Agreement between Grating Acuity at Age 1 Year and Snellen Acuity at Age 5.5 Years in the Preterm Child

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PURPOSE. To examine the relation between grating acuity at age 1 year and Snellen acuity and grating acuity at 5.5 years, in preterm children with birth weights less than 1251 g.

METHODS. Subjects were participants in the multicenter study of Cryotherapy for Retinopathy of Prematurity. The Teller acuity card (TAC; Vistech Consultants, Dayton, OH) procedure was used to measure monocular grating acuity in children at ages 1 and 5.5 years. Early-treatment diabetic retinopathy study (ETDRS) charts were used to measure the children's monocular recognition (Snellen) acuity at age 5.5 years. Data are presented for 575 eyes with measurable TAC grating acuity at 1 year and 111 eyes that had no measurable acuity at 1 year.

RESULTS. Among eyes with normal acuity at 1 year, 86.8% showed normal Snellen acuity, and 94.3% showed normal grating acuity at 5.5 years. Among eyes that were blind (i.e., had no measurable TAC grating acuity) at 1 year, 96.8% showed no quantifiable Snellen acuity, and 89.2% showed no quantifiable grating acuity at 5.5 years. Only 2.4% of eyes had acuity in the range between normal and blind at 1 year (i.e., measurable grating acuity <1.6 cyc/deg); thus, the predictive value of acuity scores in this range could not be determined. Correlation analysis indicated that the relative position within the normal range of an eye's grating acuity score at 1 year was not predictive of the relative position within the normal range of that eye's acuity score at 5.5 years.

CONCLUSIONS. Among a large population of low-birth-weight infants, eyes with normal grating acuity at age 1 year generally showed normal Snellen and grating acuity at age 5.5 years, and eyes that had no quantifiable acuity at 1 year remained blind at 5.5 years. Relative position of an eye's acuity score within the normal range was not predictive of the relative position of that eye's later acuity score.


The Teller acuity card (TAC; Vistech Consultants, Dayton, OH) procedure is a rapid, behavioral technique for assessment of grating visual acuity in infants and young children in clinical settings. The procedure provides acuity results that correlate highly with grating acuity results obtained with more rigorous laboratory-based procedures.1,2 Although the TAC procedure was developed to assess an infant's status at the time of the test, the question has been raised of whether TAC grating acuity in infancy correlates with Snellen acuity when the child reaches an age at which assessment of recognition acuity can be conducted.3

Mash and Dobson4 found modest, but significant, correlations between grating acuity measured with a modified TAC procedure in infancy and recognition acuity measured with a crowded letter chart (HOTV; Good-Lite, Chicago, IL) at age 4 years in a group of children who had been treated in the neonatal intensive care unit of Magee-Women's Hospital, Pittsburgh, Pennsylvania, for preterm birth and/or perinatal complications. Correlations (r) were as follows: 0.22 in 98 children tested at 4 months and 4 years of age, 0.33 in 104 children tested at 8 months and 4 years of age, and 0.26 in 97 children tested at 11 months and 4 years of age. These relatively low correlations may have resulted from the restricted range of acuity scores in the population, in that most subjects had acuity in the normal range (defined by preliminary norms published in the TAC Manual5).

The only other study that compared grating acuity during infancy (i.e., age 12 months or younger) with recognition acuity after age 4 years was conducted by Maurer et al.6 in a group of 35 aphakic infants after removal of congenital cataract. The correlation of 0.49 between grating acuity at 12 months, tested with the laboratory-based forced-choice preferential-looking technique, and Snellen acuity after age 4 years

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was higher than in the Mash and Dobson study, perhaps reflecting the wider range of acuity scores in this population.

In the multicenter study of Cryotherapy for Retinopathy of Prematurity (CRYO-ROP), ocular status and visual function were assessed at 1- to 1.5-year intervals from the neonatal period through age 5.5 years in more than 1000 children with birth weights less than 1251 g. In the present study we explored, in this large, low-birth-weight population, the extent to which TAC grating acuity measured in infancy agrees with Snellen and TAC grating acuity measured in early childhood. The primary goal of the analyses was to compare TAC grating acuity at age 1 year with Snellen acuity at age 5.5 years. However, because some children in the population were unable to complete Snellen acuity testing, primarily because of neurodevelopmental limitations, a comparison of TAC grating acuity results at age 1 year with TAC grating acuity results at age 5.5 years was also conducted.

**Subjects and Methods**

**Subjects**

Subjects in the CRYO-ROP study were 4172 children who were born at or transferred as neonates to one of the study's 23 centers between January 1, 1986, and November 30, 1987. All had birth weights less than 1251 g. Two hundred ninety-one children, all of whom had threshold retinopathy of prematurity (ROP) in one or both eyes, were participants in the randomized portion of the study. The remainder participated in a natural history study of ocular and visual development.

Long-term follow-up through age 5.5 years was offered to 1441 study participants, including all randomized subjects, all "special prethreshold" subjects, and all subjects at 5 of the 23 study centers. The special prethreshold group consisted of subjects who had 3+ ROP in zone 1 or zone 2 but had insufficient clock hours of disease to enter the randomized group. TAC grating acuity was assessed at age 1 year in 745 of these patients. The remaining 696 patients who did not have acuity assessed at age 1 year included 241 who did not return for the 1-year study examination and 455 who completed their 1-year eye examination before acuity testing was incorporated into the CRYO-ROP study.

**Procedures**

The research followed the tenets of the Declaration of Helsinki. Informed written consent was obtained from parents or guardians of all subjects before enrollment in the study and before entry into the follow-up phase of the study. The CRYO-ROP study was approved by the institutional review boards of all participating centers.

**Visual Acuity Assessment.** At the 1-year and 5.5-year CRYO-ROP study examinations, monocular grating acuity was assessed using the TAC procedure, according to a standard protocol. Testers for the 5.5-year examination were masked to previous acuity results. Before acuity testing, children had refractive errors corrected and amblyopia treated according to study protocol, as described previously. In the CRYO-ROP study, amblyopia was diagnosed on the basis of fixation preference and the clinician's judgment that anatomic factors alone could not explain the visual behavior of the eye.

At the 5.5-year CRYO-ROP study examination, monocular recognition (letter) acuity was assessed by the same testers. Testing was conducted using the early-treatment diabetic retinopathy study (ETDRS) Snellen letter chart acuity testing, children had refractive errors corrected and amblyopia treated according to study protocol, as previously. Acuity was estimated as the smallest letter Snellen notation) at which the subject could identify three of the five letters on the line. Different ETDRS charts were used to test the right and left eyes of each subject.

**Eye Examinations.** At the 1- and 5.5-year examinations, each study participant underwent an eye examination including cycloplegic refraction and scoring of presence or absence of retinal residua of ROP.

**Data Analysis**

**Inclusion and Exclusion Criteria.** Based on acuity results at 1 year, the 1490 eyes of the patients were categorized into one of three groups: eyes in each group, blind eyes, and eyes that were untestable with procedure at 1 year. Sighted eyes were defined as eyes with quantifiable acuity at age 1 year, measured with procedure. Included in this group were 1148 eye in the natural history study who had acuity at 1 year, measured with procedure. Included in the group who had 25 eyes from patients in the natural history study who had 1 year, measured with procedure. Included in the group were patients in whom both eyes were blind and patients in whom only one eye was blind.

Results from 109 sighted eyes that underwent cataract surgery or were included in the data analysis; the course of development in these eyes will be reported elsewhere. Eyes were defined as eyes with minimal pattern vision which detect only the 2.2-cm-wide stripes on the Low-Vision Chart, or no light perception. Included were 115 eyes: 45 eyes from patients with a diagnosis of cataract surgery; 2 eyes from patients with a fello; 73 control eyes from 73 patients in whom both eyes were blind. Included were 18 eyes from patients in whom eye was sighted and 2 eyes from patients in whom eye was blind.

Data analysis of results from the single eye was performed by an eye per patient, to avoid independence that arises when the two eyes of each patient are included in quantitative analyses. Thirteen right eyes were included in analyses selected at random (1 eye per patient) from each group of each patient in the natural history study who had a diagnosis at age 1 year; patients in whom both eyes were blind. Included were 3 eyes from patients in whom only one eye was blind.

An additional 65 eyes were excluded from the group because they had a diagnosis of new diagnosis after age 1 year of cataract surgery; vitrectomy; scleral buckling procedure; glaucoma surgery; corneal clouding; and other ocular diagnoses that might alter acuity between ages 1 and 5.5 years. The study included 1783 eyes with a diagnosis of amblyopia therapy initiated at age 1 year or later. A new diagnosis after age 1 year of cataract surgery; vitrectomy; scleral buckling procedure; glaucoma surgery; corneal clouding; and other ocular diagnoses that might alter acuity between ages 1 and 5.5 years. The study included 1783 eyes with a diagnosis of amblyopia therapy initiated at age 1 year or later.
retrolental membrane (n = 1), detachment of the central macula (n = 5), or macular hole or break (n = 4). A further 34 sighted and 4 blind eyes were excluded because no acuity data were available for these eyes at age 5.5 years. This selection process resulted in 575 sighted eyes and 111 blind eyes that were available for these eyes at age 55 years. This selection process resulted in 575 sighted eyes and 111 blind eyes that were available for these eyes at age 55 years. This selection process resulted in 575 sighted eyes and 111 blind eyes that were available for these eyes at age 55 years.

**Agreement between TAC Grating Acuity at 1 Year and Snellen Acuity at 5.5 Years**

Assessment of Snellen acuity at 5.5 years requires neurodevelopmental skills and a level of cooperation that were not present in all study patients (Fig. 1, legend). To avoid potential bias that might arise from exclusion of data of children unable to perform Snellen acuity testing at age 5.5 years, we also examined acuity results obtained with the TAC procedure, a procedure that can be used with children of all neurodevelopmental levels.\(^{18,19}\) TAC grating acuity data were obtained at 5.5 years from all but 4 of the 575 eyes that were sighted at 1 year (Fig. 2A) and all 111 eyes that were in the blind category at 1 year (Fig. 2B).

As in Figure 1, the distribution of TAC grating acuity scores at 1 year in Figure 2 is essentially bimodal, with nearly all eyes showing acuity in the normal range (Fig. 2A) or in the range categorized as blind (Fig. 2B). TAC grating acuity results remain bi-modal at 5.5 years, with 94.3% (n = 527) of the 559 eyes that had TAC grating acuity in the normal range at 1 year continuing to show normal TAC grating acuity at 5.5 years and 89.2% (n = 99) of the 111 eyes that were in the blind category at 1 year continuing to show no quantifiable TAC grating acuity at 5.5 years. Correlation analysis comparing TAC grating acuity at 1 year with Snellen acuity at 5.5 years yielded a significant correlation (r = 0.17). However, calculation of r^2 indicates that only 2.9% (0.17^2) of the variability in Snellen acuity results can be explained by knowledge of TAC grating acuity at age 1 year.

**Reanalysis of Results, Based on Recently Reported 1-Year TAC Acuity Norms**

In the CRYO-ROP study, the definition of normal TAC grating acuity was based on the preliminary normative data provided in the TAC manual,\(^5\) which were the only normative data available at the time the 1-year data were collected. More recently, two studies have provided updated estimates of monocular TAC grating acuity norms, based on large sample sizes.\(^{20,21}\) Both studies indicate that the lower limit of the normal TAC grating acuity range at 1 year is approximately 4.0 cyc/deg, not 1.6 cyc/deg, as was indicated by the preliminary TAC norms.\(^5\)

A reanalysis of the data of the present study, using 4.0 cyc/deg as the lower boundary of the "normal" TAC grating acuity category at age 1 year and 2.0 cyc/deg (one octave below normal) as the lower boundary of the "below-normal" TAC grating acuity category provided the following results: Among the 347 eyes with TAC grating acuity in the 4.0-cyc/deg or better (revised normal) range at 1 year, 294 (84.7%) showed normal Snellen acuity (see Table 1) at 5.5 years, 34 (9.8%)
neurodevelopmental delay (39 eyes that were sighted and 18 eyes that were blind at 1 year), and acuity that was too poor to be measured with Snellen letters but was measurable with grating stimuli in a child who was neurodevelopmentally capable of performing Snellen testing (2 eyes that were sighted at 1 year). ETDRS, early-treatment diabetic retinopathy study.

The goal of the present study was to determine the extent to which TAC grating acuity measured in infancy agrees with recognition (Snellen) acuity at kindergarten age in a large group of children with birth weights less than 1251 g who were at risk for ocular abnormalities. Because the subject population included children with neurodevelopmental delay who were unable to perform Snellen testing at age 5.5 years, all children also underwent assessment of TAC grating acuity, which can be measured in children of all developmental levels.

The results indicated that, in this population of low-birth-weight children, TAC grating acuity results at age 1 year were bimodal, with nearly all eyes showing acuity within the normal range (Figs. 1A, 2A) or no quantifiable pattern vision (blind; Figs. 1B, 2B). Acuity results were also bimodal at 5.5 years. Among eyes with TAC grating acuity in the normal range at 1 year, 86.8% showed Snellen acuity in the normal (20/40 or better) range at 5.5 years (Fig. 1A), and 94.3% showed TAC grating acuity in the normal (13-cyc/deg or better) range at 5.5 years (Fig. 2A). All but three of the eyes that were blind at 1 year had no quantifiable Snellen acuity at 5.5 years (Fig. 1B), and 19 (5.5%) were untestable, primarily because of neurodevelopmental delay. Among the 193 eyes with TAC grating acuity in the 2.0- to <4.0-cyc/deg (revised below-normal) range at 1 year, 145 (74.1%) showed normal Snellen acuity, 27 (14.0%) showed below-normal Snellen acuity, 6 (2.1%) showed Snellen acuity in the poor range, and 19 (9.8%) were untestable. Among the 35 eyes with measurable TAC grating acuity that was less than 2.0 cyc/deg (revised poor range) at 1 year, 14 (40.0%) showed normal Snellen acuity, 6 (17.1%) showed below-normal Snellen acuity, 1 was judged to be blind at 5.5 years, and 14 (40.0%) were untestable.

Results based on TAC grating acuity results at 1 and 5.5 years were as follows: Among the 347 eyes with TAC grating acuity in the 4.0-cyc/deg or better (revised normal) range at 1 year, 338 (97.4%) showed normal TAC grating acuity at 5.5 years, 7 (2.0%) showed below-normal TAC grating acuity at 5.5 years, and 2 (0.6%) showed TAC grating acuity in the poor range. Among the 195 eyes with TAC grating acuity in the 2.0- to <4.0-cyc/deg (revised below-normal) range at 1 year, 171 (88.6%) showed normal TAC grating acuity at 5.5 years, 14 (7.3%) showed below-normal TAC grating acuity, 6 (3.1%) showed TAC grating acuity in the poor range, 1 was judged to be blind, and 1 was untestable. Among the 35 eyes with measurable TAC grating acuity that was less than 2.0 cyc/deg (revised poor range) at 1 year, 20 (57.1%) showed normal TAC grating acuity, 2 (5.7%) showed below-normal TAC grating acuity, 8 (22.9%) showed TAC grating acuity in the poor range, 2 were judged to be blind at 5.5 years, and 3 (8.6%) were untestable.

**DISCUSSION**

The goal of the present study was to determine the extent to which TAC grating acuity measured in infancy agrees with recognition (Snellen) acuity at kindergarten age in a large group of children with birth weights less than 1251 g who were at risk for ocular abnormalities. The subject population included children with neurodevelopmental delay who were unable to perform Snellen testing at age 5.5 years, all children also underwent assessment of TAC grating acuity, which can be measured in children of all developmental levels.

The results indicated that, in this population of low-birth-weight children, TAC grating acuity results at age 1 year were bimodal, with nearly all eyes showing acuity within the normal range (Figs. 1A, 2A) or no quantifiable pattern vision (blind; Figs. 1B, 2B). Acuity results were also bimodal at 5.5 years. Among eyes with TAC grating acuity in the normal range at 1 year, 86.8% showed Snellen acuity in the normal (20/40 or better) range at 5.5 years (Fig. 1A), and 94.3% showed TAC grating acuity in the normal (13-cyc/deg or better) range at 5.5 years (Fig. 2A). All but three of the eyes that were blind at 1 year had no quantifiable Snellen acuity at 5.5 years (Fig. 1B), and 19 (5.5%) were untestable, primarily because of neurodevelopmental delay. Among the 193 eyes with TAC grating acuity in the 2.0- to <4.0-cyc/deg (revised below-normal) range at 1 year, 145 (74.1%) showed normal Snellen acuity, 27 (14.0%) showed below-normal Snellen acuity, 6 (2.1%) showed Snellen acuity in the poor range, and 19 (9.8%) were untestable. Among the 35 eyes with measurable TAC grating acuity that was less than 2.0 cyc/deg (revised poor range) at 1 year, 14 (40.0%) showed normal Snellen acuity, 6 (17.1%) showed below-normal Snellen acuity, 1 was judged to be blind at 5.5 years, and 14 (40.0%) were untestable.

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**FIGURE 1.** Snellen (ETDRS) acuity at 5.5 years versus grating acuity at 1 year in (A) 523 eyes that had measurable grating acuity at 1 year and (B) 93 eyes that were blind at 1 year. Points to the right of the solid vertical line represent favorable grating acuity results ($\geq 0.8$ cyc/deg) at the 1-year examination, and points above the solid horizontal line represent favorable Snellen acuity results (better than 20/200) at the 5.5-year examination. The dashed vertical line divides 1-year favorable grating acuity scores into the normal (2.1-6 cyc/deg) and below-normal (BN) categories. The dashed horizontal line divides 5.5-year favorable acuity scores into the normal (20/40 or better) and below-normal (BN) categories. Data points in (A) have been shifted away from their true values by a small amount in a randomly selected direction, to permit the display of as many data points as possible. Data are not presented for 52 eyes that were sighted and 18 eyes that were blind at 1 year. Snellen data were not obtained in these eyes at 5.5 years because of neurodevelopmental delay (39 eyes that were sighted and 18 eyes that were blind at 1 year).
and all but 12 of the eyes that were blind at 1 year had no quantifiable TAC grating acuity at 5.5 years (Fig. 2B). Thus, eyes of low-birth-weight infants that showed normal TAC grating acuity at age 1 year were likely to continue to show acuity within the normal range at kindergarten age, whether acuity was measured with Snellen letters or with grating acuity cards. Furthermore, eyes that had no quantifiable visual acuity at age 1 year were unlikely to show any measurable letter or TAC grating acuity at kindergarten age.

A limitation of the bimodal distribution of the 1-year and 5.5-year acuity results is that the data cannot resolve the issue of whether an acuity score in the below-normal or poor range at 1 year is predictive of a similar acuity result at age 5.5 years. The only issue of quantitative prediction that could be addressed was whether the relative position of an eye's acuity score within the normal range at age 1 year was predictive of the relative position of that eye's acuity score at age 5.5 years. The low correlations indicate that the answer to this question is no: Although an eye with normal TAC grating acuity at age 1 year was likely to have normal Snellen and TAC grating acuity at kindergarten age, TAC grating acuity at the upper end of the normal range at 1 year did not predict better-than-average acuity at 5.5 years, and TAC grating acuity at the lower end of the normal range at 1 year did not predict poorer-than-average acuity at 5.5 years.

Comparison with Results of Previous Studies

The relatively low correlation between TAC grating acuity at 1 year and Snellen acuity at 5.5 years ($r = 0.17$) is similar to the correlation between grating acuity at 1 year and Snellen acuity at 4 years ($r = 0.26$) reported by Mash and Dobson in a group of 97 children who had been treated in a neonatal intensive care unit. However, conclusions from Mash and Dobson and from the present study were limited by the restricted range of acuity scores present in the population, in that nearly all sighted eyes showed acuity within the normal range at the early and the late test ages.

Higher correlations between early grating acuity and later Snellen acuity were reported in two studies of patients with congenital cataract, both of which included a relatively small group of patients with a wide range of acuity scores. Maurer et al. reported a correlation of 0.49 between grating acuity at 1 year and recognition acuity after 4 years, and Birch et al. reported a correlation of 0.88 between grating acuity at 2 years and recognition acuity 3 to 6 years later. These studies suggest that early grating acuity is predictive of later recognition acuity, but only when the range of acuity scores is large enough that the relation between earlier and later acuity results is not masked by the variability of the acuity results obtained.

The variability in the correlations reported between early grating acuity and later Snellen acuity is also apparent in studies that have compared early versus late grating acuity. That is, relatively low correlations between early and late grating acuity were found in the present study ($r = 0.36$) and in the Mash and Dobson study ($r = 0.20$), both of which included a large number of eyes but a restricted range of grating acuity scores. In contrast, in two studies that included a small number of eyes, with acuity scores distributed across a wide range, higher correlations were found between early and late grating acuity scores. Birch and Spencer reported a correlation of 0.75 between grating acuity at approximately 1 year and grating acuity 2 to 5 years later in 19 children with cicatricial ROP who

![Figure 2. Grating acuity at 5.5 years versus grating acuity at 1 year in (A) 571 eyes that had measurable grating acuity at 1 year and (B) 111 eyes that were blind at 1 year. Points to the right of the solid vertical line represent favorable grating acuity results ($\geq 0.8$ cyc/deg) at the 1-year examination, and points above the solid horizontal line represent favorable grating acuity results ($\geq 6.4$ cyc/deg) at the 5.5-year examination. The dashed vertical line divides 1-year favorable grating acuity scores into the normal ($\geq 1.6$ cyc/deg) and below-normal (BN) categories. The dashed horizontal line divides 5.5-year favorable acuity scores into the normal ($\geq 13$ cyc/deg) and below-normal (BN) categories. Data are not presented for four eyes that were uncooperative.](http://iovs.arvojournals.org/pdfaccess.ashx?url=/data/journals/iovs/933430/ on 04/29/2017)
had acuity scores distributed across a range of greater than five octaves. Birch and Banco reported a correlation of 0.82 between grating acuity at approximately 2 years of age and grating acuity 3 to 6 years later in 11 children with cortical visual impairment.

Thus, results from the present study and from Mash and Dobson suggest that, in children whose acuity is within or near the normal range, TAC grating acuity in infancy is not highly predictive of recognition or TAC grating acuity during the preschool years. As pointed out by Mash and Dobson, the long-term reliability of any instrument is constrained by the immediate test-retest reliability. Data from Mash et al. indicate that, in 127 children 1 year old, only 29% of TAC grating acuity interobserver test-retest pairs showed perfect agreement, whereas 34% differed by one-half octave (a one-card difference), 22% differed by one octave (a two-card difference), and 14% differed by more than one octave. Thus, the apparent one-octave difference between an eye with a TAC grating acuity of 3.2 cyc/deg and an eye with a TAC grating acuity of 6.4 cyc/deg (see Figs. 1A, 2A) may be caused by test-retest variability rather than a true difference in acuity between the eyes. This means that with the restricted range of acuity scores obtained in the present study and in the Mash and Dobson study, the ability to discriminate acuity differences is limited by test-retest reliability. In contrast, in studies that included infants and young children with a wide range of acuity scores, test-retest reliability does not mask the finding that early grating acuity results are predictive of later acuity results.

Eyes with TAC Grating Acuity in the Normal Range at 1 Year and Below-Normal Snellen or TAC Grating Acuity at 5.5 Years

Although most eyes with normal TAC grating acuity results at age 1 year showed normal Snellen and TAC grating acuity at age 5.5 years, there were four eyes that had TAC grating acuity in the normal range at 1 year but Snellen acuity of 20/200 or worse at 5.5 years. There were also 11 eyes that had TAC grating acuity in the normal range at 1 year but TAC grating acuity more than one octave below the normal range at 5.5 years. In addition, 64 eyes that showed TAC grating acuity in the normal range at 1 year showed below-normal Snellen acuity (between 20/40 and 20/200) at 5.5 years, and 21 eyes that showed normal TAC grating acuity at 1 year showed below-normal TAC grating acuity (one octave or less below the normal range) at 5.5 years.

We examined these eyes on a case-by-case basis to determine whether there were ocular conditions present at the 1-year examination that might predict delayed or arrested acuity development between infancy and childhood. Results indicated that all 4 eyes in which Snellen acuity at 5.5 years was 20/200 or worse and all 11 eyes in which TAC grating acuity at 5.5 years was more than one octave below normal had one or more of the following conditions at age 1 year: nystagmus, strabismus, myopia of 4 D or more, macular ectopia, or abnormal fixation or tracking behavior. Thus, although these eyes had acuity scores that were within the normal range at age 1 year, they had other characteristics to indicate that they would be unlikely to show the improvement in measured visual acuity that normally occurs between 1 and 5.5 years.

Nystagmus, strabismus, myopia of 4 D or more, macular ectopia, and abnormal fixation or tracking behavior were also predictors of eyes with normal acuity at 1 year that would show acuity in the below-normal category at age 5.5 years. At least one of these ocular characteristics was present at age 1 year in 41% of the 64 eyes that showed normal TAC grating acuity at 1 year and below-normal Snellen acuity at 5.5 years and in 81% of the 21 eyes that showed normal TAC grating acuity at 1 year and below-normal TAC grating acuity at 5.5 years. In contrast, these ocular characteristics were present in only 12% of eyes with normal TAC grating acuity at 1 year and normal Snellen acuity at 5.5 years and in only 13% of eyes with normal TAC grating acuity at 1 and 5.5 years. Thus, nystagmus, strabismus, myopia of 4 D or more, macular ectopia, and abnormal fixation or tracking behavior at 1 year are indicators that an eye is at risk for abnormal visual development. However, the potentially detrimental effects of these ocular conditions may not be reflected in acuity measurements made at age 1 year, because the measured visual acuity of even normal infants is relatively poor at this age. Thus, it may be necessary to wait for several years, until acuity develops to near-adult levels, before these ocular conditions produce measurable acuity deficits in the preterm child.

Finally, our data are consistent with data in previous reports showing that children with developmental delay are at risk for abnormal visual acuity development and for ocular abnormalities. Seven of the 11 eyes that had normal TAC grating acuity at 1 year but had TAC grating acuity that was more than one octave below normal at 5.5 years were from children with neurodevelopmental delay, evidenced by their inability to perform the letter-matching or letter-naming task required for Snellen acuity testing at age 5.5 years. Similarly, 29% of the 21 eyes that had normal TAC grating acuity at 1 year and below-normal grating acuity at 5.5 years were from children with neurodevelopmental delay.

Eyes That were Blind at 1 Year but Had Measurable Acuity at 5.5 Years

Three eyes that were judged to be blind at 1 year (i.e., no light perception, light perception only, or detection of the grating on the Low-Vision TAC) were found to have measurable Snellen acuity (20/400, 20/500, and 20/1600) and measurable grating acuity (4.7 cyc/deg, 2.4 cyc/deg, and 0.63 cyc/deg, respectively) at 5.5 years. The two eyes with 20/400 and 20/1600 acuity were judged at 1 year to have light perception only. The eye with 20/500 acuity at 5.5 years was judged to have no light perception at 1 year. Eye examination records from the 1-year study visit indicated that the visual acuity testers had a high confidence that acuity results at 1 year (light perception only) and acuity results at 5.5 years were accurate in the eyes that showed 20/400 and 20/1600 acuity, respectively, at 5.5 years. Both eyes had macular ectopia at both test ages. The eye with 20/500 acuity was judged to have no light perception at 1 year, but the visual acuity tester commented that the acuity level was difficult to judge because of high-frequency, high-amplitude nystagmus. This eye had a partial retinal detachment involving the macula at both ages. Thus, the development of an ability to recognize very large letters or to resolve very coarse gratings can occasionally occur in eyes that appear to be blind at age 1 year.

Nine additional eyes judged to be blind at 1 year were found to have measurable, but poor, grating acuity at 5.5 years (3.3 [two eyes], 2.2, 1.2, 1.1, 0.63, 0.6, 0.44, and 0.22 cyc/deg). In two cases, children showed measurable Snellen acuity in the fellow eye. However, the remaining seven of the eyes were
from children who had neurodevelopmental delay so severe that they were unable to be taught to match or identify Snellen letters at age 55 years. Fielder et al.27,28 have shown that infants with central nervous system abnormalities may show a form of visual developmental delay in which visual acuity is not measurable until late infancy or early childhood. Thus, in these seven eyes, five of which showed evidence of optic atrophy, the improvement from blindness at 1 year to very poor, but quantifiable, acuity at 5.5 years may have been the result of maturation of cortical visual and/or attentional pathways.

Re-evaluation of Results, Based on Recently Reported 1-Year TAC Acuity Norms

The definition of normal TAC grating acuity that was used in the CRYO-ROP study was based on the preliminary normative data provided in the TAC manual.5 Although based on data from a relatively small sample of children, these were the only normative data available in 1987 and 1988, when the 1-year CRYO-ROP data were collected. Two studies published in 1993,20,21 both based on larger samples of subjects, indicated that the lower limit of the normal TAC grating acuity range at 1 year is approximately 4.0 cyc/deg, not 1.6 cyc/deg, as was indicated by the preliminary TAC norms.5 We therefore reanalyzed the data of the present study, using 4.0 cyc/deg as the lower boundary of the normal TAC grating acuity category at age 1 year and 2.0 cyc/deg (one octave below normal) as the lower boundary of the below-normal TAC grating acuity category.

Among eyes with acuity of 4.0 cyc/deg or more (revised normal range), 84.7% showed normal Snellen acuity at 5.5 years, and 97.4% showed normal TAC grating acuity. These values are similar to the values of 86.8% and 94.3%, respectively, that were obtained when normal acuity was scored as 1.6 cyc/deg or more, based on the preliminary TAC norms.5

The higher cutoff for normal grating acuity at 1 year resulted in classification of 195 eyes as having TAC grating acuity in the below-normal category and 35 eyes with TAC grating in the poor category at 1 year. Of the 193 eyes with TAC grating acuity in the revised below-normal category at 1 year, 74.1% showed normal Snellen acuity at 5.5 years, and 88.6% showed normal TAC grating acuity. These values are lower than comparable values for eyes with TAC grating acuity in the revised normal range at 1 year. Even lower were the percentages of eyes with TAC grating acuity in the revised poor category at 1 year and normal Snellen (40.0%) or TAC grating acuity (57.1%) at 5.5 years. Thus, eyes with acuity in the 4.0-cyc/deg or better (revised normal) range at 1 year were more likely than eyes with acuity in the ≥2.0- to <4.0-cyc/deg (revised below-normal) range to have normal Snellen or TAC grating acuity at 5.5 years, and eyes with acuity in the ≥2.0- to <4.0-cyc/deg range were more likely than eyes with acuity in the 2.0-cyc/deg or less (revised poor) range to have normal Snellen or TAC grating acuity at 5.5 years.

Further analysis of the data based on the recent normative data for 1-year-old children also indicated that those with 1-year TAC grating acuity scores in the revised below-normal and poor categories were more likely than children with 1-year TAC grating acuity scores in the revised normal category to be untestable with Snellen acuity at 5.5 years. Among eyes with TAC grating acuity in the revised normal category at 1 year, 5.5% were untestable by Snellen acuity at 5.5 years, whereas 9.8% of eyes in the revised below-normal category and 40.0% of eyes in the revised poor category were untestable with Snellen acuity at 5.5 years. The most frequent cause of an eye’s classification as untestable with Snellen acuity was neurodevelopmental delay, with the child unable to identify or match letters in the Snellen recognition acuity task. Untestable rates for 5.5-year TAC grating acuity, a test that can be used with most children who have neurodevelopmental delay,18,19 were much lower; there were no eyes in the revised normal category, only one eye (<1%) in the revised below-normal category, and only three eyes (8.6%) in the revised poor category at 1 year that were untestable with TAC grating acuity cards at 5.5 years. Thus, TAC grating acuity results at 1 year seem to be related to the likelihood that a child will be too neurodevelopmentally delayed at 5.5 years to perform the letter-identification and letter-matching tasks required to complete Snellen acuity testing.

Comparison with Data from Older Children and Adults

Kushner et al.29 have recently concluded, on the basis of their comparison of TAC grating acuity and Snellen acuity in ophthalmology patients between the ages of 8 and 40 years, that “if Teller Acuity Cards indicate normal visual acuity, there is still a high likelihood that it may be abnormal; if Teller Acuity Cards suggest abnormal vision, there is a high likelihood that it is abnormal.” The data of the present study support the second part of their statement, in that all eyes judged to be blind or to have low vision at 1 year continued to be categorized as blind or low vision at 5.5 years. However, the present data suggest that their conclusion that eyes judged to have normal visual acuity with TACs have a “high likelihood” of being abnormal should be modified. In the present population of low-birth-weight preterm infants, approximately two thirds of whom had acute-phase ROP,10 86.8% of eyes with TAC acuity scores in the normal range at 1 year had Snellen acuity scores in the normal range at 5.5 years, and 94.3% had TAC grating acuity scores in the normal range at 5.5 years. Thus, although there were children with normal TAC grating acuity at 1 year whose acuity failed to show the normal pattern of development, these children were by no means the majority of children with normal acuity results at age 1 year.

Conclusions

The results of the present study indicate that low-birth-weight infants who have acuity within the normal range at age 1 year are likely to continue to have acuity in the normal range when they reach kindergarten age, and infants judged to be blind or to have very poor vision at 1 year have a poor prognosis for having quantifiable visual acuity when they reach kindergarten age. However, among eyes with acuity results within the normal range at age 1 year, the particular location (high versus low) of an eye’s acuity score within the normal range is not predictive of that eye’s later acuity.

References


