Pathogenesis and Treatment of Maculopathy Associated With Cavitary Optic Disc Anomalies

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• PURPOSE: To propose a unifying theory regarding the pathogenesis of maculopathy associated with cavitary optic disc anomalies and to describe a rational approach to achieving a permanent cure in affected eyes.
• DESIGN: Interpretive essay.
• METHODS: Review and synthesis of selected literature, with interpretation and perspective in relating pathoanatomic features to pathogenesis and treatment.
• RESULTS: Congenital cavitary anomalies of the optic disc, including typical coloboma, optic pit (and other atypical colobomas), morning glory anomaly, and extrapapillary cavitation, are associated with an enigmatic maculopathy characterized by schisis-like thickening and serous detachment. The unifying anatomic theme of these anomalies is the presence of a scleral (or lamina cribrosa) defect permitting anomalous communications between intraocular and extraocular spaces. These communications enable the critical pathogenic mechanism responsible for the maculopathy, namely, dynamic fluctuations in the gradient between intraocular and intracranial pressures that direct the movement of fluid (vitreous humor or cerebrospinal fluid) into and under the retina. Vitreous traction does not seem to play a significant pathogenic role. Permanent cure of the maculopathy requires either elimination of the translaminar pressure gradient or closure of the pathway for fluid flow into the retina. We advocate carefully titrated juxtapapillary laser photocoagulation followed by vitrectomy with gas tamponade for creation of a permanent intraretinal and subretinal fluid barrier.
• CONCLUSIONS: The peculiar features of cavitary optic disc maculopathy can be explained only by considering the pressure gradients that develop along anomalous communications between intraocular and extraocular spaces. A permanent cure for this condition can be achieved by closing the pathway for fluid migration from the cavitary lesion into and under the retina. (Am J Ophthalmol 2014;158:423–435. © 2014 by Elsevier Inc. All rights reserved.)

PECULIAR AND ENIGMATIC MACULOPATHY commonly occurs in association with several congenital cavitary anomalies of the optic disc, including typical optic nerve coloboma, optic pit (and other atypical colobomas), morning glory anomaly, and extrapapillary cavitation. Although usually described as distinct clinical entities, these anomalies likely fall within a spectrum with variable pathoanatomic features but similar embryogenesis and pathologic sequelae.

The pathogenesis of serous maculopathy complicating cavitary disc anomalies is as intriguing as it is controversial, and for many decades has defied attempts to understand it clearly. This lack of clarity has spawned a diversity of treatment approaches with variable efficacy. Attempting to understand the fluid origin and pathophysiologic of this condition informs us about the structure of the optic disc and juxtapapillary retina and the dynamic forces that influence these tissues. In this Perspective, we discuss the varying clinical presentations of the cavitary disc anomalies and associated maculopathy, the probable pathophysiologic mechanisms involved, and key considerations regarding management.

CLASSIFICATION OF CONGENITAL CAVITARY OPTIC DISC ANOMALIES

TYPICAL COLOBOMA OF THE OPTIC NERVE IS A CONGENITAL excavation located in the inferonasal aspect of the disc (Figure 1, Top left). It is typically a sporadic and unilateral condition. The juxtapapillary tissues inferior to the disc may be involved. Often, the affected eye is otherwise normal, and visual field loss is confined to the site of the defect. Localized serous maculopathy may develop in eyes with optic nerve coloboma, whereas extensive rhegmatogenous retinal detachment more likely occurs in eyes with large associated chorioretinal coloboma.

Optic disc pits are focal cavitations isolated to the disc that are typically small and temporally located, but can also be quite large and involve other portions of the disc. They lie on a spectrum of anomalies often referred to as atypical optic nerve colobomas. Although classic optic pits usually are unilateral and appear as focal...
grayish cavitations (Figure 1, Top right), when atypical colobomas are bilateral, large, and centrally located, they can be mistaken for glaucomatous optic cupping (Figure 1, Bottom left). Optic pits may cause congenital field defects because of associated nerve fiber layer defects. Serous maculopathy develops in more than 50% of cases, particularly in eyes with large and temporally located excavations.6,7 Morning glory disc anomaly is a unilateral markedly enlarged optic papilla with funnel-shaped excavation involving the optic disc and peripapillary retina (Figure 1, Bottom right). It features a characteristic radial arrangement of retinal vessels emanating from the disc, glial hyperplasia over the center of the disc, a rim of elevated peripapillary pigmented tissue, and traction on adjacent retina.8 Affected patients typically have poor vision.

Because of its inferonasal location, typical optic disc coloboma is attributed to faulty closure of the embryonic ocular fissure. However, several lines of evidence suggest that all of the congenital cavitary disc anomalies associated with macular detachment may share similar embryogenic mechanisms. Because the normal embryonic fissure extends along the inferior aspect of the globe and completely surrounds the optic papilla at its most posterior extent, it is anatomically plausible that faulty closure of this fissure could result in the diversity of cavitary disc lesions under discussion.9 Furthermore, histopathologic specimens demonstrate similarities between optic pit, morning glory syndrome, and typical coloboma.8 In each case, dysplastic retina is herniated posteriorly through a defect in the lamina cribrosa, juxtapapillary sclera, or both, ranging from a focal defect in optic pits to a circumpapillary defect in morning glory anomalies. Finally, both optic pit and morning glory discs frequently occur in association with typical coloboma in the same or contralateral eye.9 In 1 extended family spanning 5 generations with an autosomal dominant inheritance pattern, 35 members had a phenotypically diverse range of optic disc anomalies, including disc pit, coloboma, and morning glory syndrome.4

In addition to these anomalies involving the optic nerve itself, cavitary anomalies that lie separate from but near to the optic nerve occasionally can cause a maculopathy identical to that seen with cavitary disc lesions. On optical coherence tomography (OCT) imaging, the pathoanatomic features of such lesions, as with the disc anomalies, seem to involve herniation of abnormal retinal tissue through a scleral defect.10

FIGURE 1. Fundus photographs showing the spectrum of cavitary disc anomalies: (Top left) typical coloboma, (Top right) classic optic pit, (Bottom left) centrally located atypical coloboma, and (Bottom right) morning glory anomaly.
CLINICAL FEATURES OF CAVITARY DISC MACULOPATHY

THE MACULOPATHY ASSOCIATED WITH CAVITARY OPTIC nerve anomalies typically develops in a 2-step process, starting with fluid accumulation within the retinal stroma that results in a peculiar schisis-like retinal edema. Lincoff and associates first observed the schisis-like intraretinal fluid with biomicroscopy and noted that it seems to emanate from the disc anomaly.11 Optical coherence tomography imaging later confirmed this observation,1,12,13 demonstrating that the intraretinal fluid accumulates most prominently in the outer plexiform layer.14 More recent high-resolution OCT imaging has shown that fluid from an optic pit can enter into and accumulate within many different retinal layers.15 The intraretinal fluid then may percolate into the subretinal space, sometimes through an outer layer break that may be detectable biomicroscopically, histopathologically, or by OCT.5,11,15,16 Although the intraretinal fluid communicates with the optic disc cavitation, the submacular fluid typically does not (Figure 2). Only rarely does fluid appear to enter the subretinal space directly from the optic disc without intraretinal fluid accumulation.15

Serous maculopathy occurs in more than 50% of eyes with cavitary disc anomalies, with onset typically in early adulthood.6,7,17 However, macular detachment can be seen in early infancy as well as late in life.15 Detachment typically is confined to the posterior pole, but can be more extensive in some cases, particularly in eyes with large atypical colobomas or morning glory anomaly. Untreated serous maculopathy associated with optic disc pits and related anomalies typically leads to poor visual outcomes. One natural history study of 15 untreated subjects over 9 years reported that 80% lost vision to a level of 20/200 or worse.19

CAUSE OF CAVITARY DISC MACULOPATHY

THERE HAS BEEN VIGOROUS AND LONG-LASTING DEBATE regarding the cause of the maculopathy associated with cavitary disc anomalies. Since Gass proposed in 1969 that cerebrospinal fluid (CSF) from the subarachnoid space migrates into the subretinal space, this has been an area of particular curiosity.20 Much of what we know about this maculopathy derives from careful clinical examination, histopathologic analysis, and embryologic studies performed in the pre-OCT era. In recent years, OCT technology has expanded our understanding and corroborated earlier hypotheses.

• ANATOMIC CONSIDERATIONS: We endorse a mechanical basis for the serous maculopathy based on congenital structural defects in the optic nerve head. The normal optic nerve exits the eye through a physiologic opening in the eye wall where 2 pressurized, fluid-containing compartments (the vitreous cavity and subarachnoid space) meet each other and abut the retina and the potential subretinal space. Disruption of these normal anatomic features by congenital cavitary defects allows vitreous, CSF fluid, or both to travel down pressure gradients, occasionally into the retinal stroma and subretinal space.

That a similar maculopathy does not occur in normal individuals is testament to the integrity provided by the intricate and robust architecture of the lamina cribrosa and associated tissues of the optic disc. In normal eyes, the 1.2 million retinal ganglion cell axons from the retinal nerve fiber layer converge to form the optic nerve head and exit the globe through the optic nerve. In the prelaminar region, these axons are grouped into 1000 fascicles, separated by glial columns. The glial columns are contiguous with the adjacent collagenous and elastic tissues that surround the optic nerve head and separate it from the adjacent retina and choroid.21 This elastic tissue seems to provide a fluid barrier as the nerve traverses past the retina and choroid. The axons then pass through the lamina cribrosa to exit the eye. The lamina cribrosa is relatively rigid and, along with its surrounding lining of
astrocytic glia, provides a pressure- and water-tight seal between the intraocular and extraocular (including subarachnoid) spaces.22

Congenital cavitory anomalies of the optic disc disrupt the intricate organization of axons and connective tissues at this critical juncture where the optic nerve exits the globe. Histologic studies and swept-source OCT imaging reveal that cavitory disc anomalies consist of a herniation of dysplastic retina through a defect in the juxtapapillary sclera, lamina cribrosa, or both into a collagen-lined sac that protrudes into the subarachnoid space.23–25 A diaphanous membrane may cover the pit, but defects in this membrane commonly are observed and provide a channel for fluid flow into the pit.5,16,26–28 As a result of the abnormal anatomic features in affected eyes, the vitreous, subretinal, subarachnoid, and possibly orbital spaces may be variably interconnected through the relatively compliant and porous tissues comprising the excavated disc anomaly.5,8,25,29

- **SOURCE OF FLUID:** Investigators have proposed many sources of the intraretinal and subretinal fluid in cavitory disc maculopathy, including liquefied vitreous, CSF, and plasma leakage from retinal vasculature, choroid, or orbital tissues. The most plausible fluid sources are the vitreous cavity and subarachnoid space, depending on the particular conformation of the congenital disc pathologic features in each affected eye.

Vitreous cavity. Clinical and experimental studies have demonstrated conclusively a connection between the vitreous cavity and subretinal space in eyes with cavitory disc anomalies. This may account for the observation that the serous maculopathy usually begins in early adulthood, coinciding with the onset of progressive vitreous liquefaction.

Histopathologic studies with Alcian blue have shown vitreous mucopolysaccharides within optic disc pits.24 India ink studies in Collie dogs with cavitory disc lesions similar to human optic disc pits demonstrated migration of the chromophore into the subretinal space via the disc anomaly.30 Numerous reports describe the passage of intraocular gas, silicone oil, or other vitreous substitutes into the subretinal or sub–internal limiting membrane (ILM) space in eyes with cavitory disc anomalies.7,31–35 Furthermore, as additional evidence of this connection, surgeons have reported successful drainage of subretinal fluid by aspiration over the disc anomaly.7,28,36,37

Vitreous fluid accesses the disc cavitation directly or via small breaks in diaphanous tissue overlying the excavation.1,25,26,28,31 Such breaks may be visible clinically or may be detected with OCT imaging of excavated disc anomalies8,13,36 as well as extrapapillary cavitory anomalies.10 We previously reported the postoperative finding of gas trapped within a disc cavitation, having passed through a small visible break in the overlying neural membrane.5 As described below, the fact that gas bubbles pass through tiny breaks overlying cavitory disc anomalies provides critical insights into the pathogenesis of the unusual maculopathy in these eyes.

Subarachnoid space. Histologically, congenital anomalous disc cavitations are known to extend posteriorly into the subarachnoid space, and OCT images often show an apparent communication between the macular fluid and a perineural space associated with the disc lesion.12,13 Recent imaging with swept-source OCT has shown subarachnoid space immediately posterior to the thin layer of tissue (thought to be pia mater) lining the bottom of the disc excavation.25 Furthermore, there is unequivocal proof that CSF may access the subretinal space in eyes with cavitory disc anomalies, a fact that may explain cases of serous maculopathy or extensive retinal detachment that occur in infants and young children before the age of significant vitreous liquefaction. Chang and associates describe a case of morning glory disc anomaly with total retinal detachment in which radiopaque dye injected into the subarachnoid space migrated into the subretinal space.40 Irvine and associates reported a case of morning glory disc where gas in the vitreous cavity was noted to bubble out of the perineural subarachnoid space at the time of optic nerve sheath fenestration.5 Kuhn and associates describe a patient with bilateral optic nerve pits in whom persistent headache developed as a result of intracranial migration of silicone oil after repair of complex retinal detachment.41 Patel and associates analyzed subretinal fluid in 2 infants with retinal detachment resulting from optic disc coloboma, finding composition consistent with CSF.29 In these 2 patients with microphthalmos-coloboma syndrome, the CSF fluid was thought to derive from a retrobulbar optic nerve cyst, a congenital anomaly that occasionally also is seen in association with optic pits.32,43

Although there are relatively few such reports of direct communication between the subretinal space and retrobulbar spaces such as the perineural subarachnoid space and optic nerve cysts, they provide convincing evidence that CSF can access the subretinal space in some eyes with cavitory disc anomalies. In fact, as detailed below, we believe that recognition of anomalous communications between intraocular (vitreous cavity and intraretinal or subretinal) and extraocular (subarachnoid, cyst cavity, or both) spaces is a necessary component of any theory of pathogenesis that purports to explain the unique features of cavitory disc maculopathy. Appreciation of these communications and their anatomic variability also has critical implications for therapeutic approaches to this condition.

- **PATHOGENIC MECHANISMS:** Vitreous traction hypothesis. Several authors have suggested a possible role for vitreous traction in the pathogenesis of serous maculopathy associated with cavitory disc anomalies. Although a precise
mechanism has not been elucidated, vitreous traction is believed possibly to induce a small tear in diaphanous tissue overlying the disc excavation, allowing for passage of liquefied vitreous into the retina. Additionally or alternatively, vitreous traction on the peripapillary retina, macula, or both is thought potentially to facilitate the accumulation of fluid in the macula. The following lines of evidence have been offered in support of a vitreous traction mechanism:

1. Posterior vitreous detachment (PVD) typically is absent when the maculopathy first appears, and resolution of serous macular detachment occasionally has been seen after spontaneous PVD.

2. Vitreous and glial tissue abnormalities often are present on or near the optic disc in eyes with pits and other cavitary anomalies. These have been interpreted by some authors as evidence for traction on the roof of the cavity. For example, unusual vitreous strands may be observed over the optic disc, and an anomalous condensed Cloquet’s canal may be seen terminating at the margin of an optic pit or optic nerve coloboma. Studies using various OCT imaging technologies have demonstrated vitreous strands or glial tissue extending into pits and related anomalies.

3. Pars plana vitrectomy with PVD induction results in resolution of cavitary disc maculopathy in most eyes. Although most of the reported series included barrier laser photocoagulation at the time of surgery, slow resolution of the maculopathy also has been described after vitrectomy alone, without laser photocoagulation or even gas tamponade. Tight vitreous adhesion to the disc margin often is noted during surgery and has been interpreted as evidence for vitreous traction.

4. Macular buckling is successful in most eyes with this condition, possibly by reducing vitreous traction on the juxtapapillary retina and macula. Alternatively, resolution of the maculopathy may result from closure by the buckle of the connection between the optic disc pit and adjacent retina, as originally suggested by the pioneers of this procedure.

Conceptually, there are a number of serious limitations to the vitreous traction hypothesis that can be summarized as follows:

1. Optical coherence tomography images of eyes with definite vitreomacular or vitreopapillary traction show an obvious traction profile, with anteroposterior tissue elevation and sharp angulations at the point of vitreous insertion. However, critical review of OCT images from eyes with cavitary disc anomalies reveals no anterior tenting of the pit roof nor of the peripapillary retina. In 1 study using time-domain OCT, the authors speculated that shallow posterior vitreous separations in 10 of 16 eyes represented vitreomacular traction, but a traction profile was seen in only 1 of these eyes. Other studies using OCT imaging have not shown evidence for vitreomacular traction.

2. All known examples of true vitreous traction are associated with partial PVD states, where traction is exerted by the separating posterior hyaloid membrane on areas of residual vitreoretinal adhesion. However, cavitary disc maculopathy routinely develops long before the earliest stages of partial PVD have begun (including in very young children). Optical coherence tomography images only rarely show partial vitreous separations in eyes with maculopathy. Furthermore, because the posterior hyaloid membrane is absent over the optic disc, it is not anatomically feasible to develop traction by the posterior hyaloid membrane on the tissue overlying cavitary disc anomalies.

3. Tight vitreous adhesion to the immediate peripapillary retina (as noted during surgery in many cases of cavitary disc maculopathy) is a routine finding in normal young eyes and, in the absence of partial PVD, does not imply vitreous traction on the optic disc margin.

4. Surgical removal of glial or vitreous strands found in optic pits does not seem to alter the surgical outcome, as would be expected if traction from these tissues were important in pathogenesis.

5. A vitreous traction model cannot explain the common and frustrating observation of recurrent macular detachment after vitrectomy with peeling of the posterior hyaloid membrane. Neither can it account for maculopathy that develops in eyes with total PVD.

6. Importantly, the vitreous traction hypothesis cannot account for the unique and enigmatic features of cavitary disc anomalies such as subretinal migration of vitreous substitutes and the intermittent sucking of vitreous strands or debris into the pit.

Dynamic pressure gradients. The observation that vitreous substitutes such as gas, silicone oil, and perfluorocarbon liquid can migrate into the subretinal space after vitrectomy in eyes with cavitary disc maculopathy provides critical insight into the pathogenesis of this disorder. As noted above, such migrations clearly prove a communication between the vitreous cavity and subretinal space through the anomalous disc excavation. However, this phenomenon also implies an unusual and complex pathogenesis, because surface tension physics dictate that passage of intravitreal gas through a small opening is not possible without a substantial pressure gradient across the opening. We previously reviewed the relevant surface tension considerations and calculated that the pressure gradient required to push a gas bubble through a generous 200-μm defect in the roof of an optic pit is at least 11 mm Hg.

It is critical to point out that within the closed system of the normal eye, significant pressure differences between
various compartments (eg, vitreous cavity and subretinal space) do not exist. For a pressure gradient to be present across the roof of a cavitary disc anomaly, there must be communication with a space outside the eye. Given its close anatomic proximity to optic disc cavitations, the perineural subarachnoid space likely is involved in most cases.

Measured with lumbar puncture in the lateral recumbent position, normal intracranial pressure ranges from 5 to 15 mm Hg, with a mean of 12 mm Hg.\(^\text{53}\) Given a mean intraocular pressure of 16 mm Hg, the average pressure gradient across the lamina cribrosa in normal individuals is 4 mm Hg.\(^\text{54}\) However, intracranial pressure varies with factors such as body position and venous pressure, and large fluctuations in CSF pressure have been measured in both normal and pathologic situations.\(^\text{55}\) Thus, the translaminar (intraocular–intracranial) pressure gradient fluctuates throughout the day and is likely sometimes to be large enough to force gas (or liquid) into a cavitary disc anomaly.\(^\text{5}\)

As shown in Figure 3,\(^\text{5}\) intracranial pressure fluctuations can be transmitted to the pit by direct CSF flow if the connective tissue capsule is porous. In cases where the pit capsule is impermeable, pressure alterations may be transmitted via small pressure-induced excursions of the capsule. In this case, the pit may behave as a bulb syringe, drawing fluid (or a vitreous substitute) into the pit sac when intracranial pressure drops, and ejecting it again when CSF pressure rises. Given the variable anatomic features and anomalous interconnections that characterize cavitary disc lesions, the fluid ejected from the pit sac in a given eye could be liquid vitreous, CSF, or even a mixture of the 2 fluids. Repeated small aliquots of fluid driven into the retinal stroma would be expected to cause progressive schisis-like retinal edema and eventually to dissect into the subretinal space.

We believe that transient alterations in the translaminar pressure gradient are necessary to explain the peculiar behavior of cavitary disc anomalies and their associated maculopathy. Clinical evidence for the occurrence of these transient gradients comes from several observations. First, subretinal migration of vitreous substitutes through cavitary lesions almost always occurs after surgery and often suddenly, suggesting abrupt changes in the pressure gradient associated with everyday activities.\(^\text{5,17,31,34,35}\) Second, several authors have observed vitreous strands or debris being sucked intermittently into optic pits and then dislodged again with either ocular movement or a sudden rise in intraocular pressure.\(^\text{43,45}\) This suggests that in addition to CSF pressure alterations caused by the Valsalva maneuver and positional changes, fluctuations in intraocular pressure induced by ocular saccades and eye rubbing are important in the production of dynamic translaminar pressure gradients.

Third, with newer OCT technologies, clinicians increasingly have observed the phenomenon of vitreous incarceration into cavitary disc anomalies (Figure 4). Similar herniations of vitreous into pit-like disc craters in Collie dogs previously were documented histologically.\(^\text{30}\) This OCT finding is common\(^\text{38,39,46}\) and is sometimes interpreted as evidence for vitreous traction on the pit. However, this configuration more plausibly suggests vitreous collagen being sucked into the cavitation and provides compelling evidence for the existence of translaminar pressure gradients. An interesting related observation is that of detached retina herniating into a colobomatous disc cavitation.\(^\text{29}\) Incarcerations of vitreous or retina can develop only along pressure gradients (at sclerotomies, corneoscleral lacerations, etc) and do not occur within the closed system of a normal eye.

Finally, the observation of transient cavitary disc maculopathy, sometimes associated with corresponding transient changes in the appearance of the optic disc excavation, is further evidence for dynamic fluctuations in the pressure gradient between the subarachnoid space and subretinal space in these eyes.\(^\text{5,34,36}\)

**Unifying theory of pathogenesis.** In summary, the peculiar features of the maculopathy associated with the various congenital cavitary disc anomalies and extrapapillary cavitary lesions\(^\text{10}\) cannot be explained by considering only the vitreous and subretinal compartments within a closed eye. Based on the histologic findings and imaging studies reviewed above, the unifying anatomic theme of these lesions is the presence of a scleral defect permitting anomalous communications between intraocular (vitreous cavity and retinal or subretinal) and extracocular (subarachnoid, cyst cavity, or both) spaces. These communications enable the critical pathogenic mechanism responsible for the maculopathy, namely, fluctuations in the gradient between intraocular and intracranial pressures that direct the movement of fluid through the cavitation into (and under) the retina.

**MANAGEMENT**

GIVEN THE NATURAL HISTORY OF PROGRESSIVE VISUAL decline in untreated cavitary disc maculopathy, clinicians have used numerous strategies to treat this condition, including pharmacologic therapy with corticosteroids or acetazolamide, optic nerve sheath fenestration,\(^\text{9}\) macular buckling,\(^\text{30,31}\) inner retinal fenestration,\(^\text{31}\) laser photocoagulation alone,\(^\text{20,26,38,39}\) and pars plana vitrectomy with or without laser photocoagulation and gas tamponade. The large number of proposed treatments and their variable efficacy reflect the unusual and variable pathoanatomic features of this condition and the resulting collective uncertainty regarding its management.

- **NONSURGICAL APPROACHES:** Pharmacologic agents. There is anecdotal evidence that some cases of cavitary disc...
Maculopathy may respond to treatment with oral acetazolamide or corticosteroids. A possible therapeutic mechanism of action of these agents is alteration of the translaminar pressure gradient by reducing intracranial pressure. The limited experience with these drugs suggests that the macular fluid tends to reaccumulate on discontinuing treatment. Empiric use of a pharmacologic agent could be considered early in the course of cavitory disc maculopathy or in patients who are poor surgical candidates. In eyes that respond with resolution of macular fluid, laser photocoagulation may offer a way to prevent maculopathy recurrence on tapering the drug.
Laser photocoagulation alone. In theory, a laser-induced juxtapapillary chorioretinal scar that functions as a barrier to fluid migration from the optic nerve should be an effective treatment for cavitary disc maculopathy, regardless of the specific anatomic features of the congenital anomaly. A complete barrier interrupts the final common pathway for serous maculopathy whether the fluid derives from the vitreous cavity or the subarachnoid space in a given eye.

However, both the published literature and common clinical experience suggest that barricade laser applied in isolation yields low success rates. Optical coherence tomography imaging has clarified that laser photocoagulation alone typically is ineffective because it fails to produce a barrier to intraretinal fluid migration. Although such treatment may stimulate an adhesion between the photoreceptors and retinal pigment epithelium, the most common route for fluid migration out of the cavitary disc anomaly (ie, through the retinal stroma) is unaffected by this adhesion (Figure 5). Permanent blockade of intraretinal fluid movement requires an intraretinal scar. In eyes with existing maculopathy, this end point is not readily achievable without the assistance of a vitreous cavity gas bubble. As discussed below, we have found that titrated laser photocoagulation given as an adjunct to vitrectomy is highly effective in producing a barrier to both intraretinal and subretinal fluid migration.

It is not unreasonable to consider the use of juxtapapillary laser photocoagulation prophylactically before there is significant accumulation of intraretinal fluid. In such eyes, it may be possible to achieve an intraretinal barrier without gas tamponade. However, these eyes, which lack intraretinal or subretinal fluid, or both, to buffer the nerve fiber layer, are also at greater risk of visual loss attributable to papillomacular bundle injury. In light of this risk and the variable natural history of cavitary disc anomalies, we generally do not recommend prophylactic laser photocoagulation for our patients without existing maculopathy.

**SURGICAL APPROACHES:** 
- **Macular buckling.** The macular buckling procedure involves fixing a scleral sponge to the posterior globe in the region of the macula. Surgical success depends on adequate indentation and accurate positioning of the sponge. Although experienced groups have reported excellent anatomic and visual outcomes with this approach, it has not been adopted widely because most vitreoretinal surgeons are unfamiliar and uncomfortable with placing buckling elements in this location. The therapeutic mechanism of macular buckling in this setting is not entirely clear. It is likely that the force of indentation itself may close the intraretinal communication between the disc anomaly and the macula, creating a barrier to fluid flow. Alternatively, some believe that the buckle modifies the direction of traction forces associated with the posterior hyaloid, converting an inward centripetal vector into an outward vector.

**Vitreous surgery.** For patients with cavitary disc maculopathy causing significant visual loss, our preferred treatment consists of carefully titrated juxtapapillary laser photocoagulation combined with pars plana vitrectomy and gas tamponade. The primary objective of this approach is to create a permanent barrier to intraretinal (as well as subretinal) fluid migration from the optic disc cavitation. We prefer this procedure because it is relatively simple, uses techniques familiar to all vitreoretinal surgeons, provides reliable and long-lasting results, and can be applied to all eyes regardless of variations in anatomic features or fluid source.
Careful titration of the laser applications is critical to safely produce a permanent barrier to fluid migration out of the optic pit and into the retinal stroma. To block fluid flow into or under the retina effectively, the laser-induced scar must extend from the retinal pigment epithelium through the middle retinal layers (Figure 6). Importantly, it must spare the retinal nerve fiber layer so as to avoid central vision loss. To maximize our ability to control and titrate the thermal reaction, we perform the juxtapapillary laser photocoagulation with slit-lamp delivery through a contact lens just before prepping the patient for the vitrectomy procedure. We typically use red (647-nm) laser light with a 200-μm spot size, titrating the power and duration to achieve a moderate-intensity end point. Carefully monitoring the laser treatment with contact lens biomicroscopy greatly enhances the ability to achieve a thermal end point that is just right: hot enough to involve the outer and middle retinal layers but not so intense as to injure the nerve fiber layer (Figure 7). Treatment is placed in 4 to 5 confluent rows in the temporal juxtapapillary area, over a circumferential extent corresponding to the presence of intraretinal or subretinal fluid (as determined by OCT and biomicroscopy). The intraretinal fluid helps to buffer the nerve fiber layer from thermal injury.59

Vitrectomy is performed within 1 or 2 hours of laser photocoagulation on the assumption that a fresh laser reaction has the best chance of becoming an intraretinal scar. The primary purpose of the vitrectomy, in our view, is to permit the placement of a large vitreous cavity gas bubble that will dry and compress the retinal layers in the juxtapapillary area and facilitate formation of an intraretinal scar during 7 to 10 days of postoperative face-down positioning. Although intravitreal gas injection without vitrectomy theoretically may achieve the same purpose, this approach likely is less effective.63 After core vitrectomy and peeling of the posterior vitreous cortex, a total fluid–gas exchange is performed. It is typically not necessary to drain submacular fluid, because this usually will be displaced out of the macula after surgery by the gas bubble. However, it is reasonable during fluid–air exchange to drain as much intraretinal or subretinal fluid, or both, as possible by careful aspiration over the optic disc cavitation.5,28,36 Because of the previously referenced reports of subretinal, intraretinal, and intracranial migration of vitreous substitutes, we avoid the use of perfluorocarbon liquid or

FIGURE 6. Schematic illustration showing a juxtapapillary fluid barrier. Laser-induced intraretinal and subretinal scarring blocks fluid flow (arrow) out of the optic pit. The scarring spares the nerve fiber layer to avoid central visual field loss. Intraretinal and subretinal fluid in the macula gradually resolve after the barrier is established.

FIGURE 7. Fundus photograph showing acute retinal opacification after juxtapapillary laser photocoagulation for disc pit maculopathy. Immediately after carefully titrated slit-lamp delivery of juxtapapillary red laser photocoagulation, there is moderate whitening of the outer and middle retinal layers, sparing the inner retina. The patient then underwent vitrectomy with gas tamponade to promote formation of an intraretinal and subretinal adhesion.
silicone oil in these cases. Liquids are more likely to migrate than gas because of their lower surface tension. Furthermore, migration of silicone oil or heavy liquid into the brain or subretinal space is significantly more problematic and difficult to manage than is gas migration.

After resolution of the gas bubble after surgery, OCT imaging is helpful in determining whether an intraretinal fluid barrier has been achieved. Successful cases show no subretinal or intraretinal fluid in the area of juxtapapillary laser treatment, although intraretinal and sometimes subretinal fluid persists in the macular area initially. The retinal tissue comprising the laser-induced fluid barrier may be slightly thinned, with less definition of its cell layers (Figure 8). After a barrier has been achieved, slow resolution of the macular fluid follows over the subsequent 3 to 12 months. If macular fluid reaccumulates, OCT can delineate the persistent channels of communication between the optic disc and macula, which can be addressed with additional laser and gas tamponade.

Our experience using this approach in 10 consecutive patients (unpublished data) suggests a high rate of success with no cases of recurrent maculopathy after the barrier has been achieved. The barrier was formed after a single surgery in 8 cases and required a second procedure (laser and fluid–gas exchange) in 2 eyes. To date, we have observed no cases of central vision loss resulting from nerve fiber layer injury. Published studies using vitrectomy, laser, and gas have reported promising yet variable outcomes, probably because of variability in achieving an adequate laser barrier.28,38,64 As an intriguing alternative to laser photocoagulation in select cases, Travassos and associates recently described the successful use of a small plug of autologous sclera to create a barrier to the passage of vitreous fluid into large optic pits in 3 eyes.65

In light of the pathogenic considerations outlined above, we believe that a long-term cure of cavitory disc maculopathy is most likely to be achieved by the establishment of a permanent barrier to intraretinal and subretinal fluid flow.
out of the cavitary anomaly. However, Hirakata and associates reported that vitrectomy alone, without barrier laser photocoagulation and with or without gas tamponade, led to resolution of maculopathy in approximately 90% of eyes in a small series. Data are not available to determine the true long-term recurrence rate after this procedure. However, this observation suggests that the vitrectomy itself has a beneficial effect in this condition, whether by altering pressure gradients, releasing unidentifiable traction forces, stimulating scarring within the cavitary anomaly, removing incarcerated vitreous that is maintaining patency of a fluid channel, or other unknown mechanisms. In a recent small series, 50% of subjects demonstrated sustained resolution of maculopathy after 1 or 2 intravitreal gas injections without vitrectomy, but it is unclear why gas alone would have a sustained effect. An earlier study demonstrated no sustained effect in any subject undergoing pneumatic displacement for optic pit maculopathy.

Other vitrectomy adjuncts. Several adjuncts to vitreous surgery for cavitary disc maculopathy have been proposed that seem to be unnecessary and may increase surgical morbidity. Although several investigators have advocated peeling the ILM in these cases, there is no plausible pathogenic role for the ILM in these eyes, which are young and have no PVD, vitreoschisis, or epiretinal membranes. Given that numerous surgical series show excellent results without ILM peeling and that ILM peeling may result in a high incidence of macular hole creation in these eyes, we believe this maneuver is unwarranted. Creation of an inner retinal fenestration during vitrectomy has been proposed as a way to redirect the flow of fluid from the cavitary anomaly away from the macula. However, such fenestrations have been shown to close spontaneously in the early postoperative period, suggesting that any benefit seen after this procedure likely derives from the vitrectomy itself. Although authors have recommended peeling condensed vitreous or glial tissue from the disc cavitation, it is unclear why gas alone would have a sustained effect. An earlier study demonstrated no sustained effect in any subject undergoing pneumatic displacement for optic pit maculopathy.

References


LXXI Edward Jackson Memorial Lecture

The American Journal of Ophthalmology and Elsevier Inc. will jointly recognize Hans Grossniklaus, MD, MBA, at this year’s American Academy of Ophthalmology meeting in Chicago as the 71st Edward Jackson Memorial Lecturer. Dr Grossniklaus of Emory University in Atlanta, GA, will present his lecture, entitled “Retinoblastoma: Fifty Years of Progress,” on October 19th during the opening session scheduled from 8:30 AM to 10 AM at Hyatt McCormick Place. Dr Grossniklaus is the founding director of the Ocular Oncology and Pathology service, director of the L.F. Montgomery Laboratory, and the F. Phinizy Calhoun Jr. Professor of Ophthalmology at Emory Eye Center. He has served on the board of the American Journal of Ophthalmology in a variety of capacities for 20 years, served as president of the American Ophthalmological Society last year, and is currently president of the American Association of Ophthalmic Oncologists and Pathologists. Dr Grossniklaus’ areas of expertise include diagnostic ophthalmic pathology, ocular oncology, ophthalmic pathology research, and translational research.

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