Visual Outcomes After 3-Port Lens-Sparing Vitrectomy in Stage 4 Retinopathy of Prematurity

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Objective: To assess the visual acuity of eyes successfully treated with 3-port lens-sparing vitrectomy for stage 4 retinopathy of prematurity.

Methods: Of 102 consecutive eyes achieving at least posterior pole reattachment, 30 eyes of 26 patients were tested by Teller or Allen acuity measurements and were subsequently converted to logarithm of the minimum angle of resolution (logMAR). Visual outcomes were also examined as either favorable or unfavorable (Snellen equivalent >20/200).

Results: Seventy-two eyes were not tested because of either inability to perform testing (age or neurologic sequelae related to prematurity) or loss of follow-up. Of those tested, mean±SD logMAR visual acuity for the stage 4A and stage 4B groups was 0.51±0.09 (Snellen approximate 20/62) and 1.03±0.19 (Snellen approximate 20/200), respectively (odds ratio, 0.39; 95% confidence interval, 0.24-0.64; P = .001). Of those eyes assessed by Teller measurements, 10 of 10 stage 4A eyes and 3 (37.5%) of 8 stage 4B eyes had favorable outcomes; among eyes assessed with Allen measurements, 4 of 4 stage 4A eyes and 0 of 8 stage 4B eyes had favorable outcomes.

Conclusions: The majority of eyes were not tested. Among eyes tested after successful 3-port lens-sparing vitrectomy, some eyes treated prior to macular detachment may be associated with a more favorable outcome and improved maintenance of functional visual acuity.

Arch Ophthalmol. 2006;124:675-679

Numerous authors have reported anatomic outcomes in eyes with stage 4A and stage 4B tractional retinal detachment (TRD) secondary to retinopathy of prematurity, but few have been able to assess functional visual outcomes in these children. Anatomic success in retinopathy of prematurity may not always equate with functional success. Although the optimal time for surgical intervention is often difficult to determine, infants and children with stage 4A TRD may have their retinas reattached prior to clinically detectable macular detachment, thus allowing for the opportunity to achieve better functional visual development and possibly reduce the risk of macular distortion and heterotopia.

Several procedures have been previously described to treat TRD related to retinopathy of prematurity, such as open-skys vitrectomy, scleral buckling alone, closed vitrectomy and lens surgery with or without scleral buckle, and lens-sparing vitrectomy (LSV) alone. Potential advantages of LSV include a high rate of anatomic success for stage 4 TRD, reduced incidence of induced anisometropia, relief of vitreous traction in posterior disease (particularly zone 1 and posterior zone 2), and avoidance of a secondary procedure to divide the buckle. Potential disadvantages include difficulty relieving anterior tractional forces because of the size of the lens.

In the current study, we report quantitative visual acuity (VA) measurements of successfully reattached retinas in stage 4A and stage 4B eyes using our 3-port LSV technique.

Methods

Institutional review board approval was obtained to retrospectively examine patient records for this study. A retrospective chart review was performed for 108 eyes of 102 consecutive patients with stage 4A or stage 4B TRD who underwent primary 3-port LSV from February 1998 to January 2004 by a single surgeon (E.R.H.). All eyes had previously undergone peripheral laser ablation and the zone of disease was established at that time. None of these eyes had previously undergone scleral...
buckle procedure. Of these 108 eyes, 102 (94.4%) ultimately achieved at least partial posterior pole reattachment at their most recent follow-up visit. From this series of 102 successful cases, 30 eyes (29.4%) of 26 patients underwent quantitative VA testing. Of those successful eyes that were not included in the series, possible reasons were lack of follow-up for vision testing and inability to perform vision tests, either because of young age or inability to cooperate (29 eyes), neurological sequelae of prematurity such as interventricular hemorrhage (22 eyes) and cerebral palsy (11 eyes), and loss of follow-up (10 eyes).

Fourteen eyes had been diagnosed with stage 4A TRD and 16 eyes with stage 4B TRD prior to LSV. Eighteen eyes (10 stage 4A, 8 stage 4B) were assessed by Teller acuity, and 12 eyes (4 stage 4A, 8 stage 4B) were assessed by Allen figures by masked technicians in the offices of consulting pediatric ophthalmologists. Values were converted to approximate Snellen equivalents and then to logarithm of the minimum angle of resolution (logMAR).

Infants were originally examined, either at the bedside or in the outpatient clinic, using an indirect ophthalmoscope and a 25-diopter condensing lens by the operating surgeon. Those eyes with suspected progressive stage 4A (macula-on TRD, involving at least 6 clock hours, threatening the posterior pole) or stage 4B retinal detachments were operated on within 48 hours of this examination. At the time of the procedure, a dilated fundus examination was performed on both eyes in every case. Thereafter, all infants underwent 3-port LSV at approximately 37 to 43 weeks (mean, 38.5 weeks) postmenstrual age.

The operative technique is described in the next section. Postoperative follow-up consisted of return visits at least once a month for the first 6 months, followed by every 3 to 6 months thereafter. The operating surgeon determined postoperative anatomic status either during an office examination or during an examination under anesthesia when an adequate office examination was not possible. Patients were then referred to a consulting pediatric ophthalmologist for VA testing, and these evaluations are described here.

**SURGICAL TECHNIQUE**

The surgical technique involves standard conjunctival opening for a 3-port vitrectomy followed by a single sclerotomy placed 1 mm posterior to the limbus in the inferotemporal quadrant. The microvitreoretinal blade incision path is vertical and advances only until the widest portion of the blade cuts the pars plicata epithelium to avoid damaging the retina immediately behind the sclerotomy. A 7-0 Vicryl suture (Ethicon, Inc, Piscataway, NJ) is preplaced across the sclerotomy, and then a 2.5-mm, 20-gauge infusion cannula is inserted into the eye and tied in place. Supporting the sclera during cannula insertion with toothed forceps ensures that the short tip fully penetrates the pars plicata epithelium. Then, the infusion cannula tip position is confirmed with the endodiathermy instrument prior to turning on the infusion line. Additional sclerotomies are made in the superonasal and superotemporal quadrants 1 mm posterior to the limbus. A standard 20-gauge endodiathermy and the Alcon Accurus InnoVit probe (Alcon Laboratories, Fort Worth, Tex) are removed for vitrectomy. Vitreous and membranes are removed with machine settings of 1200 to 1800 cuts per minute and 150 to 200 mm Hg suction. Gas injected infusion settings for intraocular pressures are set at 20 mm Hg unless intraocular bleeding required raising the pressure.

Surgical planes of vitreous are addressed in the following order: ridge/retina to lens/anterior hyaloid face; ridge to ridge; ridge to nerve; ridge to vitreous base; and circumferential along the ridge. Most dissection is carried out with the vitrectomy probe, but intraocular scissors are occasionally employed, particularly to begin dissection of the anterior trough. Layers of sheet-like vitreous membranes are dissected sequentially approaching the retina. The posterior hyaloid face is often nondissectible and cannot be removed. The ridge may be trimmed and thinned but not fully excised without creating retinal breaks.

A thorough peripheral retinal examination with scleral depression is then performed. If no retinal breaks are noted during the procedure, only balanced salt solution (BSS; Alcon Surgical, Ft Worth, Tex) is infused. If retinal breaks are noted during the procedure, perfluoropropane or silicone oil is used as a long-acting tamponade. The sclerotomies are then closed using 7-0 Vicryl sutures in a vertical mattress fashion. Postoperatively, specific positioning is required only if perfluoropropane is employed.

**VA MEASUREMENT PROCEDURE**

All follow-up examinations in which VA measurements were performed took place at the offices of unmasked referring pediatric ophthalmologists. Masked technicians performed these vision examinations because they were not informed as to which eye, if any, had undergone surgery. For Teller acuity grating, the apparatus consisted of 19 Teller acuity cards and a screen that contained a 20 × 47-cm aperture through which the cards were presented (Vistech, Dayton, Ohio). The contralateral eye was completely patched with an occluder during testing. Eighteen cards contained a 12.5 × 12.5-cm patch of grating, and one card was a blank, gray card. Using all 19 cards, 10 different 10-card subsets of consecutively ordered cards could be formed, each spanning a different range of highest-to-lowest spatial frequencies. Each subset was arranged in order from lowest to highest spatial frequency, and with the exception of subsets containing more than one 0.32 cycle/cm card, adjacent cards differed from one another by approximately 0.5 octave.

To ensure that testers were masked to the particular grating spatial frequencies used in a given test, the subset of cards to be used for each test was selected at random from among the 10 subsets. Briefly, the tester presented the subset of acuity cards in sequential order from lower to higher spatial frequencies, presenting each card as many times as necessary to decide whether the subject could resolve the grating on the card. From presentation to presentation, the tester typically rotated the cards by 180° to reverse the left-right position of the grating. However, with some children, especially those in the 2- to 4-year-old age range, testers presented on the same side on some trials to prevent the child from developing a tendency to look alternately from side to side. Presentation of cards continued until the tester decided, based on the child’s eye and head movements, which card contained the highest spatial frequency grating that could be resolved by the child.

Allen cards (Richmond Products Inc, Boca Raton, Fla) were presented as single optotypes on 4 × 4-in cards at variable viewing distances that ranged between 5 and 30 feet. Each eye was completely patched with an occluder during testing. The threshold for Allen cards was set at a minimum of 4 figures of a total 7 optotypes. The subjects were familiarized with Allen optotypes before testing. The process of familiarization with the Allen optotypes involved only the presentation of the figures once for no more than 5 seconds before the VA assessment. The VA levels were converted to their logMAR equivalents. Six eyes were tested using both Teller and Allen acuity methods, and the Tester acuity results were preferentially used because of greater reproducibility. Use of Lea symbols was not seen in postoperative notes from referring physicians, and use of HOTV letter symbols and Snellen acuity was attempted in some cases but resulted in a lack of reproducibility and inability to recognize letters in preschool children.
STATISTICAL ANALYSIS

Analyses were performed and compared with a t test and Wilcoxon rank-sum test when the data were not normally distributed. Categorical differences were compared using χ² tests. Logistic regression was used for adjustment of covariates. All P values were 2-sided, and P<.05 was considered statistically significant. Analyses were conducted using SAS statistical software (SAS Institute Inc, Cary, NC).

RESULTS

The data for these patients appear in Table 1 and Table 2. In the original cohort, 92 (85.2%) of 108 eyes were reattached after a single LSV and 102 (94.4%) of 108 eyes ultimately achieved at least partial posterior pole reattachment at the final follow-up visit. All stage 4A eyes achieved complete reattachment and 70 (92.1%) of 76 stage 4B eyes achieved partial or complete reattachment. Thus, 102 eyes were eligible by achieving at least posterior pole reattachment, and of these, 30 eyes underwent quantitative VA testing. Of the remaining 72 eyes, 34 eyes were unable to perform testing because of neurological sequelae, 16 eyes were not able to adequately perform quantitative vision testing because of young age, and 22 eyes had no follow-up testing yet.

Of the 30 eyes of 26 patients, 14 were stage 4A eyes and 16 stage 4B eyes; 19 eyes were of 15 boys and 11 eyes were of 11 girls. Thirteen eyes were in zone 1, and 17 were in posterior zone 2. Overall, mean±SD gestational age at birth was 25.83±1.15 weeks, and mean±SD gestational age at surgery was 39.81±1.49 weeks. Mean±SD birth weight was 846.54±28.30 g. Mean±SD age at VA testing was 3.74±0.36 years and mean±SD VA by logMAR was 0.79±0.30 (Snellen approximate 20/125).

In the stage 4A group, 10 eyes were of boys and 4 were of girls. Four eyes were in zone 1, and 10 eyes were in posterior zone 2. Mean±SD gestational age at birth was 26.83±0.58 weeks, and mean±SD gestational age at surgery was 39.42±1.24 weeks. Mean±SD birth weight was 873.17±15.26 g. No stage 4A eyes had required long-acting gas tamponade. Mean±SD age at VA testing was 3.68±0.30 years, and mean±SD VA by logMAR was 0.51±0.09 (20/62).

In the stage 4B group, 9 eyes were of boys and 7 were of girls. Nine eyes were in zone 1, and 7 eyes were in posterior zone 2. Mean±SD gestational age at birth was 24.96±0.72 weeks, and mean±SD gestational age at surgery was 40.14±1.66 weeks. Mean±SD birth weight was 823.71±11.30 g. Two stage 4B eyes had required long-acting gas tamponade using perfluoropropane. Mean±SD age at VA testing was 3.80±0.41 years, and mean±SD VA by logMAR was 1.03±0.19 (20/200).

Infants with stage 4A eyes were of greater gestational age at birth (26.83±0.58 vs 24.96±0.72 weeks; P<.001).

Table 1. Individual Patient Data for 30 Eyes of 26 Patients

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<th>Sex</th>
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<th>GAS, wk</th>
<th>BW, g</th>
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<th>Zone</th>
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Abbreviations: BW, birth weight; GAB, gestational age at birth; GAS, gestational age at surgery; logMAR, logarithm of the minimal angle of resolution; P2, posterior zone 2; TRD, tractional retinal detachment; VA, visual acuity; Z1, zone 1.
of greater birth weight (873.17 ± 15.26 g vs 823.71 ± 11.30 g; P < .001), and younger at VA testing (3.68 ± 0.30 vs 3.80 ± 0.41 years; P < .005) than infants with stage 4B eyes. Overall, mean ± SD logMAR VA for the stage 4A and stage 4B groups was 0.51 ± 0.09 (20/62) and 1.03 ± 0.19 (20/200), respectively. In the 18 eyes that underwent Teller grating acuity, mean ± SD logMAR VA for the stage 4A and stage 4B groups was 0.53 ± 0.18 (20/67) and 1.06 ± 0.10 (20/230), respectively. In the 12 eyes that underwent Allon optotype acuity measurement, mean ± SD logMAR VA for the stage 4A and stage 4B groups was 0.48 ± 0.08 (20/60) and 0.96 ± 0.12 (20/182), respectively. After we controlled for differences in birth weight, gestational age, age and mode of VA testing, and zone 1 disease between stage 4A and stage 4B groups, logistic regression analysis demonstrated a difference in mean ± SD logMAR VA between the 2 groups (odds ratio, 0.39; 95% confidence interval, 0.24–0.64; P = .001).

Although several authors have demonstrated that advanced stages of TRD related to retinopathy of prematurity may be successfully surgically repaired, functional outcomes of advanced TRD still are rarely better than 20/400.1–4 In terms of VA, 76% of eyes with stage 4A TRD possessed VA of less than 20/200 at 4.5 years.29 Recently, studies advocating the LSV technique have suggested that repair of a TRD prior to macular detachment may be the optimal time for surgical intervention, both anatomically and functionally.3,5–8

We have achieved success in retinal reattachment using a 3-port LSV technique. We believe that by sparing the lens, the patient has less likelihood of amblyopia and a greater likelihood of normal visual development. We believe that vitreous surgical intervention is important in these eyes because proliferative tissues often exist between the ridge, nerve, lens, and the pars plicata, areas that may not be adequately addressed by scleral buckle alone.8 Furthermore, scleral buckling increases induced anisometropia and requires a secondary dividing procedure. Also, LSV has achieved greater anatomical success than scleral buckle alone.3,5–8,11 This series and others using LSV3,8–11 also have reported superior VA outcomes.

We believe that the current study may support the utility of earlier surgical intervention. As stated, the mean VA of the stage 4A group was 20/63 while that of the stage 4B group was 20/200. Although the numbers in this study are small, they indicate that a statistically significant difference exists between these 2 groups. Also, when examining the favorable and unfavorable outcomes of visual testing, the trend may be that functional vision may be better maintained if surgical intervention occurs prior to macular detachment. However, because of the small numbers and the different testing methods, we cannot be certain if inherent biases may be pointing the data toward a better outcome. Perhaps the differences may not be as great as the data suggest because of these weaknesses in the study. Nonetheless, there may be a trend that needs further exploration.

The possible strengths of the study are that it was a single-surgeon, consecutive case series performed over several years. Staging of surgical anatomy was always performed in a controlled setting by an examination under anesthesia with surgery within 48 hours of this examination. Perhaps the lack of surgical delay may have prevented stage 4A detachments from advancing to macular detachment and thus contributed to better outcomes for those eyes in terms of VA. In looking at the results, the difference in logMAR vision (0.50 vs 0.99) indicates a possibly more favorable prognosis for stage 4A eyes. A favorable outcome was noted in 14 (100%) of 14 stage 4A and 3 (18.8%) of 16 stage 4B eyes.

Several obvious limitations exist in this study. This is a nonrandomized, noncontrolled, retrospective study, and it is important to recognize that the cohort represents a highly selected sample that excluded many children because of inability to perform the examination, neurologic sequelae related to prematurity, or loss of follow-up. We cannot be certain that the same results would have been found had all patients in this original cohort been evaluated. Nevertheless, the results are encouraging when compared with reported outcomes of patients with untreated stage 4A and 4B TRD.30,31 Also, rather than adhering to a uniform outlined protocol for follow-up examination, reliance was made on the masking of examiners at the offices of consulting pediatric ophthalmologists. We did not obtain information on the fellow eye in many instances. In some cases, amblyopia in the fellow eye may change the visual outcome in the eye that had the operation.

Finally, Allen optotypes may overestimate VA results.27,32,33 Snellen letters have been regarded as the gold standard for determining resolvable VA, but these letters may be too abstract for evaluating the VA in preschool children. In an ideal study, such as a randomized, prospective one, using other optotypes (ie, HOTV letter symbols) may be a better measurement of VA out-

### Table 2. Summary Patient Data for 26 Patients (15 Boys, 11 Girls)

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<tr>
<th>Category</th>
<th>Sex, M/F, No.</th>
<th>GAB, Mean ± SD, wk</th>
<th>GAS, Mean ± SD, wk</th>
<th>BW, Mean ± SD, g</th>
<th>Eye, OD/OS, No.</th>
<th>Zone, Z1/P2, No.</th>
<th>TRD Stage, 4A/4B, No.</th>
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<th>Age at VA Test, Mean ± SD, y</th>
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<td>25.83 ± 1.13</td>
<td>39.81 ± 1.49</td>
<td>846.54 ± 28.30</td>
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<td>13/17</td>
<td>14/16</td>
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<td>3.74 ± 0.36</td>
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<td>Stage 4A cases (n = 14)</td>
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<td>26.83 ± 0.58</td>
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<td>873.17 ± 15.26</td>
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<td>13/13</td>
<td>14/14</td>
<td>0.51 ± 0.09</td>
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<td>Stage 4B cases (n = 16)</td>
<td>7/7</td>
<td>24.96 ± 0.72</td>
<td>40.14 ± 1.66</td>
<td>823.71 ± 11.30</td>
<td>13/13</td>
<td>13/13</td>
<td>14/14</td>
<td>1.03 ± 0.19</td>
<td>3.80 ± 0.41</td>
<td>12/12</td>
</tr>
</tbody>
</table>

Abbreviations: BW, birth weight; GAB, gestational age at birth; GAS, gestational age at surgery; logMAR, logarithm of the minimal angle of resolution; P2, posterior zone 2; TRD, tractional retinal detachment; VA, visual acuity; Z1, zone 1.
comes and may also equate more easily to Snellen letter equity.

In summary, we were able to collect a cohort of children who had undergone successful 3-port LSV for stage 4A and stage 4B TRD and then subsequently underwent formal VA testing. We believe that 3-port LSV is functionally efficacious in treating eyes with stage 4 TRD. Visual outcomes in the stage 4A group were statistically significantly better than the stage 4B group. A study, preferably a prospective, multicenter trial comparing surgical intervention at stage 4A or stage 4B, may be helpful to further examine this important question.

Submitted for Publication: December 23, 2004; final revision received September 15, 2005; accepted September 21, 2005.

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Financial Disclosure: None.

Funding/Support: This study was supported in part by an unrestricted grant from Research to Prevent Blindness, Inc, New York, NY.

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