approved by and conducted in compliance with the Ethics Committee of the International University of Health and Welfare (approval no. 13-B-225). Because the subjects were under 20 years of age, informed consent was obtained from the parents or guardians of the participants. The composition of the subject population was 20 female and 15 male participants, ranging in age from 4 to 17 years (mean ± SD, 9.9 ± 3.2) (Table 1). All subjects were examined by indirect ophthalmoscopy, slit-lamp biomicroscopic examination, refraction, and best-corrected visual acuity testing. All volunteers had best-corrected visual acuity of 20/20 or better with refractive error from −3.0 to +3.0 diopter. Refraction was measured by an autorefractometer (RK-F2; Canon, Tokyo, Japan) with the use of cycloplegic eye drops (1% cyclopentolate hydrochloride or 1% atropine). Excluded were eyes with present or past vitreous, retina, or choroid diseases; trauma; abnormal intraocular pressure; history of systemic diseases relating to ocular disorders; or family history of genetic ocular diseases. Because it is sometimes difficult to obtain cooperation and high-quality images with young children, we used an image quality index, TopQ Image Quality, with swept-source OCT (DRI OCT Triton Plus; Topcon, Tokyo, Japan). Although a TopQ Image Quality of greater than 40 (full score, 100) is considered appropriate, subjects were excluded when the TopQ Image Quality was less than 40 to allow for the precise delineation of fine vitreous structure.

**Wide-Angle Montage OCT Imaging**

Standardized horizontal and vertical vitreoretinal sections through the fovea were collected with swept-source OCT and montaged in order to observe the wider vitreoretinal interface, approximately to the equator. All scans were obtained by positioning the retinochoroidal layers at the papillomacular vitreous liquefaction, where the vitreous gel is directly adherent to the posterior cortical vitreous and the retinal surface. To precisely describe the location of PVD origin was spatially located primarily in the mid-peripheral and peripheral vitreous, anterior to the papillomacular vitreous liquefaction, where the vitreous gel is directly adherent to the posterior cortical vitreous and the retinal surface. Therefore, we further investigated the very early manifestations of PVD in the peripheral vitreous, the question was raised as to when, where, and how PVD is initiated. In this study, therefore, we further investigated the very early manifestations of PVD and its evolution by applying wide-angle OCT imaging to healthy eyes in young adults under 20 years of age.

**RESULTS**

In this group of volunteers younger than 20 years of age, all 63 eyes were classified as stage 0 or stage 1a. Stage 0 was defined as without PVD, and stage 1a was defined as having an obvious contiguous line of posterior cortical vitreous separated from the surface of the retina in the peripheral region (anterior to the macular region), associated with interposed reflective material or multilayered hyperreflective lines between the retina and vitreous. Of the 63 eyes examined, 18 eyes had stage 0 PVD (28.6%; mean age, 28.6 years; range, 2–17 years). Stage 1a was defined as having an obvious contiguous line of posterior cortical vitreous separated from the surface of the retina in the peripheral region (anterior to the macular region), associated with interposed reflective material or multilayered hyperreflective lines between the retina and vitreous. Of the 63 eyes examined, 18 eyes had stage 1a PVD (28.6%; mean age, 28.6 years; range, 2–17 years).

**Table 1. Demographic Features and PVD Stages**

<table>
<thead>
<tr>
<th>Demographic</th>
<th>PVD Stage 0</th>
<th>PVD Stage 1a</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male/female, n</td>
<td>8/10</td>
<td>20/25</td>
<td>28/35</td>
</tr>
<tr>
<td>Age (yr), mean ± SD (range)</td>
<td>8.2 ± 3.0 (4–14)</td>
<td>10.5 ± 2.9 (6–17)</td>
<td>9.8 ± 3.1 (4–17)</td>
</tr>
<tr>
<td>Decade, n (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First (0–9 yr)</td>
<td>13 (44.8)</td>
<td>16 (55.2)</td>
<td>29 (100)</td>
</tr>
<tr>
<td>Second (10–19 yr)</td>
<td>5 (14.7)</td>
<td>29 (85.3)</td>
<td>34 (100)</td>
</tr>
<tr>
<td>Total</td>
<td>18 (28.6)</td>
<td>45 (71.4)</td>
<td>63 (100)</td>
</tr>
</tbody>
</table>

*Because some subjects had different stages between right and left eyes, some data are expressed as the number of eyes (% of entire group).*
Table 2. Age, PVD Stages, and Incidence of OCT Findings

<table>
<thead>
<tr>
<th>Total Incidence, n (%)</th>
<th>Age (yr), Mean ± SD (Range)</th>
<th>PVD Stage 0, n (%)</th>
<th>PVD Stage 1a, n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bursa premacularis/PPVP</td>
<td>52 (82.5)</td>
<td>10.0 ± 3.1 (6–17)</td>
<td>13 (72.2)</td>
</tr>
<tr>
<td>Prevascular vitreous fissure</td>
<td>11 (17.5)</td>
<td>10.0 ± 2.8 (6–15)</td>
<td>2 (11.1)</td>
</tr>
<tr>
<td>Perpendicular vitreous fiber insertion</td>
<td>11 (17.5)</td>
<td>10.7 ± 2.5 (6–15)</td>
<td>1 (5.6)</td>
</tr>
<tr>
<td>Granular hyperreflections</td>
<td>49 (77.8)</td>
<td>9.5 ± 3.0 (4–16)</td>
<td>17 (94.4)</td>
</tr>
<tr>
<td>Discontinuous vitreoschisis</td>
<td>5 (7.9)</td>
<td>8.5 ± 2.2 (6–12)</td>
<td>2 (11.1)</td>
</tr>
<tr>
<td>Contiguous vitreoschisis</td>
<td>41 (65.1)</td>
<td>9.8 ± 3.0 (6–17)</td>
<td>9 (50.0)</td>
</tr>
</tbody>
</table>

PPVP, posterior pre cortical vitreous pocket.

8.2 ± 3.0 years; median, 7 years; range, 4–14 years), and 45 eyes had stage 1a PVD (71.4%; mean age, 10.5 ± 2.9 years; median, 10 years; range, 6–17 years). Stage 1a PVD was present in 55.2% of eyes in the first decade and in 85.3% of eyes in the second decade (Table 1). The mean age of the individuals with stage 0 PVD was significantly younger than those with stage 1a PVD (P = 0.008, t-test).

Premacular liquefied lacuna (so-called bursa premacularis or posterior pre cortical vitreous pocket) was demonstrated in 52 eyes examined (82.5%; mean age, 10.0 ± 3.1 years; range, 6–17 years). A prevascular vitreous fissure along the vascular arcade was observed in 11 eyes (17.5%; mean age, 10.0 ± 2.8 years; range, 6–15 years). Granular hyperreflection in the peripheral cortical vitreous was identified in 49 eyes (77.8%; mean age, 9.5 ± 3.0 years; range, 6–17 years) (Table 2).

Stage 0

Among 63 healthy eyes in this group of juveniles, 18 eyes (28.6%) had no evidence of PVD in any of the four quadrants imaged (Fig. 1). Granular hyperreflections were demonstrated in 17 eyes (94.4%) with stage 0 PVD. Thirteen eyes (72.2%) had a premacular liquefied lacuna, and perpendicular vitreous fiber insertion was seen in one eye (5.6%) (Table 2). Discontinuous vitreoschisis was found in two eyes (11.1%), and nine eyes (50.0%) had contiguous vitreoschisis (Table 2, Fig. 2). Unlike contiguous vitreoschisis, there was a confined and very narrow, but distinct, stratification of the posterior vitreous cortex, conveniently defined as “discontinuous vitreoschisis,” which was consistently distributed anterior to the vascular arcade (arrowheads in C). In the right eye (D), areas of discontinuous vitreoschisis (arrowheads) later connected with and became contiguous vitreoschisis (arrows). A prevascular vitreous fissure was also present (asterisk in D).

Stage 1a

Among this group of juveniles, 45 eyes (71.4%) had stage 1a PVD. In 32 eyes (71.1%), granular hyperreflections were
Figure 3. Wide-angle montaged images of horizontal (A) and vertical (B) vitreoretinal cross-sections in an eye of a 10-year-old boy with stage 1a PVD. A highly magnified image of an inset in A corresponds to C, and the image in B corresponds to D. Arrows indicate PVD lines in the nasal and superior quadrants and septum papillomacularae. Noted were granular hyperreflectivity and vitreous fibers connected to the posterior cortical vitreous perpendicularly (asterisks in A and C). PVD in the superior quadrant was located within the mid-periphery anterior to the arcade vessel (arrowhead in D).

Associated with stage 1a PVD, thirty-nine eyes (86.7%) had a premacular liquefied lacuna, prevascular vitreous fissure was present in nine eyes (20.0%), and perpendicular vitreous fiber insertion was present in 10 eyes (22.2%). Discontinuous vitreoschisis was found in three eyes (6.7%), and 32 eyes (71.1%) had contiguous vitreoschisis (Table 2; Figs. 3, 4). All stage 1a PVD originated in the mid-peripheral region anterior to the papillomacular vitreous liquefactions, where the vitreous gel directly adheres to the retina.

PVD Distribution
Stage 1a PVD was evident in the superior quadrant of 32 eyes (71.1%), in the nasal quadrant of 24 eyes (53.3%), in the inferior quadrant of 19 eyes (42.2%), in the temporal

Figure 4. A wide-angle montaged image of vertical (A) vitreoretinal cross-sections in an eye of a 14-year-old girl with stage 1a PVD. A highly magnified image of an inset in the superior quadrant corresponds to B and in the inferior quadrant to C. Arrows indicate contiguous lines of posterior cortical vitreous separated from the retinal surface in both superior and inferior quadrants. PVD expanded beyond the arcade vessels to the margin of the premacular liquefied lacuna (arrowbeads).

Figure 5. Geographic distribution of stage 1a PVD. There was a significant difference in the location of the PVD quadrant of origin. **P < 0.01, ***P < 0.001.
quadrant of three eyes (6.7%), and in the septum papillomacular of eight eyes (17.8%). There was a significant difference in the location of the PVD quadrant of origin ($P < 0.001$, $\chi^2$ test). Similar differences in the location of PVD origin were found to be significant in each decade (first decade, $P = 0.004$; second decade, $P < 0.001$) (Fig. 5).

Because the premacular liquefied lacuna is located posterior to the vascular arcade, eyes with stage 1a PVD were subdivided with regard to distribution using the vascular arcade as a landmark. Among 36 eyes with stage 1a PVD in the vertical OCT image, the PVD was located only anterior to the vascular arcade, without any expansion beyond the vascular arcade, in 29 eyes (80.6%; mean age, 10.5 ± 3.0 years). In the remaining seven eyes, the PVD was distributed across the vascular arcade but anterior to the premacular vitreous liquefaction (19.4%; mean age, 12.6 ± 2.3 years). No eye had a PVD that was only present posterior to the vascular arcade. The mean age of individuals with stage 1a PVD across the vascular arcade tended to be higher but was not significantly greater than for those with PVD located only anterior to the vascular arcade ($P = 0.08$, $t$-test).

**Discussion**

Utilizing widefield OCT observations of the vitreoretinal interface in juveniles, we report several significant findings: (1) PVD changes were present in the majority of individuals under 20 years old (71%; 55% in the first decade and 85% in the second decade of life); (2) PVD began in the region anterior to the premacular liquefied lacuna, where the vitreous gel directly adheres to the vitreoretinal interface; and (3) in the majority of subjects, PVD was located only anterior to the vascular arcade without any posterior extension beyond the vascular arcade at this age. We also had occasion to capture images of discontinuous vitreoschisis, which is a very narrow and confined stratification of the posterior cortical vitreous. It has a morphological configuration distinct from that of continuous vitreoschisis, which is commonly seen in the aged vitreous. We interpreted this finding as a very early anatomical change that precedes PVD.

Finally, the location of initiation of PVD occurred in the following descending order of frequency: superior, nasal, inferior, septum papillomacular, and temporal quadrants in the age group of individuals less than 20 years old.

Historically, the timing of PVD has been believed to be an age-related but still acute event that occurs in much older eyes, often after the sixth decade. In recent years, conventional OCT imaging has provided more detailed information pertaining to the vitreoretinal interface; however, conventional imaging strategies provide images primarily of the macular area. In part due to these limitations, prior studies have concentrated on PVD development mainly in the posterior fundus and have continued to assume that PVD onset was a feature of the senescent vitreous.

Accordingly, despite extensive literature describing a macular or perifoveal origin of PVD, our prior and current work suggests that PVD is initiated primarily in the extramacular-peripheral vitreous, where conventional OCT imaging and imaging protocols have not visualized early changes.

We note here that in this study the origin of PVD was anterior to vitreous pockets or the area of Martegiani, where vitreous gel adheres directly to the retina. We also suggest that the impact of the tractional forces conveyed by vitreous movement during ocular saccades should significantly affect the development of PVD. Given that vitreous puck-
sectional OCT, similar to that in the current report. Leong et al. used en face OCT imaging to demonstrate that prevascular vitreous fissures are an almost universal feature of human eyes.

In conclusion, the present study indicates that the onset and limited spatial progression of PVD is evident in the first decade of life. It is most frequently initiated in the superior quadrant of the mid-peripheral fundus, mostly anterior to the vascular arcade. The youngest in this series to have stage 1a PVD was 6 years old. Tractional forces acting at the vitreoretinal interface are transmitted due, in part, to movement of the vitreous gel mass as a result of eye movement. Eye movement and further vitreous liquefaction over time serve to facilitate PVD. Tractional force transmission to the macular cortical vitreous may be in part damped by the macular liquefied structure. Vitreoschisis is a frequent phenomenon associated with PVD initiation, and micron-scale areas of “discontinuous” vitreoschisis may be among the earliest precursor observations visible on OCT that lead to development of PVD.

Acknowledgments

Supported in part by a grant-in-aid for scientific research from the Ministry of Education, Culture and Science in Japan (19K09998); by the Abbott Medical Optics (AMO) contract research grant program (AS2020A000025607); by a generous gift by Hiroyuki Isono, MD (KM); by Research to Prevent Blindness; and by gifts from the J. Willard and Alice S. Marriott Foundation, the Gale Trust, Herb Ehlers, Bill Wilbur, Rajandre Shaw, Helen Nassif, Mary Ellen Keck, Don and Maggie Feiner, Dick Worst JG. Cisternal systems of the fully developed vitreous body in the young adult. Trans Am Ophthalmol Soc UK. 1977;97(4):550–554.


References


