



Radial Retinal Incisions for Complex Pediatric Traumatic Macular Holes

The first two reports of macular holes—by Knapp in 1869 and Noyes in 1871—were both traumatic in etiology.^{1,2} Since these early reports, however, our understanding of traumatic macular holes (TMH) has lagged somewhat behind our understanding of the more common variant, idiopathic macular holes, particularly regarding appropriate intervention.

Unlike idiopathic macular holes—the pathology of which is almost purely due to vitreomacular traction, and for which pars plana vitrectomy (PPV), with or without peeling of the internal limiting membrane (ILM), yields a closure rate of 85 to 100%³—TMH results from tractional forces that are more complex and more abrupt in nature.^{4,5} The putative mechanism of hole formation begins with axial compression of the globe during blunt force trauma, which causes a compensatory equatorial expansion, yielding centrifugal shearing forces that split the retina in the macula, and also disrupting the vitreomacular interface.⁴ Most likely, the immediate shearing forces are responsible for immediate hole formation (primary concussive dehiscence of the fovea), whereas the disrupted vitreomacular interface causes delayed (or progressive) TMH.⁵ Likely, most TMH are the result of a combination of these forces.

Interestingly, a subset of TMH has been reported to close spontaneously in both adult and pediatric patients, further complicating the therapeutic paradigm in these cases.^{6–13} Visual acuity results in these cases of spontaneous closure tend to be favorable, with greater than 50% achieving a final visual acuity of $\geq 20/40$ in many

series.^{8–14} However, spontaneous closure tends to be less common if the TMH is larger, if there is no evidence of residual vitreomacular traction, or if a “cuff” of subretinal fluid is evident at the hole margin.⁹ In these cases, surgical intervention may be the better option, and a number of retrospective series report good closure rates after PPV with or without adjuvant techniques (e.g., ILM peeling and use of platelet concentrate).^{15–21}

Similar success has been reported in series of pediatric TMH, with hole closure rates as high as 100% in some small series²²—a highly relevant point, given that TMH patients demonstrate a strong pediatric skew.⁴ As with adults, however, success in pediatric TMH seems to be associated with smaller TMH, persistent vitreomacular traction, and the absence of a fluid cuff at the hole margin.²³ Pediatric TMH with higher risk factors may be more expeditiously treated using adjuvant techniques to promote reapposition of the hole margin.

To this end, we present a surgical technique for promoting anatomical correction of TMH through the creation of radial retinal incisions at the rim of the hole that, to our knowledge, has not been previously reported in pediatric patients. In both cases, anatomical closure of the TMH was noted postoperatively.

Surgical Technique

The **Supplemental Digital Content 1** (see **Video 1**, <http://links.lww.com/IAE/A394>) demonstrates the surgical technique performed in the case of Patient 1 by one of the authors (AC). The patient was a 5-year-old boy who developed a TMH in the left eye after sustaining a blow with a baseball bat. Initial examination of the patient allowed for appreciation of the TMH, although the patient was not amenable to imaging with optical coherence tomography at that time. He subsequently underwent examination under anesthesia, which confirmed the presence of a large full-thickness TMH, followed by 25-gauge (G) PPV, with peeling of the ILM assisted by indocyanine green staining. Peeling of the ILM was performed beyond the vascular arcades in an attempt to remove all pathologic traction. Given the patient's age and the anticipation of poor compliance with positioning, silicone oil tamponade was chosen.

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Examination under anesthesia was repeated 1 month later, and the patient was found to have a persistent TMH which, although somewhat smaller than initial presentation, remained open with a taut border and a clinically apparent cuff of subretinal fluid. (Figure 1) A second surgery was then performed, as shown in **Supplemental Digital Content 1** (see **Video 1**, <http://links.lww.com/IAE/A394>). Again, a 25-G PPV approach was used with the Alcon Constellation system (Alcon Laboratories, Inc, Fort Worth, TX). After removal of the silicone oil, indocyanine green staining of the macula was repeated to confirm the absence of residual ILM at the border of the TMH. Additionally, a Tano diamond-dusted membrane scraper (Synergetics, Inc, O'Fallon, MO) was used to (1) confirm the absence of ILM surrounding the TMH and (2) loosen the taut edges of the hole, presumably by disruption of proliferative glial tissue.

Next, Grieshaber vertical scissors (Alcon Laboratories, Inc) were used to create two full-thickness radial incisions at the horizontal meridians (i.e., nasally and temporally). The lead blade of the scissors was carefully inserted under the edge of the TMH, and a single cut was performed, creating two incisions that were the approximate length of the scissors' blades. Finally, fluid–air exchange was performed, including extrusion of highly viscous subretinal fluid from within the TMH, and silicone oil was instilled. Care was taken at this point to avoid further disruption of the hole margin with the extrusion cannula.

At 1-month follow-up, the macular hole was noted to be closed on clinical examination, and this was confirmed by optical coherence tomography imaging

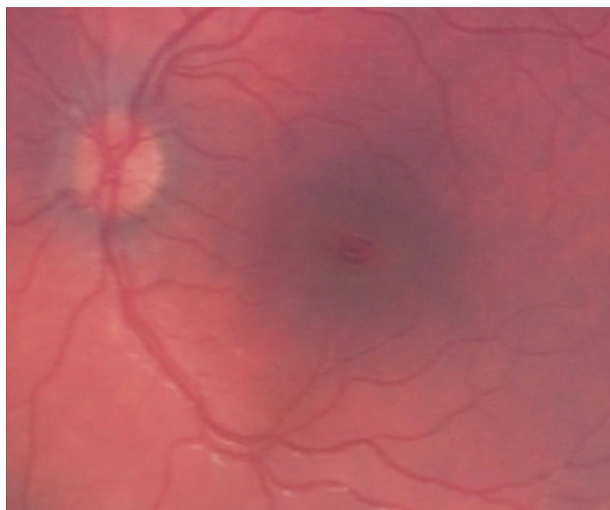


Fig. 1. Patient 1 is a 5-year-old boy who sustained a TMH after blunt ocular injury with a baseball bat; the hole remained open in spite of PPV with peeling of the ILM. Intraoperative fundus image of the left eye of Patient 1 demonstrates a refractory full-thickness TMH.

(Figure 2, A and B). Subsequent PPV with removal of silicone oil was performed at postoperative Month 2. Final follow-up at postoperative Month 4 disclosed persistent closure of the macular hole. Final visual acuity left eye was measured as counting fingers at 4 ft, although visual acuity testing was limited in this case by patient cooperation. There were no intraoperative or postoperative complications.

The **Supplemental Digital Content 2** (see **Video 2**, <http://links.lww.com/IAE/A395>) demonstrates a similar surgical approach for Patient 2. The patient was a 9-year-old boy who developed a large TMH right eye after blunt trauma to the eye with a soccer ball. On initial examination, a TMH with an approximate diameter of 600 μm was noted with surrounding changes of the retinal pigment epithelium. The patient was taken for examination under anesthesia and a PPV with peeling of the ILM was performed. As described above, a 25-G approach was used with an Alcon Constellation system. A core vitrectomy was performed, followed by elevation of the posterior hyaloid membrane using the vitreous cutter and subsequent completion of the vitrectomy. Indocyanine green-assisted ILM peeling was then performed using Tewari Omnicep forceps (Synergetics, Inc), and the peel was performed to the vascular arcades. As described above, a Tano diamond-dusted membrane scraper was used to confirm the absence of residual ILM and loosen the edges of the TMH.

Given the relatively large size of the hole, we elected to make two radial retinal incisions to promote hole closure. Of note, the subretinal fluid cuff in this patient was somewhat smaller and, thus, did not safely permit introduction of a vertical scissors under the TMH margin. Instead, a 25-G microvitoretinal blade (Alcon Laboratories, Inc) was used to create the two radial incisions in the horizontal meridians. As described above, this was followed by complete fluid–air exchange and instillation of silicone oil for tamponade.

The silicone oil was removed after a repeat examination under anesthesia at postoperative Week 6. Clinical examination and optical coherence tomography imaging performed on the same day confirmed full anatomical closure of the macular hole. At 3-month postoperative follow-up (from the patient's original surgery), the TMH remained closed and final visual acuity had improved to 20/100 (Figure 3, A–F). There were no intraoperative or postoperative complications.

Discussion

All macular holes are not created equal: long-term macular holes and large macular holes carry a poor

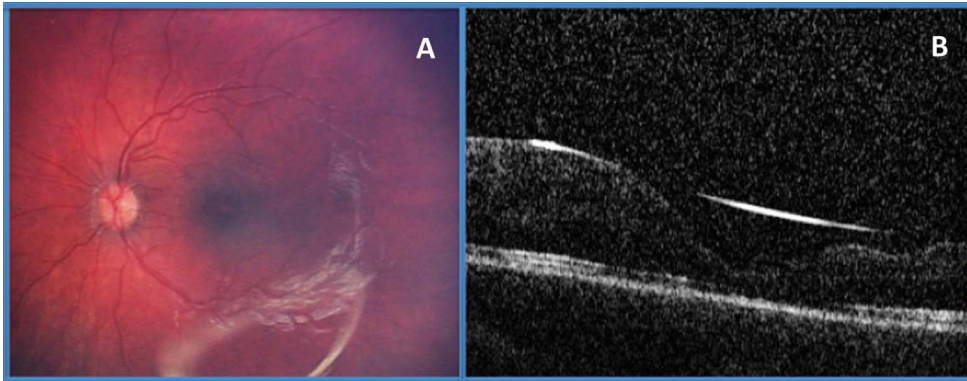


Fig. 2. A and B. A is a postoperative color fundus photograph at postoperative Month 1 demonstrating closure of the macular hole. Postoperative optical coherence tomography confirms closure of the TMH (B).

prognosis for closure, and also those associated with high myopia, retinal detachments, or trauma.²⁴ The most consistent risk factor for poor surgical outcome, however, remains size: holes with a minimum diameter of less than 400 μm have an anatomical success of 92% to 97% closure, compared with holes with a diameter of greater than 500 μm , which have a success rate less than 50%.⁸

Several treatment options exist when addressing these high-risk TMH in pediatric patients; as mentioned above, spontaneous closure of TMH is possible and has been reported with large holes.¹¹ Younger patients tend

to have a more favorable prognosis for spontaneous closure, usually between 1 week and 6 months after the injury.⁴ However, the variable timing and frequency of closure, combined with the threat of amblyopia in younger patients, make observation less appealing as a treatment option.²⁵

Vitrectomy with ILM peeling is reported to increase the odds of anatomical closure of TMH, and it does so in a more expeditious and predictable manner. As such, some favor immediate surgical intervention with PPV rather than a period of initial observation, although no

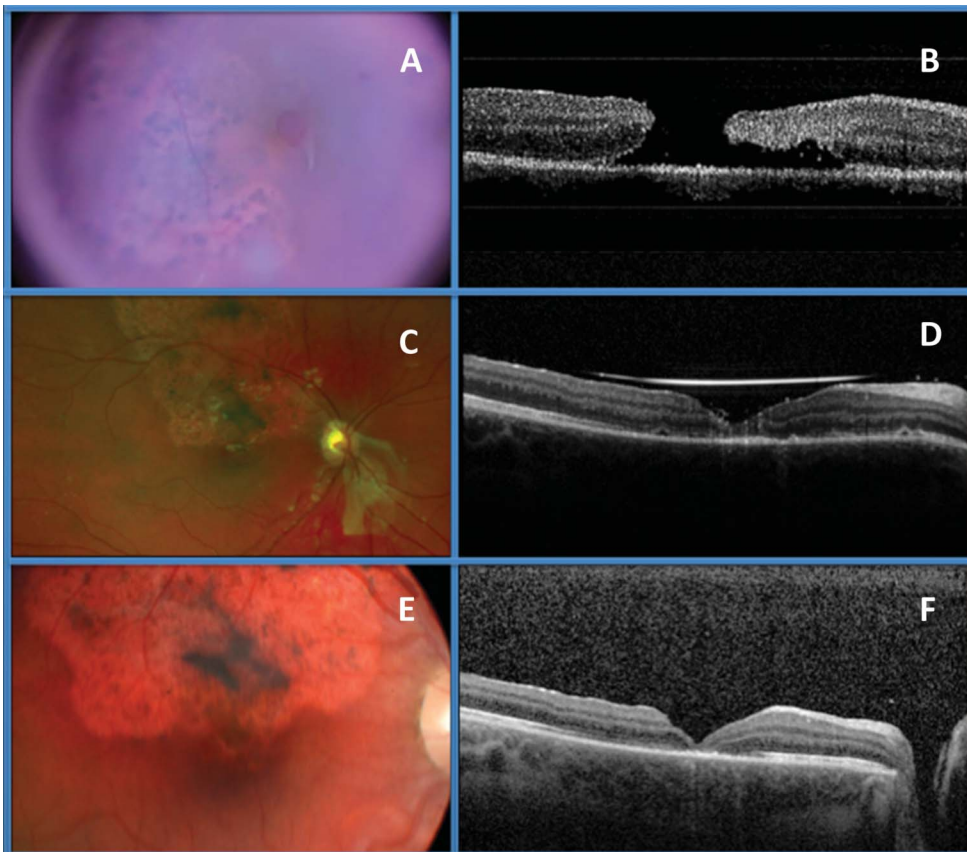


Fig. 3. A–F. Patient 2 is a 9-year-old boy who sustained a blunt ocular injury to the right eye with a soccer ball, with subsequent formation of a TMH. Intraoperative color fundus image (A) and Preoperative optical coherence tomography (B) demonstrate a full-thickness TMH. Imaging from postoperative Week 6 after repair demonstrates closure of the macular hole, with a small amount of residual subretinal fluid (C and D). Repeat imaging at postoperative Month 3 shows persistent closure of the TMH with resolution of subretinal fluid (E and F).

head-to-head comparison data are available.²³ Combining PPV with intraocular gas tamponade is convenient (as it does not require follow-up surgery), but difficulties with positioning among younger patients usually necessitate silicone oil tamponade with a follow-up procedure for removal (as with our patients).⁴ Additionally, a number of other adjuvant therapies—aimed at diminishing tractional forces and promoting hole closure—have demonstrated safety in pediatric eyes: notably, the use of autologous plasmin²⁵ and platelet concentrate.²²

What surgical options exist, however, in a case such as that of Patient 1 (if surgery is even the most appropriate course at all)? The TMH in this patient remained open, despite complete removal of the posterior hyaloid and thorough peeling of the ILM. Reis et al reported a technique for addressing refractory macular holes in adults that involved making five radial retinal incisions with a 25-G needle or 25-G microvitoretinal blade along the margin of the hole—a maneuver that, they postulated, relaxed the hole margin and allowed subsequent gliosis to close the hole.²⁴ Anatomical closure was achieved in seven of seven cases reviewed.²⁴ Similar techniques using full-thickness macular incisions have been described by both Smiddy²⁶ and Charles²⁷ to address refractory macular holes.

We report the first experience in the use of radial retinal incisions for pediatric TMH, which, to our knowledge, has not been reported in the pediatric population. This technique seemed to demonstrate short-term safety and efficacy in addressing two very challenging cases in children—a refractory TMH and a very large TMH—both of which closed within 4 to 6 weeks of the described surgery (and remained closed at 3–4 months of follow-up). The advantages of this method include the relative speed of the maneuver (for example, compared with the duration necessary for autologous plasmin to exert its effect²⁵) and the material ease (requires only one additional surgical instrument). Also, the technique can be adapted to multiple instruments (vertical scissors, microvitoretinal blade, 25-G needle) according to availability and, more importantly, the configuration of the TMH.

This method is, unfortunately, disadvantaged by the potential risk of trauma to the subfoveal retinal pigment epithelium during creation of the incisions (especially in cases without an underlying cuff of subretinal fluid), and also the very real trauma to the disrupted foveal tissues by creating the incisions themselves. Thus, patient selection should be limited to a small subset of TMH with poor prognostic characteristics, as with our small series. Additionally, such techniques—when appropriate—are likely most appropriate in the hands of a pediatric retinal surgeon.

More importantly, we are still awaiting the long-term visual acuity outcomes for our patients after a trial of occlusive therapy and improved compliance with visual acuity testing (though early visual acuity in Patient 2 seems favorable). Still, we are able to report a novel technique that achieved anatomical closure in two cases of high-risk pediatric TMH with a sound intraoperative and postoperative safety profile.

Key words: internal limiting membrane peeling, macular hole, maculotomy, pediatric, radial retinal incision, refractory macular hole, retinotomy, traumatic macular hole.

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References

1. Knapp H. About isolated ruptures of the choroid as a result of trauma to the eyeball. *Arch Augenheilkd.* 1869;1:6–29.
2. Noyes HD. Detachment of the retina with laceration at the macula lutea. *Trans Am Ophthalmol Soc* 1871;1:128–129.
3. Steel DH, Lotery AJ. Idiopathic vitreomacular traction and macular hole: a comprehensive review of pathophysiology, diagnosis, and treatment. *Eye (Lond)* 2013;27:S1–S21.
4. Miller JB, Yonekawa Y, Elliott D, Vavvas DG. A review of traumatic macular hole: diagnosis and treatment. *Int Ophthalmol Clin.* 2013;53:59–67.
5. Huang J, Liu X, Wu Z, et al. Classification of full-thickness traumatic macular holes by optical coherence tomography. *Retina.* 2009;29:340–348.
6. Kusaka S, Fujikado T, Ikeda T, Tano Y. Spontaneous disappearance of traumatic macular holes in young patients. *Am J Ophthalmol.* 1997;123:837–839.
7. Parmar DN, Stanga PE, Reck AC, et al. Imaging of a traumatic macular hole with spontaneous closure. *Retina.* 1999;19:470–472.
8. Mitamura Y, Saito W, Ishida M, et al. Spontaneous closure of traumatic macular hole. *Retina.* 2001;21:385–389.
9. Yamashita T, Uemara A, Uchino E, et al. Spontaneous closure of traumatic macular hole. *Am J Ophthalmol.* 2002;133:230–235.
10. Yamada H, Sakai A, Yamada E, et al. Spontaneous closure of traumatic macular hole. *Am J Ophthalmol.* 2002;134:340–347.
11. Yeshurun I, Guerrero-Naranjo JL, Quiroz-Mercado H. Spontaneous closure of a large traumatic macular hole in a young patient. *Am J Ophthalmol.* 2002;134:602–603.
12. Menchini U, Virgili G, Giacomelli G, et al. Mechanism of spontaneous closure of traumatic macular hole: OCT study of one case. *Retina.* 2003;23:104–106.
13. Carpineto P, Ciancaglini M, Aharrh-Gnama A, et al. Optical coherence tomography and fundus microperimetry imaging of spontaneous closure of traumatic macular hole: a case report. *Eur J Ophthalmol.* 2005;15:165–169.
14. Smiddy WE. The current status of macular hole surgery. *Bull Soc Belge Ophthalmol.* 1996;262:31–42.
15. Rubin JS, Glaser BM, Thompson JT, et al. Vitrectomy, fluid-gas exchange and transforming growth factor-beta-2 for the

- treatment of traumatic macular holes. *Ophthalmology*. 1995;102:1840–1845.
16. De Bustros S. Vitreous surgery for traumatic macular hole. *Retina*. 1996;16:451–452.
 17. García-Arumí J, Corscostegui B, Cavero L, Sararols L. The role of vitreoretinal surgery on the treatment of posttraumatic macular hole. *Retina*. 1997;17:372–377.
 18. Margherio AR, Margherio RR, Hartzler M, et al. Plasmin enzyme-assisted vitrectomy in traumatic pediatric macular holes. *Ophthalmology*. 1998;105:1617–1620.
 19. Chow DR, Williams GA, Trese MT, et al. Successful closure of traumatic macular holes. *Retina*. 1999;19:405–409.
 20. Amari F, Ogino N, Matsumura M, et al. Vitreous surgery for traumatic macular holes. *Retina*. 1999;19:410–413.
 21. Kuhn F, Morris R, Mester V, Witherspoon CD. Internal limiting membrane removal for traumatic macular holes. *Ophthalmic Surg Lasers*. 2001;32:308–315.
 22. Wachtlin J, Jandek C, Potthöfer S, et al. Long-term results following pars plana vitrectomy with platelet concentrate in pediatric patients with traumatic macular hole. *Am J Ophthalmol*. 2003;136:197–199.
 23. Azevedo S, Ferreira N, Meireles A. Management of pediatric traumatic macular holes – case report. *Case Rep Ophthalmol*. 2013;4:20–27.
 24. Reis R, Ferreira N, Meireles A. Management of stage IV macular holes: when standard surgery fails. *Case Rep Ophthalmol*. 2012;3:240–250.
 25. Wu WC, Drenser KA, Trese MT, et al. Pediatric traumatic macular hole: results of autologous plasmin enzyme-assisted vitrectomy. *Am J Ophthalmol*. 2007;144:668–672.
 26. Smiddy W. Macular hole surgery technique. *Retina Today* 2012;71–74.
 27. Charles S. Arcuate Retinotomy for Repair of Very Large Failed Macular Holes. *Macula Society 29th Annual Meeting, San Diego, 2006*.