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Original Article

Early treatment with Nd:YAG laser membranotomy and spectral-domain OCT evaluation for Valsalva retinopathy

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Abstract: Aim: The present study aimed to evaluate the outcome of Valsalva retinopathy treated with Nd:YAG laser membranotomy. Design: This study was a retrospective case series. Methods: Six eyes in six patients had Nd:YAG (neodymium-doped yttrium aluminium garnet) laser treatment to open a trapped hemorrhage overlying the macula. One to four laser membranotomies were performed. Best-corrected visual acuity, color fundus photographs, and spectral-domain optical coherence tomography (SD-OCT) scans were obtained before and after laser treatment. In some cases, fluorescein angiography was done before laser treatment. The average follow-up after laser treatment was 20.5 months. Results: All eyes had marked clearing of the hemorrhage and immediate improvement in vision following laser treatment, except for one patient with the clotting of the hemorrhage. In all the cases, OCT demonstrated two distinct membranes: a highly reflective band immediately above the premacular hemorrhage, corresponding to the internal limiting membrane, and an overlying patchy membrane with low optical reflectivity consistent with the posterior hyaloid membrane. The site of the laser puncture was visible in two patients, and the retinal side of the inner limiting membrane (ILM) became rough with several highly reflective spots attached to the retinal surface of the ILM. Conclusions: Nd:YAG laser treatment for Valsalva retinopathy is an effective, noninvasive, and safe procedure for patients, with rapid visual recovery and favorable outcomes. It should be performed as early as possible to avoid the clotting of the hemorrhage. OCT supported the clinical impression that the plane of the premacular hemorrhage in Valsalva retinopathy is probably under the ILM.

Keywords: Nd:YAG membranotomy, premacular hemorrhage, spectral-domain OCT, Valsalva retinopathy

Introduction

Valsalva retinopathy is a rare disease presenting with sudden visual loss in healthy individuals caused by a premacular hemorrhage due to a rapid increase in intraocular venous pressure (Valsalva stress). Generally, it is an isolated and self-limited event, but even a small premacular hemorrhage of one disk diameter (DD) may take several months to clear [1].

Materials and methods

A retrospective study was conducted on six eyes of six consecutive patients with premacular hemorrhage without vitreous hemorrhage due to Valsalva retinopathy, which were treated with Nd:YAG (neodymium-doped yttrium aluminium garnet) laser membranotomies to drain the entrapped blood into the vitreous cavity. The laser procedures were performed between January 2013 and April 2014 at the Department of Ophthalmology at the Affiliated Hospital of Weifang Medical University in Shandong Province, China.

A history was obtained from all patients with special emphasis on strenuous physical activity, trauma, labor, coughing, vomiting, lifting heavy weights, or any other event associated with visual loss. Systemic evaluation was all normal. So, any predisposing risk factors, including diabetes, hypertension, sickle cell disease, anemia, and other blood dyscrasias, could be ruled out. Additional tests for inflammatory markers and an autoimmune screen were negative.

Baseline examination included a record of the time elapsed between the onset of hemorrhage

Table 1. Patient demographic data and clinical characteristics

Patient No.	Age/ Sex	History	Duration (day)	Size of hemorrhage (DD)	Preop BCVA	Total energy used (mJ)	No. of laser	Postop BCVA				Follow -up period months	Features on SD-OCT
								1 Mo	3 Mo	6 Mo	Last visit		
1	25/F	Vomiting (pregnant)	7	14	CF	3	2	1	1	1	visit	25	Site of puncture visible, two reflective lines
2	45/F	During labor	3	7	0.05	2.5	2	1	1	1	1	22	Two reflective lines
3	31/M	Sneezing	5	6	0.1	6.7	4	1	1	1	1	20	Two reflective lines
4	38/F	No special event	10	9	0.02	5	4	0.8	1	1	1	19	Rough ILM
5	41/M	During labor	4	7	CF	4	1	1	1	1	1	19	Two reflective lines
6	46/F	During beauty massage	13	5	0.05	2	2	0.67	1	1	1	18	Site of puncture visible, two reflective lines

DD = disk diameter; preop = preoperative; BCVA = best-corrected visual acuity (Snellen fraction); postop = postoperative; SD-OCT = spectral-domain optical coherence tomography; CF = counting fingers.

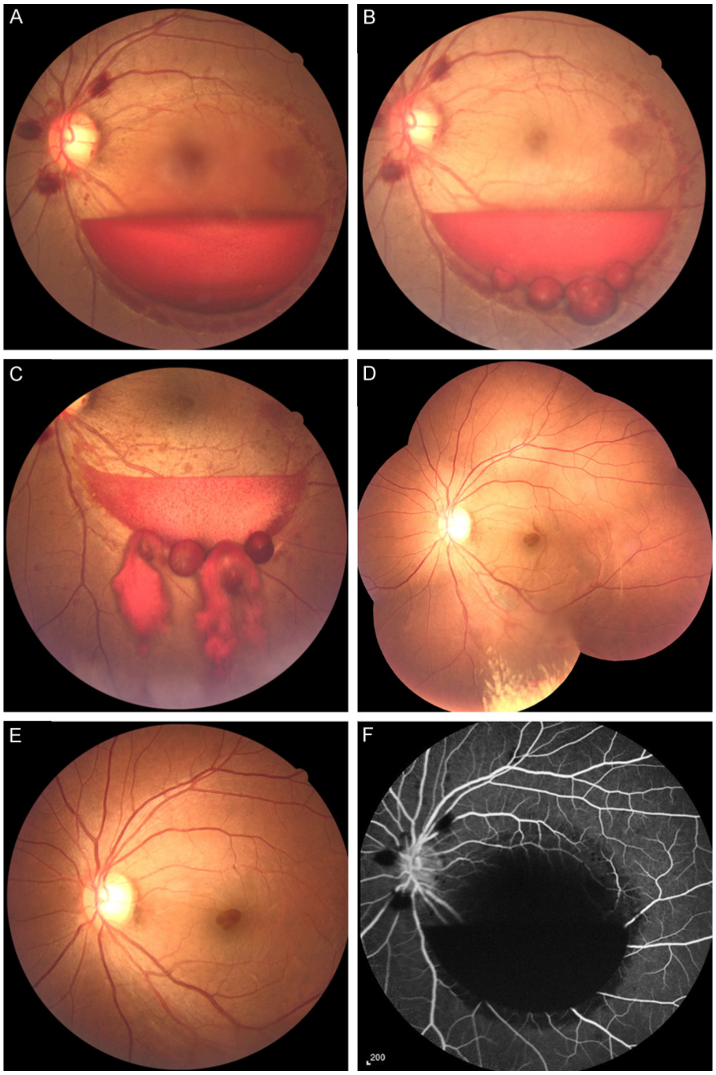

Figure 1. Patient 4. A. Fundus photograph of the right eye at presentation showing a massive premacular hemorrhage about 9DD in size with a fluid level. B. Color fundus photograph immediately after Nd: YAG membranotomy shows blood flowing through the membranotomy site, but drainage was minimal due to coagulation. C. Color fundus photograph 1 week after Nd:YAG membranotomy shows blood flowing through the membranotomy site, but drainage was very slow due to coagulation. D. Color fundus photograph 2 months after Nd:YAG membranotomy shows blood completely flowing through the membranotomy site, and little hemorrhage was found in the vitreous cavity. E. Fundus photograph shows that hemorrhage was completely absorbed 3 months after laser membranotomy. F. Fluorescein angiography demonstrated that fluorescence was blocked by the hemorrhage, with no evidence of any other pathology.

and the laser treatment, best-corrected visual acuity (BCVA) expressed as the Snellen fraction, and slit-lamp biomicroscopy with a 120D lens for the posterior pole and retinal periphery. Fundus photography and spectral-domain optical coherence tomography (SD-OCT) were performed on all the patients, and fluorescein angiography was performed in selected patients. The horizontal and vertical diameters of the preretinal hemorrhage were measured by comparing with the optic disk, expressed as DD, and averaged (**Table 1**).

All patients were informed of treatment options and possible risks, and written consent was obtained. The procedures followed were in accordance with the ethical standards set by the Committee on Human Experimentation (Helsinki Declaration 1975).

The pupil was maximally dilated using 1% tropicamide and 1% cyclopentolate before the procedure. All laser treatments were performed under topical anesthesia with the use of benoxinate hydrochloride eye drops. After pupil dilation and topical anesthesia, the patients were treated using a Q-switched neodymium (Nd): YAG laser. A fundus laser lens (Ocular Instruments, WA, USA) was used for focusing with a slit-lamp delivery system. A single burst of pulsed Nd:YAG laser was applied, starting with low energies (2 mJ) and then gradually increasing until a perforation became visible. The power required varied from 2.0 to 6.7 mJ. The puncture was made on the inferior surface of the premacular hemorrhage at a location distant from the fovea and retinal blood vessels but with a sufficient thickness of blood to protect the underlying retina. Also, the aiming beams at the inferior edge of the hemorrhage were facilitated to drain the hemorrhage as a result of gravity. In all cases, one to four shots of the laser were sufficient.

The patients were immediately examined after laser treatments to ensure that the entrapped blood had been released into the vitreous cavity. Further examinations occurred at about 1, 3, and 6 months and the last visit after treatment. The BCVA was reassessed at each of

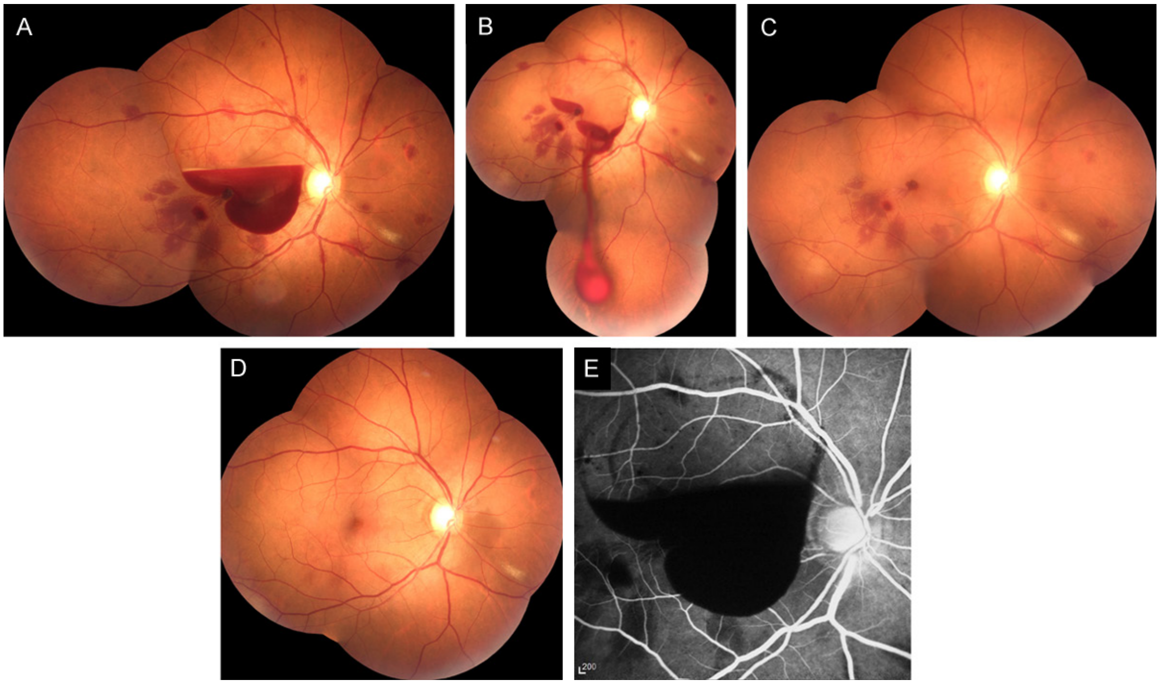

Figure 2. Patient 6. A. Fundus photograph of the right eye at presentation showing a massive premacular hemorrhage about 5DD in size with a fluid level. B. Fundus photograph shows rapid dispersion of the hemorrhage into the vitreous cavity immediately after Nd:YAG laser membranotomy. C. Fundus photograph shows little hemorrhage 1 week after laser membranotomy. D. Fundus photograph shows that hemorrhage was completely absorbed 2 months after laser membranotomy. E. Fluorescein angiography demonstrates that fluorescence was blocked by the hemorrhage, with no evidence of any other pathology.

these visits along with color fundus photography. In addition, SD-OCT was performed at 1, 3, and 6 months and the last visit after treatment using Spectralis HRA-OCT (Heidelberg Engineering, Heidelberg, Germany).

The total number of laser bursts, treatment strategy that included clear media without vitreous hemorrhage, and the lowest energies to achieve an adequate membranotomy were recorded.

Results

Four patients were females, and two were males. **Table 1** lists the demographic data and clinical characteristics of the patients. Their ages ranged from 25 to 46 years, with an average of 37.7 years. All patients were diagnosed with Valsalva retinopathy by eliminating other causative factors. The mean follow-up duration was 20.5 ± 2 months. The average size of the preretinal hemorrhage was 8 DD, with a range of 5-14 DD. All patients presented within 13 days of onset of symptoms.

Nd:YAG laser membranotomy was successful in all cases in causing the release of trapped blood into the vitreous cavity. The range of energy used was 2.0--6.7 mJ. In one patient (patient 4), the hemorrhage was almost immediately immobile after the membranotomy with two visible perforations. Then, two perforations were added by laser bursts, but an obvious flowing hemorrhage could not be seen immediately after the second laser membranotomy (**Figure 1B**). The hemorrhage diffused into the vitreous cavity over the following week, although it did so very slowly (**Figure 1C**). The dispersed hemorrhages in the vitreous cavity completely resolved in 3 months in all the patients. A visual acuity level of 1.0 was achieved in most of the patients by the end of 1 month because the hemorrhage was completely absorbed in the macula with the exception of patients 4 and 6. In patient 4, the hemorrhage was partly clotted and the outflow of the hemorrhage was slow. So, the hemorrhage did not completely flow out until the end of 2 months (**Figure 1D**) and the hemorrhage in the vitreous cavity was completely absorbed by the end of 3 months (**Figure**

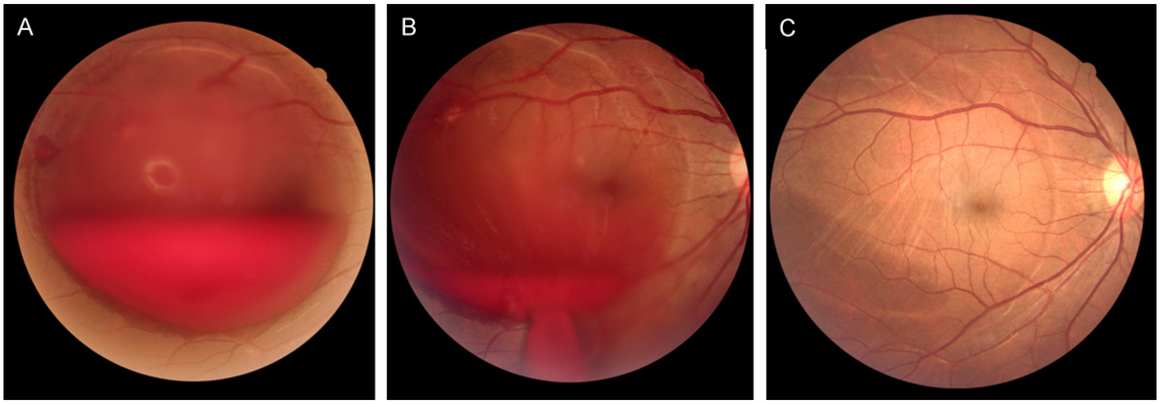

Figure 3. Patient 1. A. Fundus photograph of the left eye at presentation showing a massive premacular hemorrhage with a fluid level. B. Fundus photograph shows rapid dispersion of the hemorrhage into the vitreous cavity immediately after Nd:YAG laser membranotomy. C. 25 months after Nd:YAG laser membranotomy, a wrinkled membrane was still present at the foveal region with radial striae.

1E). In patient 6, a traction and hemorrhage in the macula were observed until the end of 1 month and the hemorrhage was completely absorbed by the end of 2 months (**Figure 2D**).

Pretreatment BCVA ranged from counting fingers at 20 cm to 0.1. After laser treatment, the outflow of the blood through the membranotomy site into the vitreous cavity was visible by biomicroscopy (**Figures 2B**, **3B**, **4B**). All of the patients immediately felt a floater sensation.

In all of the patients, SD-OCT performed before and after the membranotomy demonstrated two distinct membranes: a highly reflective band immediately above the premacular hemorrhage, corresponding to the internal limiting membrane, and an overlying patchy membrane with low optical reflectivity consistent with the posterior hyaloids (**Figures 5C**, **6A**, **7B** and **8B**). So, it confirmed the sub-inner limiting membrane (ILM) location of the preretinal hemorrhage. SD-OCT also revealed a prominent hyporeflective convex dome-shaped premacular cavity in all six cases at 1 month following laser treatment that persisted until the end of follow-up except one case in which the premacular cavity almost disappeared by the end of the sixth month (**Figure 6C**). The site of the perforation was visible in two patients on SD-OCT (**Figures 5B** and **8C**).

It was found that the retinal side of the ILM became rough with several highly reflective spots attached to the retinal surface of the ILM (**Figure 7B**, yellow arrow, and **Figure 8B**, yellow arrow). The underlying retinal layers were unremarkable on SD-OCT. No disruptions of the nerve fiber layer were found in any patient.

By the end of the follow-up, all of the patients had no complication and all had a good result.

Discussion

Valsalva retinopathy was first described in 1972 by Thomas Duane as a superficial retinal hemorrhage that is caused by a sudden increase in intrathoracic or intra-abdominal pressure [2].

A controversy exists in the literature about the exact anatomical location of the premacular hemorrhage. It was thought to be either between the retina and the sub-ILM or between the ILM and the posterior hyaloid membrane (subhyaloid). It was more commonly sub-ILM than subhyaloid, and rarely, it may be a combination of the two [3-7]. Gass [1] identified the ILM by glistening reflexes and surface striae and described the Valsalva-related premacular hemorrhage as sub-ILM. Others, however, were doubtful about the reliability of biomicroscopy in locating the plane of the hemorrhage [7, 8]. Hisatomi et al [9, 10] developed a method that allowed the whole excised ILM to be viewed as a flat sheet on a glass slide, and reported that the surgically excised ILM from eyes with the epiretinal membrane had multilinear patterns.

Two distinct membranes of differing optical reflectivity were observed in all of the patients. OCT demonstrated two distinct membranes: a highly reflective band immediately above the

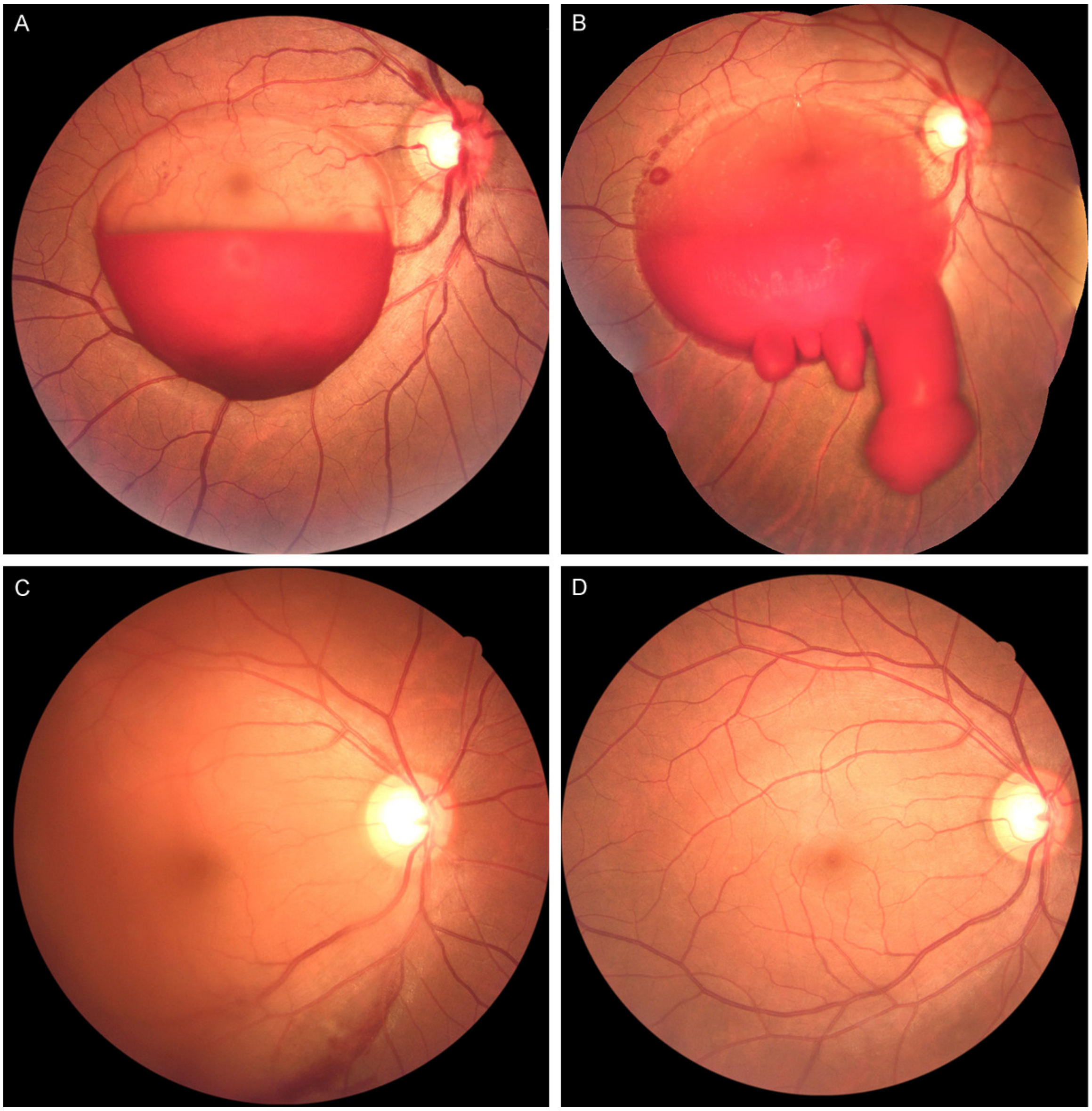

Figure 4. Patient 3. A. Fundus photograph of the right eye at presentation showing a massive premacular hemorrhage about 6DD in size with a fluid level. B. Fundus photograph shows rapid dispersion of the hemorrhage into the vitreous cavity immediately after Nd:YAG laser membranotomy. C. Fundus photograph shows little hemorrhage in the vitreous cavity 10 days after Nd:YAG laser membranotomy. D. Fundus photograph shows that the hemorrhage was completely absorbed 6 months after laser membranotomy.

premacular hemorrhage and an overlying patchy membrane with low optical reflectivity, and blood was under the hyperreflective membrane closer to the retina, which was identified as the ILM (**Figures 5C**, **6A**, **7B** and **8B**). The present finding was in accordance with the result of Shukla's study [3]. So, it was ascertained that the hemorrhage was located in the sub-ILM.

No structural changes in the underlying retinal layers were visible on SD-OCT. Gibran et al [11] found that highly reflective spots attached to the retinal surface of the ILM were transdifferentiated retinal pigment epithelial (RPE) cells. The present study confirmed Gibran's finding about sub-ILM mixed cells (**Figure 7B**, yellow arrow, and **Figure 8B**, yellow arrow). However, as mentioned earlier, a special reflective layer was observed in the SD-OCT, tightly lying on the retinal nerve fiber layer (RNFL) and just under the hemorrhage in the ILM elevated area, which was derived from the intact ILM. Further histopathological research is required to confirm

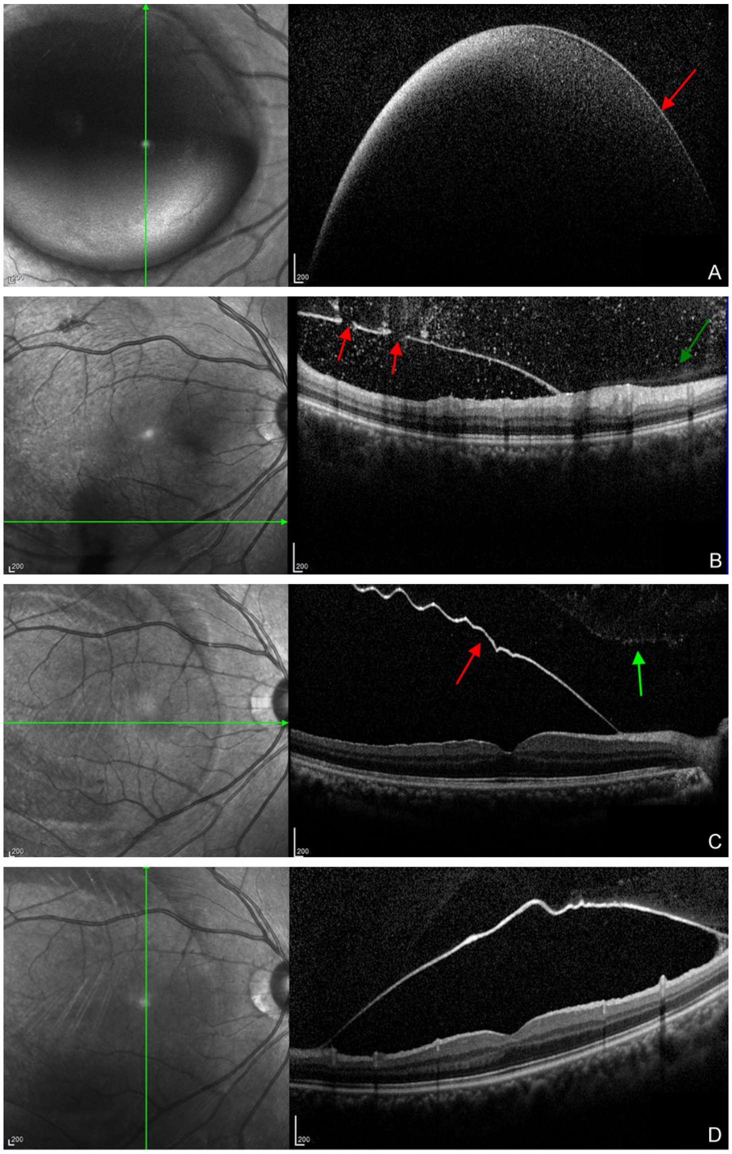

Figure 5. Patient 1. A. SD-OCT reveals a massive hemorrhage beneath a thin membrane (red arrow). B. Horizontal SD-OCT scan at 1 week reveals a premacular cavity anteriorly lined by a hyperreflective membrane. In addition, it shows the site of two perforations (red arrow), which was not visible clinically. The prominent hyperreflective membrane, presumably, is the internal limiting membrane (ILM), under which is a hyporeflective premacular cavity. Another fainter reflecting layer, the posterior hyaloid, is visible separately and partly fused with the ILM at some areas (green arrow). C. Horizontal SD-OCT scan images show a thin membrane (red arrow) with remarkable folds after 6 months of Nd:YAG laser membranotomy, and the posterior hyaloid is visible separately with the ILM (green arrow). D. A membrane still existed by the end of 25 months.

this structure. The SD-OCT evaluation of Nd: YAG laser treatment for Valsalva retinopathy confirmed the cleavage plane of the premacular hemorrhage and identified the location of the laser photodisruption on spectral-domain OCT (**Figures 5B** and **8C**); no obvious disruption of the retinal layers was observed.

Although favorable results have been reported following laser membranotomy in Valsalva retinopathy, secondary membrane formation can be found in the form of a premacular cavity following the procedure. SD-OCT is useful in demonstrating this cavity and following up with the patients. This has been described in isolated case reports as resolving on follow-up [12], persisting [5, 8], or requiring surgical intervention [13, 14]. A premacular cavity was evident in all of the patients. Six month after the hemorrhage resolved, one patient presented with a prominent hyporeflective convex premacular cavity evident on OCT, which was delimited above by a hyperreflective membrane (**Figure 5C**). Six months later, two premacular cavities resolved (**Figure 6C**). This finding confirmed the sub-ILM plane of the blood in these cases.

This cavity may not resolve with observation alone and may result in metamorphopsia despite the successful evacuation of the blood. As observed in patient 1, at the end of 25-month follow-up, this cavity persisted but no metamorphopsia was found (**Figure 5D**). Color fundus photography demonstrated a translucent cavity corresponding to the initial premacular hemorrhage with overlying glistening reflexes and fine retinal striae (**Figure 3C**).

In one of the patients in the present study, SD-OCT made it possible to observe the detached membrane above the macula, and showed the radial structure of the ILM. From these findings, it was hypothesized that these striae might reflect the microstructure of the ILM not fused with the posterior hyaloid membrane (**Figure 5C**).

Different approaches have been reported about Valsalva retinopathy. Observation [1, 15], vitrectomy [16], or Nd:YAG [4, 17] laser mem-

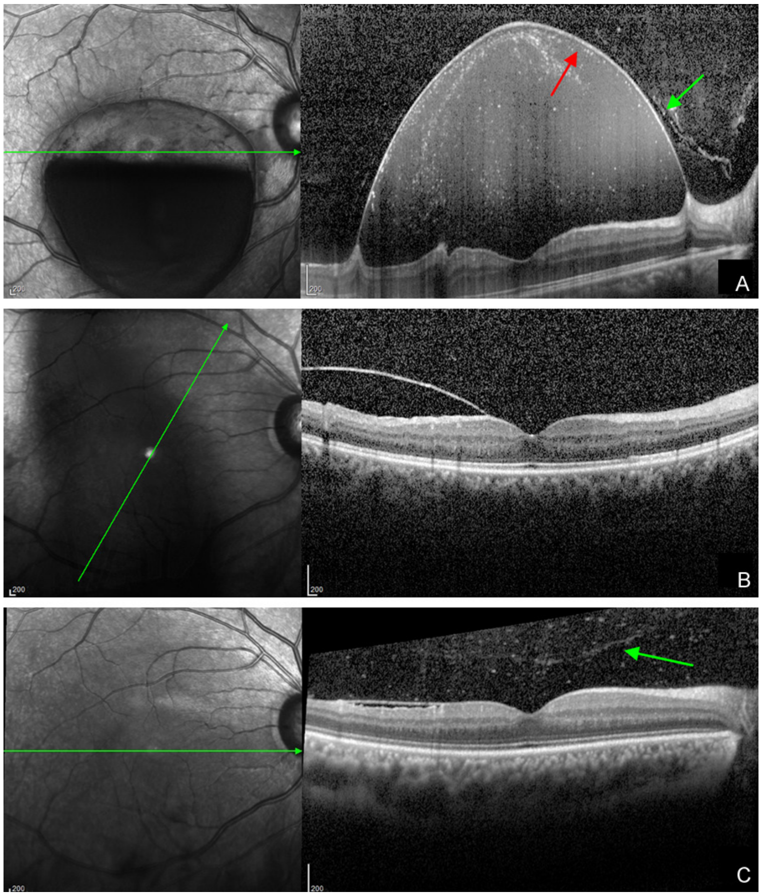

Figure 6. Patient 3. A. SD-OCT reveals a massive hemorrhage beneath a thin membrane (red arrow). Another fainter reflecting layer, the posterior hyaloid, is visible (green arrow). B. A hyperreflective membrane, presumably the internal limiting membrane (ILM), is visible 10 days after Nd:YAG laser membranotomy. C. At Follow-up by Spectralis OCT, 6 months after Nd:YAG laser membranotomy, the elevation of ILM decreased and the cavity almost disappeared. A fainter reflective membrane, presumably the hyaloid, is visible (green arrow).

branotomy are the current treatment options. The prognosis of Valsalva retinopathy is generally good, and the condition in most patients spontaneously resolves in a few weeks to several months [1]. If observation is chosen as a conservative medical treatment for the patient, the patient should be advised not to engage in any strenuous activity and to elevate the head of their bed while sleeping. If the macula is not involved or the hemorrhage is less than one DD, it tends to spontaneously resolve in a short period of time, and a conservative approach is generally justifiable. However, sometimes even small hemorrhages of this kind may gradually resolve over a period of 6-9 months under observation and without intervention [18]. In patients with a large and dense hemorrhage, the spontaneous resorption of the blood entrapped in the subhyaloid or sub-ILM space may take months, and may result in permanent visual impairment due to pigmentary macular changes, formation of epiretinal membranes, or toxic damage to the retina caused by prolonged contact with hemoglobin and iron [16].

Pathological specimens have shown tissues more similar to proliferative vitreoretinopathy than idiopathic epiretinal membranes including transdifferentiated RPE cells within the retina underneath the ILM [7]. However, a quick recovery is desired by most of the patients belonging to the younger age group. This is particularly important for patients with poor vision in their fellow eye and patients requiring rapid visual rehabilitation to be able to continue working. This suggests that the early removal of the blood with laser or vitrectomy may be warranted for reasons other than early visual recovery [4, 11, 19].

Nd:YAG membranotomy was first described by Faulborn in 1988 when treating a patient with the Nd:YAG laser using a multiple grid of impacts on the surface of a premacular hemorrhage to drain the premacular subhyaloid hemorrhage into the vitreous cavity [20]. Since then Nd:YAG laser membranotomy has moved to the forefront for treating large macular hemorrhages in Valsalva retinopathy [21]. Gabel, in 1989, reported three eyes with Nd:YAG laser photodisruption, which created a single opening in the anterior surface of a hemorrhagic detachment of the ILM in the posterior pole, allowing the blood to enter the vitreous cavity leading to prompt visual improvement. Four additional eyes were similarly treated [22, 23]. The relative distance between the posterior hyaloid face and the retina owing to the convexity of the anterior surface of subhyaloid hemorrhages has encouraged several

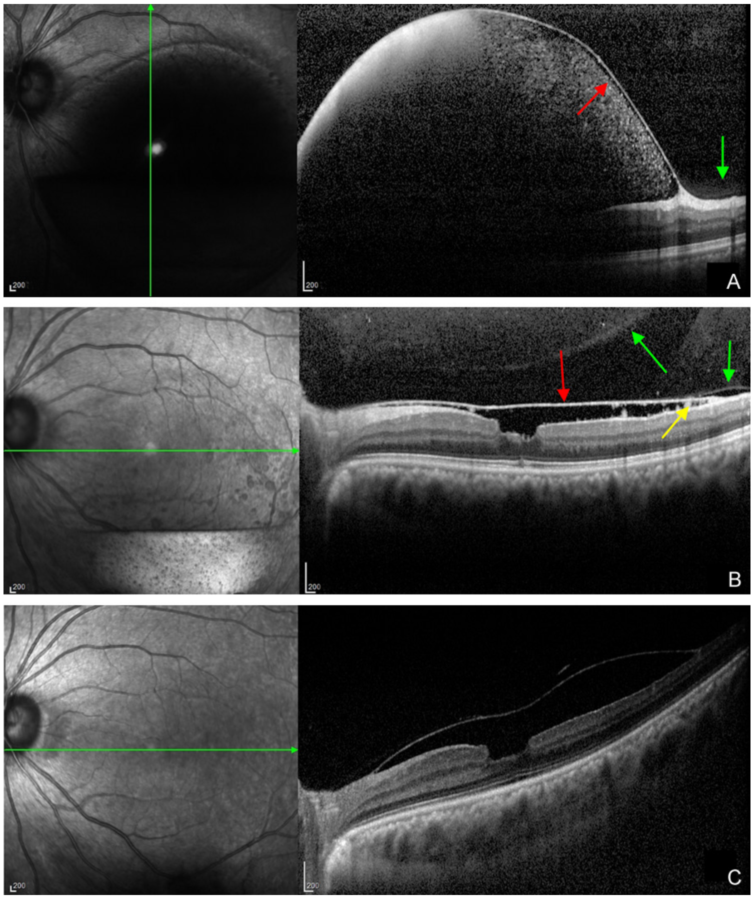

Figure 7. Patient 4. A. SD-OCT reveals membranes similar to those in patient 3. The fainter reflecting posterior hyaloid (green arrow) is fused with the ILM (red arrow) over the preretinal hemorrhage. Blood is present in the vitreous cavity as well. B. SD-OCT showed the rough side of elevated ILM (yellow arrowheads) and the RNFL; the posterior hyaloids (Green arrow) and the ILM (red arrow) are visible 1 week after Nd:YAG laser membranotomy. C. SD-OCT reveals the formation of the cavity 4 months after laser membranotomy.

investigators to drain entrapped blood into the vitreous cavity via focal posterior hyaloidotomy or membranotomy.

However, a risk of photomechanical retinal injury exists. Others have suggested early Nd:YAG laser treatment to achieve maximum benefit and allow the complete drainage of a hemorrhage [24]. Yumita et al [25] studied the histological effect of the Nd:YAG laser on the targeted retinal site of the eyes of a healthy monkey, with energy ranging from 1.4 to 3.5 mJ. With increasing energies, the tissue damage progressively extended beyond the ILM to the middle layer of the neuroretina with the ultimate disruption of the Bruch's membrane. Since then, outcomes and complications of the Nd: YAG laser treatment of premacular hemorrhage of various causes have been reported [4, 18, 26]. Complications of Nd:YAG laser membranotomy include creating a macular hole [27], retinal detachment [4], epiretinal membrane formation [7], and a persistent premacular cavity [14, 28]. Kwok et al [7] reported epiretinal membrane formation with ILM wrinkling 10 months after the ND:YAG membranotomy of a Valsalva hemorrhage.

In comparison with other published series, the patients in this study presented with retinal hemorrhages due to the Valsalva phenomenon and had better post-treatment results. Nd:YAG hyaloidotomy is suggested in the case of preretinal hemorrhages threatening the macula as a treatment option when patients are not willing to undergo surgery or in places where modern vitreoretinal facilities are not available.

It is believed that several important criteria exist to safely perform Nd:YAG membranotomy for Valsalva retinopathy.

Undertake Nd:YAG membranotomy as early as possible. The timing for treatment is critical, as successful displacement of the hemorrhage depends on its ability to flow through the membranotomy as a liquid. With time, the blood becomes clotted resulting in failure of drainage into the vitreous cavity [17, 18].

Sufficiently dilate the pupil. It is presumed that the pupil size is an important parameter that may influence the power setting. The Nd:YAG laser is an instrument designed especially for anterior segment use. Accurate aiming and focusing of the laser are dependent on the convergence angle.

Choose the most appropriate location. The aimed beam should be focused precisely on the surface of the premacular hemorrhage at a location close to the inferior edge but far dis-

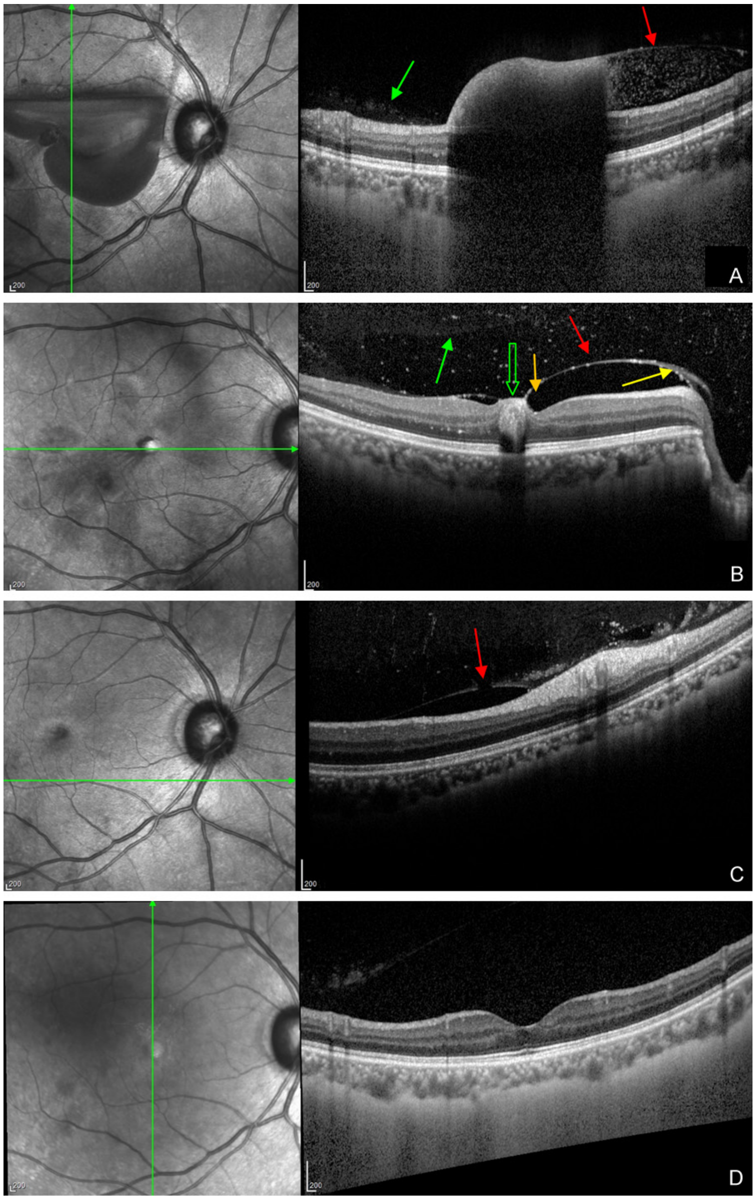

Figure 8. Patient 6. A. Vertical SD-OCT scans similar to **Figure 7A**. B. SD-OCT shows the intact ILM (red arrow), the rough side of elevated ILM (yellow arrow), the posterior hyaloids (green arrow), and the hemorrhage in the macula (the hollow green arrow) 1 week after laser membranotomy. C. SD-OCT scan shows the site of one perforation (red arrow) visible 1 month after laser membranotomy. D. SD-OCT scan shows that the macula became normal and no vitreous macular traction was observed by the end of 18 months.

tant from the fovea and the retinal blood vessels with a sufficient thickness of blood to protect the underlying retina.

Use the least amount of power to create an adequate opening. Common sense dictates that it is best to use the least amount of power to create an adequate opening.

In conclusion, the SD-OCT evaluation of ND:YAG laser treatment for Valsalva retinopathy confirmed the cleavage plane of the premacular hemorrhage. In addition, it revealed the exact location of the ILM disruptions caused by the laser spots, and the safety of the procedure, with no involvement of the underlying retinal layers. Laser membranotomy is a simple, noninvasive, inexpensive, outpatient procedure that results in rapid visual recovery and favorable outcomes. All of the patients in this study had good results with a short follow-up time. The result of longer follow-up times needs further observation.

Disclosure of conflict of interest

None.

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