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REVIEW

Safety and Efficacy of YAG Laser Vitreolysis for the Treatment of Vitreous Floaters: An Overview

Andreas Katsanos · Nikoleta Tsaldari · Konstantina Gorgoli · Fotios Lalos · Maria Stefaniotou · Ioannis Asproudis

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ABSTRACT

Emerging evidence has suggested that the entoptic phenomena associated with vitreous opacities (i.e. vitreous floaters) are more bothersome than previously believed. In addition, the prevalence of vitreous floaters is likely increasing due to the evolving global pandemic of myopia. The use of YAG laser vitreolysis for the treatment of annoying vitreous floaters has attracted significant attention in recent years as the technique offers a number of potential advantages. Unfortunately, the currently available evidence that is needed to guide clinical practice is both very limited and contradictory. As a consequence, the technique remains highly controversial. A review of the existing literature sheds light on patient- and treatment-related factors that may significantly affect both the effectiveness and the safety of the procedure. The current article discusses important aspects of key publications on the topic, offers suggestions for clinical practice, and highlights unmet needs that should be addressed by future research.

Keywords: Floaters; Myodesopsia; Ophthalmology; Posterior vitreous detachment; PVD; Vitreolysis; Vitreous floaters; Weiss ring; YAG

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A. Katsanos (✉) · M. Stefaniotou · I. Asproudis
Ophthalmology Department, University of Ioannina, Ioannina, Greece
e-mail: katsanos@uoi.gr

N. Tsaldari
General Hospital "G. Genimatas- Ag. Dimitrios", Thessaloniki, Greece

K. Gorgoli
Private Practice, Ioannina, Greece

F. Lalos
Department of Ophthalmology, University of Essen, Essen, Germany

Key Summary Points

Emerging evidence suggests that vitreous floaters are more bothersome than previously thought.

The disruption of vitreous opacities using YAG laser vitreolysis has stirred significant controversy, as the safety and efficacy of this method has not been confirmed by all reports.

By carefully considering the clinical features and peculiarities of floaters in each individual case, it may be possible for clinicians to safely and effectively relieve the bothersome symptoms of some patients.

As the currently available evidence is limited, future studies should characterize the exact role of YAG laser vitreolysis for the treatment of vitreous floaters.

INTRODUCTION

Despite the commonly held belief that the symptoms caused by vitreous floaters are not particularly annoying, certain evidence has challenged this notion [1–4]. In recent years, neodymium-doped yttrium-aluminum-garnet (YAG) laser vitreolysis has gained significant popularity [5, 6], as the technique offers a fast, relatively inexpensive, non-incisional therapeutic option for the treatment of vitreous floaters. However, the publication of studies showing conflicting results [7, 8] and potentially sight-threatening complications [9–13] have fueled dispute and may have prevented the widespread adoption of the technique.

This review article presents selected pertinent evidence on the efficacy and safety of YAG laser vitreolysis, highlights possible explanations for the currently available contradictory data, and points to potentially fruitful directions for future research. Articles published in PubMed in English or German, without restriction on year of publication were considered. Keywords with appropriate Boolean operators were used using the terms “YAG”, “laser”, “vitreous floaters”, “myodesopsia”, “Weiss ring”, “posterior vitreous detachment” and “vitreolysis”. In addition, the reference list of all electronically-retrieved articles was carefully reviewed for potentially relevant articles that had not been identified electronically.

The current article is based on previously conducted studies and does not contain any studies with human participants or animals performed by any of the authors.

TYPES OF FLOATERS

The vitreous body is an extracellular matrix consisting of 98% water and macromolecules, the most important being hyaluronan and collagens organized in a transparent gel [6, 14]. At birth, the vitreous body is exceedingly homogenous and clear. Over the course of years, however, the homogeneity of the vitreous is decreased due to structural changes that may result from diverse processes such as aging, inflammation, vitreoretinal dystrophies, diabetic vitreopathy, or myopia. Primary floaters (i.e. the ones induced by degenerative changes associated with aging and/or myopia) should be clearly distinguished from secondary floaters occurring as a result of ocular inflammation (e.g., uveitis), lymphoma, amyloidosis, or haemorrhage (e.g., synchysis scintillans). Primary degenerative changes caused by aging induce liquefaction within the vitreous body so that small lacunae or cisterns are formed [6]. Although the exact pathophysiology of these events is unclear, it has been postulated that such liquefaction results from the dissociation of hyaluronan from collagen molecules, thereby allowing the cross-linking and aggregation of collagen into light-scattering macroscopic fibers [15, 16]. In addition, aging induces the separation of the posterior vitreous from its attachment to the internal limiting membrane of the retina (posterior vitreous detachment, PVD) [6, 16, 17]. Vitreous floaters [Greek: myodesopsia; Latin: muscae volitantes (i.e. flying flies)] are entoptic images caused by vitreous opacities that cast a shadow on the retina, thereby producing the visual perception of gray linear, circular or nodular patterns that move with eye and head movements in a fashion reminiscent of debris changing positions within a gelatinous substance. Typically, floaters are more pronounced when viewed against a light-colored background such as a white wall or clear sky. Floaters produced by the liquefaction of central vitreous have often been noticed for months or years by the patients and are typically described as tiny multiple spots or linear, spider web-like opacities. On the other hand, PVD usually causes the sudden onset of floaters. A particular type of floater associated with PVD is a Weiss ring, i.e. the remnant of a vitreopapillary attachment that contains glial tissue of the optic nerve head [16]. Weiss rings can sometimes cast a relatively dense solitary shadow onto the retina, which patients usually describe as round or semicircular in shape. As discussed later in this review, in symptomatic patients, the particular type of floaters can have significant clinical and prognostic relevance if YAG laser vitreolysis is attempted.

PATIENT BURDEN

In recent years, it has become increasingly recognized that the perception of floaters and the associated visual disturbances are more common than once thought [1, 6]. In an electronic survey that recruited 603 smartphone users, 76% of the participants reported seeing floaters, while 33% complained of noticeable visual impairment because of them [1]. Admittedly, the methodology of this survey and the relatively young age of the participants might limit the applicability of these findings in other settings; nonetheless, this study questions the long-held notion that floaters are uncommon or not bothersome [1]. Further, it may be prudent to consider that, in recent decades, floaters are in fact becoming ever more common due to the increasing prevalence of myopia worldwide [18]. Especially in myopes, symptoms may appear in a younger age due to the fact that vitreopathy occurs earlier in life in such eyes. In addition, symptoms can be quite bothersome in myopes due to retinal image magnification.

The generally held belief that patients will either gradually adapt to their symptoms or that the floaters will resolve in the course of time was challenged by Wagle and collaborators: these authors found that patients were bothered by their floaters irrespective of their duration of complains [2]. In other words, patients with chronic floaters had failed to adapt to their symptoms.

Recent evidence confirms that a certain percentage of patients indeed experience remarkable annoyance due to vitreous floaters [2–4]. In their cross-sectional utility analysis study with predominantly Chinese participants, Wagle and collaborators [2] included data from 266 patients who presented with symptoms of floaters. The authors used the time-trade-off (TTO) and the standard gamble (SG) methods to assess the burden of floaters to the patients' well-being. The TTO method determines the number of years of remaining life that an individual is willing to trade off for a hypothetical intervention that restores perfect vision, whereas the SG method determines the risks ("SG-blindness" or "SG-death") associated with a hypothetical intervention that the patient is prepared to take in order to return to a state of perfect health. The authors [2] found that patients with floaters were willing to exchange an average of 1.1 years of every 10 years of their remaining life to become symptom-free. In addition, the patients were willing to take an 11% risk of death and a 7% risk of blindness to get rid of floater-related symptoms [2]. Interestingly, the average utility values for these participants were comparable to the utilities previously reported by patients suffering from conceivably more debilitating ophthalmic conditions, such as age-related macular degeneration or diabetic retinopathy [2, 19, 20]. It is also noteworthy that these patients had TTO utility values comparable to the ones reported by patients with systemic conditions, such as mild angina or stroke, systemic hypertension or asymptomatic HIV infection [21–23].

In a controlled cross-sectional study, Kim and associates [4] examined the level of depression, perceived stress, anxiety and floater-associated discomfort in Korean patients. They found that symptomatic vitreous floater patients had higher psychological distress compared to controls. In addition, complete PVD, depression and younger age were significantly associated with symptomatic floaters [4]. The authors also divided the patient group into three sub-groups based on their discomfort level (i.e. mild, moderate, severe), and noted that there were no significant differences in the proportion of complete PVD among them. However, patients in the severe discomfort group suffered more from depression, perceived stress and anxiety compared to the two milder discomfort groups [4].

Although the subjective feeling of floater-related discomfort is probably influenced by poorly studied constitutional attributes, such as personality traits, symptom self-awareness, etc., it is nonetheless important to note that PVD may in fact decrease objectively-measured contrast sensitivity [24, 25] and thus explain the seemingly out-of-proportion complaints of some patients.

YAG LASER TREATMENT OF VITREOUS FLOATERS

YAG laser treatments for conditions of the posterior ocular segment have been performed with variable success since the 1980s [26–32]. These conditions included vitreoretinal tractions due to proliferative diabetic retinopathy [26, 27, 31], sickle cell retinopathy [28], vitreous cyst [29] and rhegmatogenous retinal detachment [30]. The first report of YAG laser vitreolysis for floaters was published in 1993 [33]. In that study, Tsai and collaborators [33] used YAG laser with energy levels of 5–10 mJ per burst and total energy 71–742 mJ to treat 15 patients with localized prepapillary or central vitreal opacities who reported significant psychological burden from their symptoms. The authors reported high patient satisfaction without any intra- or postoperative complications with a follow-up of at least 1 year [33].

Several years later, Delaney et al. [7] performed a single-center retrospective study with 31 patients (42 eyes) who underwent either YAG laser vitreolysis (maximal energy per burst: 1.2 mJ) or pars plana vitrectomy (PPV) for vitreous floaters. Patients who were not relieved following one or more YAG laser sessions were offered PPV. Posterior vitreous detachment was the primary cause of floaters in all eyes, with few patients having coexistent vitreous veils ($n = 3$) or asteroid hyalosis ($n = 2$). A single bothersome opacity was found in 25 eyes, while multiple opacities were seen in 17 eyes. To minimize the chances of ocular damage, YAG laser treatment was only performed for floaters having a distance longer that 2 mm from the retina and the crystalline lens. The primary treatment was YAG laser vitreolysis for 39 eyes and PPV for 4 eyes. After a mean follow-up period of 14.7 months, the symptomatic relief following YAG laser treatment was described as "moderate" (30–50% benefit) in 35.8% of cases and "significant" (50–70% benefit) in only 2.5% cases. Almost 54% of patients experienced no relief, while 7.7% felt worse. On the other hand, full resolution of symptoms was noted in 93.3% of patients who underwent PPV. No complication was observed in laser-treated patients (follow-up: 14.7 months), but there was one case of post-vitrectomy cataract formation and one case of retinal detachment. Overall, the authors concluded that YAG laser vitreolysis is safe but only moderately effective as a primary treatment, since it only seems to benefit approximately one-third of patients [7].

Several years later, Shah and Heier [8] in a single-center, masked, randomized, sham-controlled study investigated the usefulness of YAG vitreolysis in 52 eyes of 52 patients (36 cases, 16 controls) whose symptoms were specifically caused by Weiss ring floaters. Only patients who had symptoms for more than 6 months were included. The participants were followed-up with examinations 30 min after the procedure and then after 1 week, 1 month, 3 months and 6 months. The primary outcomes were subjective improvement assessed using a visual disturbance score (0–100% scale), a 5-level qualitative scale, and the National Eye Institute Visual Function Questionnaire 25 (NEI VFQ-25). Secondary outcomes included objective improvement determined by masked assessment of color fundus photographs and Early

Treatment Diabetic Retinopathy Study (ETDRS) best corrected visual acuity (BCVA). The energy was titrated between 3 and 7 mJ per burst. Only opacities with a distance greater than 3 mm from the retina and 5 mm from the crystalline lens were considered. Laser-treated patients reported greater symptomatic relief (54% vs. 9%, $P < 0.001$) and greater improvement in the visual disturbance score (3.2 vs. 0.1, $P < 0.001$). According to the authors, a total of 19 laser-treated patients (53%) noted significant or complete removal of symptoms versus none of the sham-treated controls. In addition, the NEI VFQ-25 scores of the laser-treated patients were better in the domains of general and peripheral vision, role difficulties, and dependency (all $P < 0.005$). No differences were detected in BCVA and adverse events (no retinal tears, retinal detachment, or elevated IOP in either group). Interestingly, there was a notable discrepancy between the investigator-determined improvement and patient-reported responses: several patients judged to have substantial improvement by means of masked color fundus photography admitted only minor or no subjective relief. Unrealistic expectations and the persistence of vitreous floaters in addition to the treated Weiss ring may explain these results.

A critical review of the notable differences in the results by Delaney et al. [7] versus those by Shah and Heier [8] may be warranted (Table 1). The subjective improvement in YAG-treated eyes was meaningful in the study by Shah and Heier [8], but rather disappointing in the study by Delaney et al. [7]. One of the explanations may lie with the patient inclusion criteria: Delaney et al. [7] included patients with various types of vitreous floaters, while Shah and Heier [8] only included patients with a solitary Weiss ring. It is reasonable to assume that clearing a single Weiss ring is more likely to offer symptom relief compared to the treatment of numerous opacities. Another explanation may be that Delaney and colleagues [7] used low energy settings (maximum energy: 1.2 mJ per burst), while Shah and Heier [8] used significantly higher energy levels (between 3 and 7 mJ per burst). It is possible that lower energy levels disrupt floaters but do not completely eliminate them by vaporization, which conceivably can occur with

Table 1 Summary of study characteristics and results of the reports by Delaney et al. [7] and Shah and Heier [8]

Studies	Study design	Number of patients/eyes	Type of floaters	Maximum energy per burst (mJ)	YAG laser vitreolysis	Alternative treatment	Follow-up period	Symptomatic relief after treatment
Delaney et al.	Single center, retrospective	31 patients 42 eyes	Single opacity: $n = 25$ Multiple opacities: $n = 17$	1.2	39 eyes	4 eyes PPV	14.7 months	YAG laser vitreolysis: moderate 35.8% Significant 2.5% PPV: 93.3%
Shah and Heier	Single center, prospective, masked, randomized, sham-controlled	52 patients/eyes	Weiss ring floater: $n = 52$	7	36 eyes	16 eyes control	6.0 months	YAG laser vitreolysis: 53% improvement Controls: 9% improvement

PPV pars plana vitrectomy, *YAG* yttrium-aluminum-garnet plasma-induced shock waves at higher energy levels [34]. A further important difference in these studies [7, 8] is that Shah and colleagues recruited patients with symptomatic Weiss rings that had been present for at least 6 months. In these patients, any debris associated with acute PVD had probably disappeared by the time of the treatment, which may have increased the probabilities of the patients remaining symptom-free after the disruption of a solitary Weiss ring in an otherwise clear vitreous.

Although favorable safety results have been reported in some of the aforementioned studies [8, 33], it should be noted that safety data beyond a 6- or 12-month follow-up period are scant. In addition, not all reports mention if scleral depression had been performed while examining for retinal tears or holes in the postoperative period [7]. Consequently, retinal damage that remained undetected may in fact have occurred. A further concern is that retina damage following YAG laser treatments for posterior pole conditions cannot be excluded with certainty unless fluorescent angiography [35] or imaging examinations, such as optical coherence tomography or autofluorescence photography, is performed. Unfortunately, such examinations were not performed in the previously mentioned studies. Another problem with those reports is that they have only included a rather small number of participants from selected populations. Conceivably, the occurrence of less frequent complications that can only be detected if many more patients are treated cannot be excluded.

Early experiments with rabbits and monkeys by Bonner and collaborators [36] showed that pulse energies of 2–6 mJ, which were necessary to disrupt vitreal membranes in rabbits with clear media, could not be focused within 2 mm of the retina without a substantial risk of damaging it. The authors also found that pulses of 4–8 mJ that were used to rupture vitreal membranes located 2–4 mm from the retina were quite likely to damage the retina due to errors in focusing. Importantly, in eyes with unclear vitreous, the authors [36] noted that one effect of haze was to reduce the non-linear energy absorption at the point of focus, which may result in higher retinal irradiance and thus increase the risk of damage behind the focus. In addition, Little and Jack [32] have shown that energy settings of 4–15 mJ delivered with 2–5 pulses per burst resulted in potentially serious complications such as crystalline lens damage, retinal hemorrhages, and tears with retinal detachment.

Table 2 Proposed indications for YAG laser vitreolysis for the treatment of floaters

Chronic floater (> 6 months)
Weiss ring
Single floater
Clear vitreous
Floater > 2 mm from the retina
Floater > 5 mm from the crystalline lens
No peripheral retinal pathology

In a clinical setting, it has been argued [34] that, since the chances of retinal tears and retinal detachment is highest in the first 6–12 month period after an acute PVD, it may be advisable for clinicians to observe and counsel rather than treat patients with YAG laser vitreolysis during this period. Further, it has been suggested [37] that floaters that seem tightly tethered from vitreous strands (“well-suspended”) may be more amenable to YAG laser vitreolysis compared to floaters loosely located in the vitreous cavity (“ill-suspended”): in the former variety, the laser can be used to cut the vitreous attachment and dislodge the opacity below the visual axis, while, in the latter variety, the laser is used for the disruption of the opacity.

In addition to retinal [9, 38, 39] or crystalline lens and posterior capsule damage [9–12, 39], the occurrence of refractory open-angle glaucoma has been reported after YAG laser vitreolysis for floaters [9, 13]. Cowan and coauthors reported the cases of 3 eyes (2 patients) that underwent YAG laser vitreolysis for floaters and eventually suffered chronic open angle glaucoma after sustaining very high intraocular pressures (> 40 mmHg) [13]. Although the pathomechanism explaining such extreme elevation in intraocular pressure is unknown, the authors [13] hypothesized that the treatment may have caused the obstruction of the trabecular meshwork by floater debris, macrophages, or other inflammatory cells. Alternatively, YAG laser energy might have caused shockwave damage to the trabecular endothelial cells [40]. Another theoretical possibility is that YAG laser vitreolysis produces or liberates an unknown substance that has a long-lasting detrimental effect on the trabecular meshwork [13].

CONCLUSION

The currently available evidence offers some indications that YAG laser vitreolysis may be a viable option for the symptomatic relief of selected patients with bothersome complaints due to vitreous opacities (Table 2). In particular, cases with chronic Weiss rings may represent a patient group that will likely benefit the most from this procedure. On the other hand, notwithstanding how annoying the symptoms can be, the safety profile of this treatment seems far from optimal considering that the presence of vitreous floaters is not a vision-threatening condition. Clearly, the importance of careful case selection, detailed counseling, written informed consent, and careful postoperative follow-up cannot be overemphasized.

Future research will need to address a number of issues before the exact role of YAG laser vitreolysis is fully determined. For example, it is known that vitreoschisis is more common with advancing age, especially in eyes with myopia; thus, the presence of a Weiss ring does not necessarily signify a complete PVD. The impact of YAG laser vitreolysis on the behavior of the vitreous and the process of liquefaction over the long term is unknown. Conceivably, the disruption of vitreous opacities could precipitate a complete PVD along with its attendant risks of retinal tear formation. Obviously, appropriate trials will need to be conducted in order to characterize the long-term safety and efficacy of the procedure [41]. In particular, future studies will need to clarify the role of YAG laser vitreolysis in relation to the more established option of PPV for bothersome floaters [6, 42]. Emerging refinements in imaging and documentation [37, 43, 44], as well as technique [43], will likely help establish more robust patient selection criteria and treatment algorithms. Until more controlled evidence is available to guide clinical practice, a more conservative approach as to which floaters and patients should be treated may be advisable.

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