Random Dot Stereoacuity Following Surgical Correction of Infantile Esotropia

Eileen E. Birch, PhD; David R. Stager, MD; and Mary E. Everett, CO

ABSTRACT

Surgical correction of infantile esotropia prior to age 2 is associated with a higher prevalence of fusion and stereopsis than surgical correction after 2 years of age. The advantages and disadvantages of surgical intervention at the early or late end of this window have been debated in the literature. In the present study, random dot (RD) stereoacuity outcomes were evaluated in order to determine whether a binocular sensory benefit is associated with early or late surgery. Participants were 73 healthy children enrolled in a prospective study of visual development in infantile esotropia. All children had initial surgical correction at 5 to 16 months of age. RD stereoacuity was evaluated approximately 5 years of age (59.7 ± 14.9 months). Overall, 41.1% of children demonstrated RD stereopsis. The percentage of children demonstrating RD stereopsis was not significantly different among groups that were surgically corrected at 5 to 8 months (43.8%), 9 to 12 months (47.4%), and 13 to 16 months (31.8%). However, among those children who achieved RD stereopsis, the prevalence of foveal (<60 sec) or macular (61 to 200 sec) stereoacuity was significantly higher among those who had surgery at 5 to 8 months (42.9%; Z = 2.06, p < 0.02) or 9 to 12 months (55.6%; Z = 2.38, p < 0.009) than among those who had surgery at 13 to 16 months (0%). Although surgical correction of infantile esotropia during the first year of life is not associated with a higher prevalence of RD stereopsis, it is associated with better RD stereoacuity among those children who achieve stereopsis following surgery.

INTRODUCTION

Surgical correction of infantile esotropia prior to age 2 is associated with a higher prevalence of fusion and stereopsis than surgical correction after 2.1 3 However, the advantages and disadvantages of surgical intervention at the early or late end of the 2-year window proposed in the clinical literature continue to be debated. It has been suggested that surgery during the first 12 months of life may be less likely to yield a good functional outcome because of difficulty in obtaining valid and reliable diagnostic measures of the fixation characteristics of each eye, comitance, refractive error, and stability of the basic deviation in young infants.4 Other factors that have been cited in arguments against surgery during the first year of life include monofixation syndrome, which may increase the risk for amblyopia,5 and the time needed to try alternative treatments, such as glasses for hyperopia and occlusion therapy.6

On the positive side, it has been argued that surgery during the first 12 months of life causes less psychic trauma to the child and may result in a higher likelihood of maintaining good alignment due to the early opportunity for development of fusion.7 Nonetheless, the single most important factor that continues to fuel this debate is the total absence of quantitative data supporting a functional benefit of surgery during the first 12 months in the human infantile esotropia population.

The present study was designed to evaluate potential functional benefits of surgery for infantile esotropia at 5 to 8 months, 9 to 12 months, and 13 to 16 months. Specifically, random dot (RD) stereoacuity outcomes were evaluated at age 5 to determine whether a binocular sensory benefit is associated with earlier surgery.

METHODS

Participants were 73 healthy children enrolled in a prospective study of visual development in infantile esotropia. All children participated in a battery of motor and sensory tests throughout the first 5 years of life, including forced-choice, preferential-looking, and operant tests of acuity. Here, we report stereoacuity outcomes of 73 consec-
TABLE 1
Clinical Data Age at Initial Alignment

<table>
<thead>
<tr>
<th></th>
<th>5 to 8 months</th>
<th>9 to 12 months</th>
<th>13 to 16 months</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( N )</td>
<td>32</td>
<td>19</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Age at diagnosis (months)(^1) range, mean, SD</td>
<td>2-7 4.3±1.3</td>
<td>3-7 5.0±1.3</td>
<td>3-7 4.7±1.3</td>
<td>( F_{2,70} = 1.71 \text{ ns.} )</td>
</tr>
<tr>
<td>Initial deviation (( \Delta )) range, mean, SD</td>
<td>35-90 61.6±14.4</td>
<td>30-65 45.3±11.6</td>
<td>30-65 48.9±10.9</td>
<td>( F_{2,70} = 11.86 ) p&lt;0.001</td>
</tr>
<tr>
<td>Initial refractive error (D)(^3) range, mean, SD</td>
<td>-0.50±0.50</td>
<td>1.29±0.72</td>
<td>1.61±1.05</td>
<td>( F_{2,70} = 0.29 \text{ n.s.} )</td>
</tr>
<tr>
<td>Prevalence of amblyopia on initial visit(^4) (% of infants)</td>
<td>34.4%</td>
<td>31.6%</td>
<td>36.4%</td>
<td></td>
</tr>
<tr>
<td>Number of horizontal procedures(^5) range, mean, SD</td>
<td>1-3, 1.2±0.5</td>
<td>1-2, 1.1±0.3</td>
<td>1-2, 1.3±0.5</td>
<td>( F_{2,70} = 0.32 \text{ n.s.} )</td>
</tr>
<tr>
<td>Prevalence of inferior oblique surgery(^6) (% of infants)</td>
<td>40.6%</td>
<td>31.6%</td>
<td>27.3%</td>
<td></td>
</tr>
<tr>
<td>Age at last visit (months) mean, SD</td>
<td>59.2±16.1</td>
<td>61.5±18.5</td>
<td>58.8±8.8</td>
<td>( F_{2,70} = 0.63 \text{ n.s.} )</td>
</tr>
<tr>
<td>Prevalence of adequate alignment at last visit(^7) (% of infants)</td>
<td>87.5%</td>
<td>89.4%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>ET &gt;( \Delta )</td>
<td>9.4%</td>
<td>5.3%</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>XT &gt;( \Delta )</td>
<td>3.1%</td>
<td>5.3%</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Prevalence of amblyopia (( \geq 2 ) lines) at last visit(^8) (%in infants)</td>
<td>18.8%</td>
<td>10.5%</td>
<td>9.1%</td>
<td></td>
</tr>
<tr>
<td>Prevalence of DVD(^9) (%infants)</td>
<td>56.3%</td>
<td>47.4%</td>
<td>45.5%</td>
<td></td>
</tr>
</tbody>
</table>

\(^1\) Age at time of diagnosis by an ophthalmologist.
\(^2\) Measured by the prism and cover when possible; or with the Krinsky method.
\(^3\) Measured with cycloplegia; Cyclogyl 0.2% (cyclopentolate hydrochloride, 1% phenylephrine hydrochloride) or Cyclogyl 1% (1% cyclopentolate hydrochloride) at <6 months; Cyclogyl 1% at 6 to 12 months; Cyclogyl 2% (2% cyclopentolate hydrochloride) at >12 months.
\(^4\) Assessed by fixation preference in cover/uncover test (poor or fair fixation by one eye or failure to maintain fixation when preferred eye was uncovered).
\(^5\) All patients had bilateral medial rectus recessions of 4 to 7 mm as the initial procedure; secondary procedures included both bilateral medial rectus recessions and lateral rectus resections.
\(^6\) Vertical surgical procedures (anterior transpositions and recessions) were undertaken when inferior oblique overaction was 2+ or greater (2 mm or more elevation on adduction).
\(^7\) Measured by prism-and-cover test at distance and near; +8 \( \Delta \).
\(^8\) Measured using linear arrangements of Sloan letters on a BVAT-II BVS system.
\(^9\) Dissociated vertical deviation at the last follow-up visit.

Table 2 summarizes the causes for delay in achieving alignment.

Common childhood illnesses, parents’ choice, late referrals, and the necessity for a second surgical opinion to satisfy third-party payers account for more than 80% of the delays. The remaining delays were due to ongoing preoperative treatment or failure to achieve adequate alignment with a single surgical procedure.

Patients were grouped according to the age at which initial adequate alignment was achieved (±8 \( \Delta \) stable for at least 3 months postoperatively); in 91.8% of cases, this was the same as the age at initial surgery. As shown in Table 1, the three treatment groups did not differ significantly in age at diagnosis or the prevalence of amblyopia on the initial visit.

The amount of esodeviation on the initial visit was significantly different among the three groups (Table 1), with a higher prevalence of large-angle esotropia (>60 \( \Delta \)) in the earliest treatment group (significantly different from the
other two treatment groups by posthoc Scheffe tests with p<0.001. Since the age at diagnosis did not differ significantly among groups, the higher prevalence of large-angle esotropia in the 5-to-8-month treatment group is not due to earlier referral for treatment for this subgroup.

The primary outcome measure was RD stereopsis, evaluated with an operant or the Randot test at approximately 5 years of age (59.7±14.9 months). As in an earlier study, excellent agreement was found for these two tests of RD stereopsis in the 4-to-7-year age range. In the small number of cases in which test outcomes were not in agreement, the more conservative outcome measure was used for data analysis.

Diagnostic, treatment, and clinical outcome data were obtained for the study. Diagnostic data included preoperative alignment, preoperative refractive error, and evidence of preoperative amblyopia. Included treatment data were age at surgery, amount of surgery, age when adequate alignment was first achieved, the total number of horizontal muscle procedures, and evidence for, or surgical treatment of inferior oblique overaction or dissociated vertical deviation. Outcome data included Sloan letter acuities and "final" alignment.

RESULTS

Alignment Outcome

Most patients achieved and maintained adequate horizontal alignment after a single bilateral medial rectus recession procedure of 4 mm to 7 mm (59/73 = 80.8%). Of the 14 patients requiring a second horizontal muscle surgical procedure, nine required correction of consecutive exotropia at 1½ to 4 years of age and five required correction of residual (n = 2) or recurrent (n = 3) esotropia. Alignment at age 5 was within ±8 Δ for 64 of 73 patients (87.7%); the remaining patients were esotropic (6/73 = 8.2%) or exotropic (3/73 = 4.1%). Dissociated vertical deviation was prevalent, occurring in 49.3% of patients. As summarized in Table 1, no significant differences were found among treatment age groups in the number of horizontal muscle or vertical muscle surgical procedures, the prevalence of adequate alignment at age 5, the prevalence of amblyopia at age 5, or the prevalence of dissociated vertical deviation.

RD Stereopsis Outcome

Overall, 41.1% of children demonstrated RD stereopsis. As shown in Figure 1, the percentage of children demonstrating RD stereopsis was not significantly different among groups that achieved adequate alignment at 5 to 8 months (43.8%), 9 to 12 months (47.4%), and 13 to 16 months (31.8%). However, among those children who achieved RD stereopsis (Fig 2), no child who achieved initial alignment at 13 to 16 months showed stereocuity greater than 250 sec. The prevalence of foveal (<60 sec) or macular (61 to 200 sec) stereocuity was significantly higher among those who had surgery at 5 to 8 months (42.9%; Z = 2.06, p<0.02) or 9 to 12 months (55.6%; Z = 2.38, p<0.009) than among those who had surgery at 13 to 16 months (0.0%).

There was no significant difference between the 5 to 8 months and 9 to 12 months groups (Z = 0.591, nonsignificant). Two patients, one in the 5 to 8 months group and one in the 9 to 12 months group, achieved RD stereocuity of <60 sec. In both cases, this result was confirmed using the Randot test, on three separate occasions at least 1 year apart (spanning 5 to 9 years of age); two of the tests were conducted in the laboratory by two different investigators and one of the tests was administered in a private practice setting by a pediatric ophthalmologist. However, both patients performed more poorly on the Titmus-sterecocust (80 sec to 140 sec, by two independent testers) and described small suppression scotomas on testing with Bagolini lenses.

DISCUSSION

Surgical correction of infantile esotropia during the first 12 months of life did not result in a higher prevalence
of RD stereopsis than achieved by surgical correction at 13 to 16 months. This result confirms the results of earlier studies that employed line stereograms, such as the Titmus and Wirt tests.\(^1\)\(^2\) However, among those children who achieved stereopsis following surgical intervention, the prevalence of foveal (<60 sec) or macular (<200 sec) stereoaucuity was significantly higher among children who had achieved alignment by 12 months of age. This result supports a benefit of early surgery among a subgroup of infantile esotropes who have potential for stereopsis. That is, at least some infantile esotropes who may have an innate capacity for stereopsis and stereoaucuity outcomes in this subgroup are optimized by early alignment. This hypothesis is consistent with the finding that the capacity for stereopsis exists in at least 40% of infantile esotopes prior to any treatment.\(^3\) The remainder of infantile esotropes, those who fail to achieve any stereopsis regardless of age at alignment, may have a genetic or congenital defect of fusion or stereopsis. Whether it may be possible to identify these two subgroups prior to treatment is unknown. Alternatively, the data presented here may represent a benefit of early surgery for those children who achieve alignment adequate to support the development of macular or foveal binocularity. Although alignment within ± 8 Δ is a typical outcome following bilateral medial rectus recessions for infantile esotropia, current surgical technique does not yield precise alignment of the visual axes. Alignment within ± 8 Δ is adequate for the development of monofixation syndrome that is generally considered the optimal outcome, which can be expected following treatment of infantile esotropia. However, it is possible that only some patients achieve a postoperative alignment, which allows for the development of macular or foveal stereoaucuity.

Previous studies of binocular outcomes following early treatment of infantile esotropia have been criticized on the basis that the methods of stereotesting were not satisfactory (ie, not RD)\(^1\)\(^2\); that results were analyzed only for those patients who had achieved adequate alignment\(^1\)\(^2\); and that the results appear overly optimistic because patients with neurological deficits, asymmetry of refractive errors, incomitance, or vertical deviations have been excluded from study.\(^1\)\(^2\)

The present study overcomes the first two objections and confirms the results of earlier studies in establishing a high prevalence of stereopsis (41.1%) in patients treated during the first 16 months of life. The final objection applies to our study, as well as earlier studies; however, this study design is required in order to investigate the necessary and sufficient conditions for the development of stereopsis in infantile esotropia. Only when this complex topic is understood will there exist a possibility of sorting out how other co-existing factors play a role in preventing the development of stereopsis in infantile esotropia.

The present data are compatible with anatomical, electrophysiological, and functional data from cat and monkey that show permanent deficits in binocular function when artificial or natural strabismus is present during the first year of life.\(^10\)\(^11\)\(^12\) During the first year of life, rapid anatomical and functional development normally occur in cat, monkey, and human visual cortex. Ocular dominance column segregation, which supports preservation of eye-of-origin information necessary for stereopsis, begins prenatally, but continues postnatally.\(^15\)\(^16\) Stereopsis has an abrupt postnatal onset and stereoaucuity develops rapidly to near-adult levels.\(^17\)\(^22\) This rapid anatomical and functional development is accompanied by susceptibility to disruption by abnormal visual experience.\(^23\)\(^25\) Moreover, data from animal models of infantile strabismus support the hypothesis that early correction of a strabismic deviation gives a greater opportunity for development of binocular function. Artificial misalignment of the visual axes during infancy results in a loss of binocular cortical neurons and a loss of stereopsis in monkeys.\(^8\)\(^10\)\(^11\) Recovery from abnormal development appears to be limited to cases in which normal eye alignment is restored during the earliest period of susceptibility.\(^26\)\(^27\) Taken together, the findings in animal models and the data from the present study support the hypothesis that early surgical alignment optimizes the development of stereopsis.

**REFERENCES**

7. Parks MM. Operate early for congenital strabismus. In: Brockhurst