Vitreous Surgery for Macular Holes

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Background: To surgically treat patients with macular holes, the authors previously reported both anatomic (re-attachment) and visual success (2 lines of improvement) in a series of 52 eyes. They now have operated on an additional 118 eyes using similar techniques, for a total of 170 eyes.

Methods: After ophthalmologic examination and history, the authors operated on suitable patients. The surgical objectives included relief of all tangential traction and retinal tamponade with intraocular gas. All eyes were followed for at least 6 months postoperatively.

Results: In the total population of 170 eyes, anatomic success was achieved in 73% and vision improved at least two lines in 55%. Twenty-nine percent (49/170) of patients had a visual acuity of 20/40 or better at last examination. Patients with symptoms of less than 6 months' duration managed better than those with symptoms of longer duration ($P = 0.3001$). In the former group of 66 eyes, anatomic success was achieved in 80% ($n = 53$), whereas visual acuity improved at least two lines in 68% ($n = 45$) and at least four lines in 55% ($n = 36$).

Conclusions: The authors suggest that macular hole surgery may provide meaningful improvement in visual acuity in most patients, especially in those whose symptoms are of less than 6 months' duration. *Ophthalmology 1993;100:1671–1676*

Macular holes were described over a century ago, and their early characterization as having a regular outline, appearing to "have been cut out with scissors or cut with a punch," remains essentially unmodified.[1,2] The importance of the vitreous in macular holes also was recognized many decades ago.[3] In two postmortem studies of elderly patients (mean age, 78–82 years), histopathologic examination of idiopathic full-thickness macular holes showed variable photoreceptor degeneration around the hole.[4,5] Such studies have contributed to the longstanding belief that the photoreceptor tissue in macular holes is afunctional.

Eyes with idiopathic macular hole lose vision secondary to tissue loss (operculum), cystic retinal changes, detachment of the rim of retina surrounding the hole, and subsequent photoreceptor degeneration. Clinical observations have led to the impression that the macular hole and cuff enlarge secondary to persistent tangential traction from the vitreous, tangential traction from epiretinal membranes, and the development of large cystic spaces within the surrounding cuff.[6]

The impact of idiopathic macular holes on visual acuity is well defined. Aaberg et al[7] noted visual acuities of 20/100 to 20/400 in 80% of 73 eyes, with nearly half being 20/200. McDonnell et al[8] reported visual acuities of 20/100 to 20/400 in most of the 17 eyes examined with macular holes. Morgan and Schatz[9] observed visual acuities of 20/100 to 20/400 in 60% of 132 eyes and 20/80 or better in 30%. There have been case reports of the disappearance of macular hole with development of an epiretinal membrane and improvement of visual acuity from 20/70 to 20/30.[10] Guyer et al[11] have shared similar observations. However, most retinal specialists would concur that such remission is the rare exception, and that macular holes persist, generally at stage III or IV.

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One attempt at therapeutic intervention in macular holes has been laser photocoagulation to flatten the localized detachment around the hole.[12,13] Intuitively, laser treatment to the cuff may actually impair visual function. This form of treatment has gained little acceptance.

Two recent publications have altered ideas about macular hole etiology and the possibility of treatment. Gass[14] hypothesized that macular holes were caused by focal shrinkage and tangential traction of the attached posterior cortical vitreous layer. In addition, scanning laser ophthalmoscopy suggests that good visual function persists at the edge of the hole.[15] These observations led investigators to perform vitreous surgery to lyse posterior vitreomacular adhesions to prevent progression of early to full-thickness macular holes.[16,17]

Vitrectomy and gas tamponade have been used to achieve retinal reattachment in eyes with large retinal detachment and macular holes.[18,19] Bidwel et al[20] reported recovery of excellent visual acuity (20/20) and disappearance of the macular hole in one eye spontaneously, and retinal reattachment with disappearance of the hole and visual acuity of 20/20 after vitrectomy and gas tamponade in another eye. Our new understanding of the pathogenesis of this disorder and the observation that visual loss progresses in some eyes, despite no further apparent tissue loss, led to the hypothesis that vision might stabilize or improve, if it were possible to relieve the tangential traction, reduce the cystic changes, and reattach the cuff of detached retina surrounding the hole. We attempted vitreous surgery for idiopathic full-thickness macular hole beginning in 1987. We published the results of the first 52 eyes on which we operated in 1991.[21] We have now operated on an additional 118 eyes, and report on the total population of 170 eyes.

Materials and Methods

Patient selection criteria, surgical procedure, and follow-up for this patient population have been described previously.[21] We selected patients from our practice with a macular hole in at least one eye who were good surgical candidates, and who might be able to comply with the postoperative requirements for strict occiput-up positioning for at least 1 week. Snellen visual acuity was measured using a projected chart, both with the patient's current spectacle correction and pinhole vision. For entry, patients were required to have a central visual acuity of 20/50 or worse and stage III or IV macular holes, as defined by Gass.[14] Before entry, all patients provided informed consent.

The surgical procedure consisted of a pars plana vitrectomy, removal of adherent cortical vitreous, stripping of epiretinal membranes (when present), and a total gas-fluid exchange (typically with sulfurhexafluoride). Tangential traction was relieved by identification and removal of the cortical vitreous or posterior hyaloid and, if present, removal of fine epiretinal membranes around the hole. Three additional surgeons participated in this larger patient sample, for a total of five surgeons.

We defined anatomic success as the edges of the macular hole being attached to the underlying retinal pigment epithelium (RPE), with flattening of the cuff of retinal detachment around the hole. Improvement of two and four lines in visual acuity was used for visual success. Comparisons among various subpopulations were made using a chi-square test, with a criterion of 0.05.

Results

This updated series of 170 consecutive eyes includes 128 eyes from women (mean age, 67 years) and 42 eyes from men (mean age, 69 years). Nearly all of the eyes had stage III macular holes (n = 158, 93%) and preoperative visual acuity of 20/100 or less (n = 161, 95%). All of the eyes had at least 6 months' follow-up.

The overall anatomic success rate for this series was 73% (125/170). As shown in Figure 1, the rate of anatomic success was inversely related to the duration of symptoms. The proportion of patients with anatomic success was 80% (53/66), 74% (48/65), and 62% (24/39) for patients with symptom duration of 6, 6 to 24, and 24 months, respectively ($P = 0.109$). Most anatomically successful patients also commented that their distortion and central scotoma improved or resolved. Two eyes that were initially anatomically successful have subsequently reopened 4 or more months postoperatively. Reoperation was not performed.

The overall visual success rate for this series was 56% for the two-line criterion (95/170) and 41% for the four-line criterion (70/170). Of the anatomically successful eyes, 76% (95/125) improved by two lines or more. As with anatomic success rate, visual success rate showed an inverse relationship to the duration of symptoms (Fig 2), although the statistical relationship was stronger for the

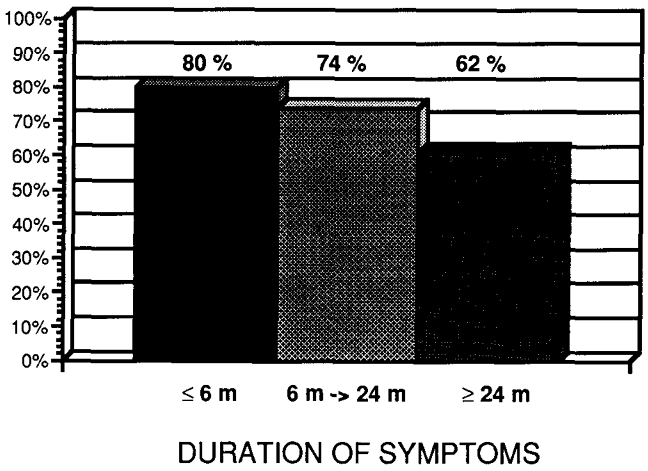

Figure 1. Histogram of proportion of eyes that were anatomically successful, stratified by duration of symptoms (m = months).

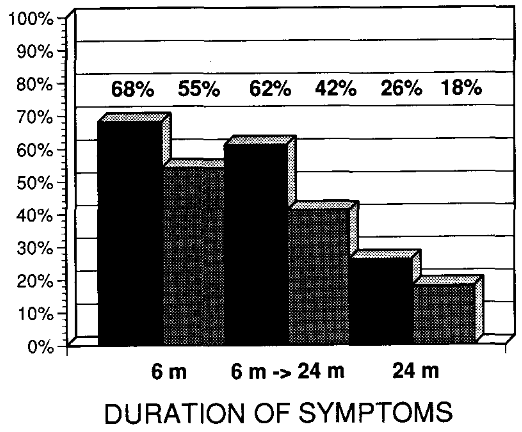

Figure 2. Histogram of percent of eyes that improved by two (solid bars) and four (shaded bars) lines of visual acuity after surgery, stratified by duration of symptoms.

latter (P = 0.037 and 0.001 for 2- and 4-line criteria, respectively). The proportion of patients with visual success at the two-line criterion was 68% (n = 45), 62% (n = 40), and 26% (n = 10) for patients with symptom duration of 6, 6 to 24, and 24 months, respectively. The proportion of patients with visual success at the four-line criterion was 55% (n = 36), 42% (n = 27), and 18% (n = 7) for the same symptom strata. Visual results generally lagged approximately 6 weeks subsequent to anatomic success.

Intraoperatively, we observed a set of common vitreous findings in these patients. There was usually a zone of collapsed vitreous fibers lying anterior to a posterior optically clear cavity. The vitreous cortex or posterior hyaloid may frequently be invisible, and it may remain attached to the underlying internal-limiting membrane of the retina. In some cases, an operculum floating above the macular hole may suggest the presence of a focally detached vitreous cortex. At times, this focal vitreous detachment can be demonstrated in photographs[22] and on ultrasound examination (unpublished data, Fisher YL; presented at the 1991 American Academy of Ophthalmology Annual Meeting).

At the 1-week visit, in cases where sulfurhexafluoride was used, approximately 50% to 60% of the gas bubble remained. Patients who have complied with the positioning requirement generally had cellular debris precipitated on the corneal endothelium, which we named a "good positioning spot." Our impression was that visualization of the macula, especially if the edges of the macular hole were flattened, predicted anatomic success. In contrast, if the edges are still visible and the cuff elevated, anatomic failure was generally the rule, despite additional prone positioning. Postoperatively, there were some eyes where the edges could be detected by contact lens examination, whereas in others the edges were imperceptible. In a few successful cases, the edges appeared to have slid together, forming a curvilinear line. In every anatomically successful case, the cystic retinal changes around the edges of the hole resolved. It is also our impression that the smaller holes are easier to close and are more likely to experience significant visual improvement.

We have had limited experience with eyes with good preoperative visual acuity or with re-operations. Eight of the nine patients with visual acuity of 20/80 (89%) on whom we operated achieved anatomic success as well as visual success at the two-line criterion. Reoperation on patients who initially failed because of poor compliance has been successful in two of four cases. When anatomic failure was believed to be secondary to residual epiretinal membranes, reoperation has been successful in a few eyes. Minimal laser intervention with in-office gas–fluid exchange has been attempted unsuccessfully in a few cases.

To date, 28 (22%) anatomically successful eyes have undergone cataract surgery. Additional complications developed in 17 eyes (6%, Table 1), with variable effects on vision. The most frequent complication was disturbance of the RPE. All nine of these eyes were anatomically "closed." Three eyes improved one or more lines of visual acuity, one eye lost one line of vision, one eye lost more than one line of vision, and four had no change in acuity. Other complications included an increase in the size of the cuff of elevation after failed surgery in one patient. The visual acuity dropped to counting fingers because most of the macula detached. An in-office gas–fluid exchange followed by face-down positioning reattached all

Table 1. Complications in 170 Eyes Undergoing Macular Hole Surgery

Complication	No. of Patients	Visual Change			
		Loss ≤ 1 Line	*Loss ≥ 1 Line*	*None*	*Improvement*
Retinal pigmented epithelium disturbance	9	1	1	4	3
Larger hole	2	—	1	1	—
Retinal detachment	2	—	—	—	2
Postoperative retinal tear	2	—	—	—	2
Macular detachment	1	—	—	1	—
Vascular occlusion	1	—	1	—	—

but the cuff surrounding the hole. Visual acuity returned to 20/400, and the eye has remained stable. Retinal detachments developed in two eyes postoperatively. One which was a "macula on" detachment after successful macular hole surgery was repaired using pneumatic retinopexy. Visual acuity in this eye has improved from 20/200 to 20/70. A "macula off" detachment with reopening of the previously repaired macular hole developed in the other eye. This eye underwent repeat vitrectomy with internal drainage through the macular hole and cryoretinopexy to the causative peripheral retinal break. Surprisingly, visual acuity has now improved to 20/25. Postoperative retinal tears treated with cryoretinopexy in the office developed in two eyes. Seven eyes lost one line of visual acuity without having any identified operative complications. Two of these were anatomic successes and five were anatomic failures.

Discussion

Our objective was to evaluate the therapeutic benefit of macular hole surgery in a larger patient population. In expanding the population threefold, we extended our observations of the benefit of this procedure. The anatomic success rate in the large sample (73%) was greater than that in the earlier pilot study (58%). Similarly, the visual success rate for the two-line criterion also increased, from 42% to 56%. In contrast, there was no increase in the complication rate, even with the addition of surgeons new to this technique for whom there was a learning curve.

The proportion of patients in whom cataract extraction was required is a function of the postoperative follow-up period. The longer the postoperative follow-up period, the more likely a cataract extraction was required. On the other hand, once the cataract has been removed, the visual acuity may show improvement. Changes in central scotomata found with automated central perimetry also can be followed, but variability due to difficulty in fixation makes this difficult in some patients.

In selecting patients who might best benefit from this procedure, we emphasize two aspects. First, the patient and family must understand and be willing to cooperate with the strict prone positioning for the first postoperative week. This requirement may be less burdensome by obtaining straws so that the patient can drink fluids, massage tables for comfortable prone sleeping, small portable television sets, prism glasses that aid in ambulation, and over-the-counter analgesics and anti-inflammatory drugs for back or neck pain. Second, patients in whom the onset of symptoms of macular hole are relatively recent ($\leq$6 months) appear to have a greater chance of a successful outcome. This relationship was not statistically significant for anatomic success, but it was for visual success. Although related, it is the latter which is clearly the most meaningful for the patient's quality of life.

Although the exact duration of symptoms is sometimes difficult for patients to recall, this difference appears significant, and seems associated with our understanding of progressive photoreceptor and pigment epithelial degeneration. The average age of the patients in this series was nearly 70 years, which suggests that the previous histopathologic studies showing widespread photoreceptor degeneration were mostly of longstanding holes.[4,5] Recently, a 78-year-old woman from this series who had successful bilateral macular hole surgery died of other causes. After death, her retinas were examined histopathologically. One macula was found to have a 50-μm plug of fibrous astrocytes sealing the hole, and the other had apparently sealed without any tissue proliferation. The photoreceptors at the margins of the hole appeared relatively normal in both eyes.[23] It is striking that excellent vision can be recovered with full-thickness macular holes, despite months of localized detachment around the hole. This is in contrast to "macula off" retinal detachments, in which central vision is permanently reduced after days to weeks of detachment. We hypothesize that the focal detachments around macular holes have an environment more similar to serous detachments in conditions such as central serous chorioretinopathy, as opposed to "macula off" retinal detachments. This may be due to loculation of the cuff of fluid under the elevated rim by an attached posterior hyaloid and because of the relatively shallow elevation of these detachments.

We described important aspects of the surgical procedure in our previous report. We again stress attention to evaluation of the position of the posterior hyaloid face, the size of the hole and surrounding cuff, and the presence of thin epiretinal membranes.

We were unable to anatomically reattach the macula in approximately one fourth of cases. The cause of failure is uncertain, but numerous factors may contribute. Postoperative tamponade is probably an important factor, which may be compromised with incomplete compliance with the occiput-up positioning. Epiretinal membranes may remain on the retinal surface, producing residual traction. Intrinsic retinal changes causing stiffness could prevent relaxation and retinal reattachment. Insufficient retinopexy, a consequence of atraumatic surgery, possibly plays a role. The involvement of the RPE and choroid in the pathogenesis of hole formation, if any, is not addressed by vitrectomy surgery. Subsequent to our initial report of macular hole surgery, Glaser et al[24] reported that intraoperative application of transforming growth factor $\beta 2$ improved both anatomic success, and subsequent visual success. Perhaps a pharmacologic adjunct such as transforming growth factor $\beta 2$ might enhance the anatomic and visual success of this procedure.

As with most invasive procedures, surgical complications occurred. An enhanced awareness of the possible complications may minimize the risk of their occurrence. The free edge of the macular hole is mobile and susceptible to incarceration during aspiration maneuvers, which can lead to tearing and enlargement of the hole. Peripheral retinal tears may develop during stripping of the cortical vitreous. During membrane stripping, care must be taken to avoid excessive traction and inadvertent damage to the edge of the macular hole and inner retina. Blunt trauma, damage to the internal-limiting membrane, and prolonged exposure to the light pipe can lead to RPE disruption and visual loss.[21,25] Retinal detachment and cataract are known complications after vitrectomy, the latter occurring with high frequency.[26]

Our preoperative and intraoperative observations confirm those of Gass.[14] Some holes appear to start eccentrically, opening in can-opener fashion until an operculum is formed. In other cases, a central dehiscence occurs, with gradual enlargement, and no operculum is seen. In eyes with operculum, we have noted that the size of the hole is usually larger than the operculum. This may occur due to persistent tangential traction on the edges of the hole with subsequent enlargement, the elevation of the edges giving the appearance of a larger opening, and due to shrinkage of the operculum. Intraoperatively, the edges of the hole appear to slide closer together during removal of the last drop of fluid from the hole, in the final phase of gas–fluid exchange. We hypothesize that a smaller central opening is achieved in eyes in which an operculum was present. Total closure with re-approximated edges is sometimes achieved in those eyes in which the hole formed with a central dehiscence without operculum. The variable clinical picture with respect to detection of edges may relate to the inconsistent shrinkage noted intraoperatively and to the variable mechanisms of reattachment and healing. In every anatomically successful case in our study, the cystic retinal changes resolved.

The role of anterior posterior vitreous traction and posterior vitreous detachment has been emphasized for many years as the important pathogenic mechanism in macular hole formation. Gass[14] and others have emphasized the difficulty in distinguishing posterior vitreous detachment from a zone of posterior vitreous liquefaction and attached posterior cortical vitreous over the macula. Gass has emphasized that unless the sheet-like structure (posterior cortical vitreous) contains the vitreous condensation ring over the optic nerve, or the sheet can be traced nasally to its attachment at the optic nerve, or an operculum or pseudo-operculum is present on its surface, the diagnosis of posterior vitreous detachment is uncertain. Smiddy et al[16] also have noted the difficulty in making an accurate clinical diagnosis of posterior vitreous detachment, and commented that intraoperative observations during vitrectomy provide the most accurate means of determining the status of the posterior cortical vitreous.

The mechanism of retinal reattachment has been speculative. Three cases of spontaneously healed macular holes were studied by Guyer et al.[5] In this postmortem study, two holes were sealed by hyperplastic RPE and one by fibroglial proliferation. No method of thermal or synthetic retinopexy was used in our surgical cases. We have speculated that the release of macular traction coupled with the microtrauma of surgery may create the necessary environment to reattach the cuff surrounding the macular hole in most cases. Occasionally, micro-hemorrhage occurs at the edge of the hole during membrane stripping, and we have hypothesized that this may make the retina more "sticky" and help achieve anatomic success. Study of the postoperative fluorescein angiogram may help elucidate the mechanism of retinal reattachment. The central hyperfluorescence has been noted to resolve in some anatomically successful cases,[21,25] possibly related to RPE hyperplasia, fibroglial proliferation, either because of xanthophyll migration or because the edges of the hole have slid together. With our understanding of the importance of duration of symptoms, we also are operating earlier in the course of the disease, and this has probably contributed to improved results. Finally, progressive nuclear sclerosis occurs in a high percentage of eyes, and best visual results are only obtained after cataract extraction. With longer follow-up since the initial report, more patients with anatomic success have now had cataract surgery and further visual success.

Vitreous surgery for macular holes offers a therapeutic promise for an otherwise untreatable condition. We look forward to the work of other investigators to establish whether biologic modulation intraoperatively and postoperatively can improve the results of this surgery.

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