A Population-Based Study on the Visual Outcome in 10-Year-Old Preterm and Full-Term Children

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Objectives: To report the visual outcome in prematurely born and full-term children at the age of 10 years and to evaluate the effects of prematurity per se, retinopathy of prematurity (ROP), and cryotreatment on visual acuity.

Methods: The study included 216 prematurely born children and 217 children born at term from the same geographical area and study period. Best-corrected distance and near visual acuities were assessed with linear letter logarithm of the minimum angle of resolution charts. Crowding was evaluated.

Results: Prematurely born children had reduced distance and near visual acuities compared with full-term children, even when children who had retinopathy of prematurity and neurologic disorders were excluded (P < .001). Children who had been treated with cryotherapy had the highest risk of a reduced visual acuity. Two percent of the prematurely born children were visually impaired (<20/60).

Conclusions: Although we found an overall good visual outcome in the prematurely born cohort, the risk of reduced visual acuity was greater than in full-term children. Children who had been treated with cryotherapy had the highest risk, but prematurity per se was also associated with reduced visual acuity.

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A HIGH PREVALENCE OF OPHTHALMIC AND NEURODEVELOPMENTAL DISORDERS HAS BEEN REPORTED IN PREMATURELY BORN CHILDREN. Retinopathy of prematurity (ROP) and lesions of the posterior visual pathways are known to affect visual outcome. Severe damage of the retina and the visual pathways are usually diagnosed early in life. Minor lesions may be detected later at preschool or school age. Therefore, long-term follow-up studies of prematurely born children are important. Many such investigations of visual outcome have been done, but most of them are hospital based, and only some are population based. However, we have found few strictly population-based studies in which the children have also been screened prospectively for ROP in the neonatal period.

In Stockholm (Sweden) County, children with a birth weight of 1500 g or less, born between 1988 and 1990, were included in a prospective population-based study on the incidence of ROP. A follow-up of the children at 3½ years has been reported by Holmström et al. At the age of 10 years, we did an ophthalmologic follow-up study of various visual functions in the same cohort together with a control group of children born at term. The refractive outcome has already been described. The aim of the present article is to report the visual outcome in these prematurely born and full-term children at the age of 10 years and to evaluate the effects of prematurity per se, ROP, and cryotreatment on visual acuity (VA).

METHODS

PARTICIPANTS

In the previous prospective study by Holmström et al, 260 prematurely born children with a birth weight of 1500 g or less who had survived 8 weeks or longer were included. Forty percent (105) of the children had any stage of ROP and 11% (28) had received cryotherapy. The criterion for treatment was ROP stage 3 in at least 4 contiguous clock hours in zone II, even in the absence of plus disease. The children had been followed up for 3½ years. In the present study, the prematurely born children and their caregivers were asked by letter whether they wished to participate in a 10-year ophthalmologic follow-up study. They had been located with the help of the HIN identification number used in Sweden. During the 3½-year follow-up, 12 of 260 children were excluded. Seven died and 1 emigrated. Four were excluded because of oph-
Thalidomide or general diseases unrelated to prematurity. One child had ichthyosis with severe corneal opacities, 2 children (twins) had optic atrophy due to undiagnosed metabolic disease, and the fourth child had hereditary bilateral congenital cataract. Of the remaining 248 children from the previous follow-up, 1 child died and the child, who had previously moved abroad, returned at the age of 10 years and was relocated. Moreover, 32 children dropped out of the present study: 6 emigrated, 1 had a protected identity, and 25 declined to participate. The control group consisted of 217 children born in exactly the same period and in the same geographical area as the prematurely born ones. These children had been randomly selected to provide a control group and were born in the 39-41 weeks (3000-4000 g). The full-term children had a GA at birth of 39 to 41 weeks and a birth weight of 3000 to 4000 g.

Retinopathy of prematurity was classified as no ROP, mild ROP (stages 1-2), and severe ROP (stages 3-5). All eyes fulfilling the definition by the World Health Organization (WHO). VA “was defined as VA less than 20/60, which is in accord with the definition by the World Health Organization (WHO).

We used a preferential looking test with acuity cards23 for 1 child who could not take part in tests with linear optotypes. The results were converted from grating acuity to linear acuity. Crowding was determined by using a logMAR Lea Hyvarin [LH] chart with linear optotypes, at a distance of 3 m.24 To pass a line, the child had to identify 4 of 5 symbols on the line.20 “Poor VA” was defined as VA less than 20/60, which is in accord with the definition by the World Health Organization (WHO).

We obtained from the Swedish National Board of Health and Social Welfare a similar number of children, born at term (39-41 weeks) who had normal birth weights (3000-4000 g). The full-term children had been randomly selected to provide a control group and were born in exactly the same period and in the same geographical area as the prematurely born ones. These children and their families were also contacted and asked to participate. The control group consisted of 217 children born at term, which was approximately 50% of those contacted.

All children were examined between 9 years ± 9 months and 10 years ± 3 months, except 1 prematurely born child who was examined at 10½ years. Data on demographics and ROP stage are given in Table 1.

**PROCEDURES**

Subjective refraction was performed and best-corrected distance and near VAs were assessed with linear optotypes. For distance VA, a linear letter logarithm of the minimum angle of resolution (logMAR) chart designed for an observation distance at 4 m, measuring the VA up to −0.3 logMAR (20/10), was used (Anders Hedin [AH] chart). The AH chart is commonly used in Sweden and is extensively described elsewhere.20 Distance VA was assessed monocularly.

To obtain an accurate and thorough comparison between the groups, frequency-of-seeing curves were constructed.20-22 This was done by letting the child read all letters on each line, starting on a line in which the child could identify all letters correctly, and continuing downward until the line in which no letters could be identified was reached. The number of correct answers on each line was noted on a copy of the chart. The percentage of correct answers on each line was plotted in a diagram (y-axis), with MAR as a logarithmic scale on the x-axis. The best-fitting straight line in the graph was drawn by the computer and the logMAR at 50% correct answers was found and used to compare the groups as regards continuous data.

In the analysis of the distribution of distance VA, we included children who could not participate in the frequency-of-seeing procedure as well as the 10 children examined elsewhere. In these children the VA had not been assessed at 50% correct answers but as in ordinary clinical practice. Consequently, we also evaluated the VA corresponding to clinical practice in the total study group using the AH chart, of which 7 of 10 letters had to be correctly identified to pass a line.20 “Poor VA” was defined as VA less than 20/60, which is in accord with the definition by the World Health Organization (WHO).

We used a preferential looking test with acuity cards23 for 1 child who could not take part in tests with linear optotypes. The results were converted from grating acuity to linear acuity.

Crying was determined by using a logMAR Lea Hyvarin [LH] chart with linear optotypes, at a distance of 3 m.24 To pass a line, the child had to identify 4 of 5 symbols on the line. Single LH optotypes were also shown at the same distance. The crowding ratio was calculated, that is, the VA assessed with single symbols, divided by the VA assessed with linear symbols. A crowding ratio of 1.2 has been found in healthy older children and in adults.25 We, therefore, considered a crowding ratio of 1.5 or more to be increased.

Near VA was evaluated binocularly with a logMAR LH chart at a distance of 0.4 m. For approval of a line, the child had to correctly identify 4 of 5 symbols on the line.

The assessments were performed in the following order: distance VA with AH chart, right (RE) and left eye (LE); distance VA with linear LH chart and single LH chart symbols, RE and LE; and near VA binocularly.

The fundus was evaluated after dilatation of the pupil with a mixture of 1.5% phenylephrine hydrochloride and 0.8% cyclopentolate hydrochloride. As in the 3½-year follow-up,18 we scored the macula as follows: 0, clinically normal macula; 1, macular heterotopia; 2, macular pigment epithelial scarring; 3, posterior retinal folds, retinal detachment, and retrolental mass. Retinoscopy during cycloplegia was performed. The spherical equivalent and astigmatism were noted.

The presence of a neurologic complication was defined as an intraventricular hemorrhage in the neonatal period and/or obvious neurologic sequelae (epilepsy, cerebral palsy, or mental retardation) in the 3½-year follow-up.18 No pediatric examination or magnetic resonance imaging were performed in the present study. Altogether 34 (15.7%) of 216 prematurely born children had obvious neurologic sequelae.
born children had some kind of neurologic complication according to this definition.

The study was approved by the local ethics committee at Karolinska Institutet, Stockholm, Sweden. Informed consent was obtained by the caregivers.

STATISTICAL METHODS

The results of the better and worse eyes were analyzed separately. When binocular VA was analyzed, the preterm group was divided into no ROP, mild ROP, severe untreated ROP, and cryotreated ROP, according to their most severely affected eye.

To compare nominal or ordinal data, an independence test of contingency tables (Fisher asymptotic or exact test) was performed. An unpaired t test or 1-way analysis of variance (ANOVA) (controls vs prematurely born children divided into subgroups) was used to analyze continuous data. When variances were not homogeneous, the Mann-Whitney test was used or an ANOVA model with separate variance estimates, Proc Mixed in SAS.26 The P values were corrected according to the Bonferroni procedure. A stepwise multiple regression analysis was used to evaluate the effects of gestational age at birth, birth weight, stage of ROP, cryotherapy, and neurologic complications, and refraction on the VA at 50% correct answers in the better eye.

RESULTS

DISTANCE VA

In the study population of 216 prematurely born children, we performed the frequency-of-seeing procedures in 213 REs and 212 LEs. All 217 full-term children participated with both eyes monocularly. The mean (SD) values of VA at 50% correct answers are summarized in Table 2. Monocular VA was significantly better in full-term than in prematurely born children, as regarding better (P<.001) and worse eyes (P<.001). We found significant differences between the control group and the prematurely born children without ROP (better eyes, P<.001; worse eyes, P<.001) even after exclusion of the 15 children with neurologic complications.

Within the preterm group, the VA of the children who had received cryotherapy was lower than in the other subgroups. However, no difference was found between children without ROP and in those with untreated ROP. Children with neurologic complications had a significantly lower VA than those without (better eyes, P<.001; worse eyes, P<.001).

Table 2. Distance Visual Acuity (logMAR) of 50% Correct Answers

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. of Better Eyes</th>
<th>Mean (SD)</th>
<th>No. of Worse Eyes</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control subjects</td>
<td>217</td>
<td>−0.184 (0.07)</td>
<td>217</td>
<td>−0.145 (0.08)</td>
</tr>
<tr>
<td>Premature children, total group</td>
<td>213</td>
<td>−0.130 (0.09)</td>
<td>212</td>
<td>−0.051 (0.19)</td>
</tr>
<tr>
<td>No ROP</td>
<td>136</td>
<td>−0.151 (0.08)</td>
<td>133</td>
<td>−0.083 (0.15)</td>
</tr>
<tr>
<td>Mild ROP</td>
<td>43</td>
<td>−0.115 (0.09)</td>
<td>39</td>
<td>−0.076 (0.12)</td>
</tr>
<tr>
<td>Severe ROP, untreated</td>
<td>11</td>
<td>−0.128 (0.07)</td>
<td>16</td>
<td>−0.057 (0.08)</td>
</tr>
<tr>
<td>Cryotreated ROP</td>
<td>23</td>
<td>−0.036 (0.13)</td>
<td>24</td>
<td>0.168 (0.33)</td>
</tr>
</tbody>
</table>

Abbreviations: logMAR, logarithm of the minimum angle of resolution; ROP, retinopathy of prematurity.

Table 3. Multiple Regression Analysis of the Visual Acuity (logMAR) at 50% Correct Answers in the Better Eye in the Preterm Group

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>SE of Coefficient</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant*</td>
<td>−0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cryotreatment</td>
<td>0.07</td>
<td>0.02</td>
<td>&lt;.001</td>
</tr>
<tr>
<td>Neurologic complication</td>
<td>0.05</td>
<td>0.02</td>
<td>.003</td>
</tr>
<tr>
<td>Astigmatism ≥1 diopter</td>
<td>0.03</td>
<td>0.02</td>
<td>.03</td>
</tr>
</tbody>
</table>

*The constant represents a predictive visual acuity (at 50% correct answers) of −0.182 (logMAR) in a prematurely born child without neurologic complications, cryotherapy, or astigmatism of 1 diopter or more. The visual acuity would have been reduced to −0.111 if the child had received cryotherapy, to a visual acuity of −0.062 if the child also had neurologic complications, and to −0.028 if astigmatism of 1 diopter or more was present.

In a multiple regression analysis, we included gestational age at birth, birth weight, stage of ROP (including cryotherapy), neurologic complications, spherical equivalent, and astigmatism as independent risk factors for a reduction of the VA (50% correct answers) of the better eye. All parameters affected the VA of the better eye in a univariate analysis. However, in the following stepwise multiple regression analysis, only neurologic complications, cryotherapy, and astigmatism of 1 diopter (D) or more were significantly correlated with a reduced VA (Table 3).

The distribution of VA, which was evaluated in the usual clinical manner (see “Procedures” subsection of the “Methods” section) in the better and worse eyes, is listed in Table 4. Visual acuities were determined in 226 prematurely born and 217 full-term children. In 213 REs and 212 LEs from the study population of 216 preterm children, VA was assessed with linear letters (AH chart) and in 1 RE and 2 LEs with linear symbol optotypes (LH chart). Preferential looking was used in 1 child and 1 child was blind and had no perception of light. Moreover, 10 children examined elsewhere, who had also been tested with linear optotypes, were included in this analysis. In 3 of 226 children, the VA could be assessed only binocularly, and the results were recorded as the VA of the better eye. Finally, in the analysis of distribution, we excluded 9 children with exactly the same VA but with different stages of ROP in their eyes, since the stage of ROP in the better or the worse eye could not be established. Hence, the distribution of VA in altogether 217 better and
Table 4. Distribution of Visual Acuity (logMAR) in Better and Worse Eyes*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Better Eye</th>
<th>Worse Eye</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>≤20/200</td>
<td>≥20/20/60</td>
</tr>
<tr>
<td>Control subjects</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Premature children, total group</td>
<td>3 (1.4)</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>No ROP</td>
<td>0</td>
<td>1 (0.7)</td>
</tr>
<tr>
<td>Mild ROP</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Severe ROP, untreated</td>
<td>2 (14.3)</td>
<td>0</td>
</tr>
<tr>
<td>Cryotreated ROP</td>
<td>1 (4.2)</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 5. Prevalence of Crowding Ratio of 1.5 or More in Either Eye in Prematurely Born and Full-Term Children

<table>
<thead>
<tr>
<th>Variable</th>
<th>No. (%) of Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control subjects</td>
<td>9 (4.1)</td>
</tr>
<tr>
<td>Premature children, total group</td>
<td>18 (8.5)</td>
</tr>
<tr>
<td>No ROP</td>
<td>6 (3.8)</td>
</tr>
<tr>
<td>Mild ROP</td>
<td>5 (9.0)</td>
</tr>
<tr>
<td>Severe ROP, untreated</td>
<td>2 (14.2)</td>
</tr>
<tr>
<td>Cryotreated ROP</td>
<td>5 (17.4)</td>
</tr>
</tbody>
</table>

CROWDING

Crowding was evaluated in 212 REs and 213 LEs of the prematurely born and in 217 of the full-term children. The prevalence of crowding according to our definition (a ratio of ≥1.5) is given in Table 5. Crowding was more common in the preterm group, but it did not differ statistically from that in the full-term group. However, we found a difference in the preterm group (RE, P =.05; LE, P =.02); the children who had received cryotherapy having a greater prevalence of an increase in the crowding ratio in the RE and the children with severe untreated ROP in the LE. Altogether 18 prematurely born children had a crowding ratio of 1.5 or more in either eye. Of these, 3 were classified as having neurologic complications, 7 had strabismus, 1 had both, and 7 had neither neurologic complications nor strabismus. In the entire group of prematurely born children with neurologic complications, crowding could be assessed in 32 children, of whom 3 (9.4%) had crowding. In the full-term group, a crowding ratio of 1.5 or more in either eye was found in 9 children, of whom 1 had strabismus.

NEAR VA

Near VA was assessed in 211 of 216 preterm children and in all of the full-term children. A significantly poorer near VA was found in prematurely born children than in those born at term (P <.001) (Figure). We also found differences between the control group and the prematurely born children without ROP (P <.001) and within the preterm group (P <.001). The children who had received cryotherapy differed from all other subgroups except those with severe untreated ROP. Moreover, in the preterm group, children with neurologic disorders had a significantly lower near VA than those without (P =.001).

CHARACTERISTICS OF CHILDREN WITH POOR VA (<20/60) IN EITHER EYE

Nine of 216 prematurely born children in the entire study group and 3 of 10 children from whom medical records were obtained (12/226 [5.3%]) had a VA below 20/60 in either eye (Table 6). No child in the control group had a VA below 20/60. Four (1.8%) of the prematurely born children were visually impaired according to WHO’s criteria, that is, a VA below 20/60 in the better eye.27 Two of these were visually impaired owing to sequelae of ROP—1 was blind owing to retinal detachment and 1 had macular changes. Two children were visually impaired
owing to neurologic complications. Of the 8 children with poor VA in 1 eye, 4 had macular heterotopia.

MACULAR OR OPTIC FINDINGS
AND NYSTAGMUS

In the preterm group, macular changes were seen in 8 children of whom 6 are listed in Table 6 (those not listed had a VA ≥20/60). One child had a detached retina in both eyes (macular score 3). This child's severe ROP was diagnosed too late for cryotherapy. Two children had bilateral macular changes (1 had a score of 2 and 1 had a score of 1); the other 5 had unilateral changes (1 had a score of 2 and 4 had a score of 1). Optic atrophy was noted in 2 children, and 1 child had optic hypoplasia. Thirteen of the prematurely born children had nystagmus. All children with nystagmus received cryotherapy or had neurologic complications.

In the control group, 1 child had optic drusen and 1 child had a slight optic hypoplasia. No child had macular changes or nystagmus.

COMMENT

In the present population-based study, prematurely born children had poorer VAs than those born at term. The difference was 0.05 logMAR in the better eye. A poorer VA was also found in prematurely born children withoutROP and neurologic complications than in the controls (difference, 0.03 logMAR). Cryotherapy, neurologic complications, and astigmatism of 1 D or more were significantly correlated with a reduced VA in the preterm group. Of the prematurely born children, 1.8% were visually impaired according to WHO's criterion (<20/60)\(^{27}\); 5.3% had a VA below 20/60 in either eye. Crowding was more frequent in the preterm group than in the control group, but the difference was not statistically significant. Near VA was reduced in the prematurely born children and most marked among the ones who had received cryotherapy.

DISTANCE VA

Distance VA has been evaluated in prematurely born children of similar ages in several other studies,\(^{5,11-15,28,29}\) but the findings are difficult to compare because of differences in epidemiology and method. Some studies are hospital based,\(^{5,28,29}\) while others are population based.\(^{11-15}\) To our knowledge, there are only 3 population-based studies, apart from this one, that regard the VA in about 10-year-old preterm children in which they were also screened prospectively for ROP in the neonatal period.\(^{13-15}\)

The use of a control group born at term permitted the detection of minor differences between preterm and full-term children. The present study was strictly population-based and both the preterm and the full-term children were born in the same period, in the same geographical area, and were examined in exactly the same way, which ensured an accurate comparison of the groups. Such a comparison was also possible in the study by O'Connor et al,\(^{15}\) who used schoolchildren as a control group. Fledelius\(^{13}\) referred to a control group examined by himself in a previous study\(^{30}\) and Darlow et al\(^{14}\) referred to a study\(^{31}\) done in New Zealand 1 decade before. As in the preterm group, comparison of the VA in the full-term group with other studies of normal children is difficult because populations and methods vary. However, the results were comparable to those of other Scandinavian studies\(^{11,30,32-34}\) and the group of controls in this study, therefore, seemed to be representative of the visual outcome in 10-year-old full-term children in our population.

The present study shows a reduction in distance VA in prematurely born children compared with full-term ones, as also reported in the 3 previous population-based studies.\(^{13-15}\) In the cohort of prematurely born children, Fledelius\(^{13}\) and Darlow et al\(^{14}\) found that children with ROP in the neonatal period ran the highest risk of a reduced VA. This was also noted by O'Connor et al,\(^{15}\) but only as regards children with severe ROP, while children with mild ROP were reported to have VAs similar to those without ROP. In our study, children who had received cryotherapy had the highest risk of a reduced VA. However, we found no difference between children without ROP and those with mild or severe but untreated ROP. This was confirmed by a multiple regression analysis, performed in the preterm group, in which the stage of ROP was correlated with a reduced VA only when children who had received cryotherapy were included. Whether the reduced VA in the eyes that received cryotherapy was owing to the treatment or the severe ROP per se could not be determined. The American Multicenter Trial of CRYO-ROP\(^{7}\) reported a more favorable visual outcome, defined as a VA of greater than 20/200, in eyes that received cryotherapy than in eyes with untreated threshold ROP. Such a comparison could not be made in this study since all eyes fulfilling the criteria for treatment had been treated.\(^{16}\)

In the American Multicenter Trial of CRYO-ROP\(^{7}\) and in a study by Ng et al,\(^{29}\) the visual outcome at the age of 10 years among children who received cryotherapy is worse than in the present study. It has been hypoth-
prematurity (ETROP) Cooperative Group37 found a beta correlation of 0.44 (p < 0.01) in the multivariate analysis, indicating that the risk of regressed ROP was higher in children with neurologic complications. However, the effect of neurologic disorders or damage to the visual pathway was not significant in the multivariate analysis. Darlow et al14 and O’Connor et al15 did not relate their results to neurologic findings.

An increase in the prevalence of refractive errors in the premature born cohort, compared with the controls, has been reported.19 In the multiple regression analysis of the present study, astigmatism seemed to have a negative effect on good VA. However, children with moderate to high myopia, in accord with Fledelius,13 had a reduced VA, although children with refractive errors in both eyes had a better VA than those with refractive errors in only one eye. The effect of myopia on good VA was significant in the multivariate analysis.

In the present study, visual impairment was found in 4 (1.8%) of the prematurely born children of whom 1 (0.4%) was blind by WHO’s definition (20/400).22 The prevalence was lower than in other population-based studies.13,14 However, in the studies by Fledelius,13 Darlow et al,14 and O’Connor et al,15 none of the children received cryotherapy since they had been born before the recommendation for treatment of “threshold disease” was introduced.20 This probably explained the various prevalences of visual impairment in these studies. Most blind children in the studies by Fledelius13 and Darlow et al14 were blind because of ROP. Since treatment of threshold ROP affects the long-term visual outcome,7 the prevalence of blindness might have been lower in the other studies if the children had been treated. In this study, 2 of 4 children with a VA below 20/60 in the better eye were visually impaired because of ROP and the other 2 because of cerebral visual impairment (1 of whom also had optic atrophy). This shows that although ROP causes less visual impairment in Sweden,39 it remains a risk factor for a visual handicap in our population.

Although the distance VA was poorer than in children born at term, we found a surprisingly good overall visual outcome in the prematurely born children. In the distribution analysis (Table 4), VA better or equal to 20/20 in the better eye was found in 86% of the prematurely born children, which was a higher prevalence than in the studies of Fledelius13 (48%) and O’Connor et al15 (76%), but equal to that in a study by McGinnety and Bryars.28 A VA of 20/40 or more was noted in 97%, which was higher than that in the study by Darlow et al14 (87%). Compared with other Swedish population-based studies, we found a higher prevalence of VA of 20/20 or above in a study by Hård et al,23 but a prevalence of VA above 20/30 similar to that in a study by Gallo and Lennerstrand.11 Although the overall visual outcome was good, the prematurely born children still differed from those born at term. In the distribution analysis (Table 3), 86% of the former and 98% of the latter had a VA of 20/20 or above. The difference was even more apparent when comparing a VA of 20/15 or above (53% vs 82%). Moreover, the VA in prematurely born children without ROP and neurologic complications differed from the VA in the full-term children, unlike in a study by Dowdeswell et al.50 In accord with our finding of reduced central visual fields in the preterm children,60 this indicates that prematurity per se also affects the visual outcome. It remains unknown whether the cause is to be found in the retina or in the posterior visual path-

### Table 6. Characteristics of Children With Poor Visual Acuity (<20/60) in Either Eye

<table>
<thead>
<tr>
<th>GA, wk</th>
<th>Birth Weight, g</th>
<th>Visual Acuity</th>
<th>ROP Stage</th>
<th>Fundus</th>
<th>Neurologic Complications</th>
</tr>
</thead>
<tbody>
<tr>
<td>27</td>
<td>1040</td>
<td>No perception</td>
<td>Severe</td>
<td>Bilateral retinal detachment</td>
<td>No</td>
</tr>
<tr>
<td>29</td>
<td>1210</td>
<td>20/40</td>
<td>Cryotreated</td>
<td>Macular heterotopia both eyes, optic atrophy, and peripheral cryoscars</td>
<td>No</td>
</tr>
<tr>
<td>30</td>
<td>1188</td>
<td>20/25</td>
<td>Cryotreated</td>
<td>Macular heterotopia worse eye and peripheral cryoscars</td>
<td>No</td>
</tr>
<tr>
<td>26</td>
<td>810</td>
<td>20/25</td>
<td>Cryotreated</td>
<td>Macular heterotopia worse eye and peripheral cryoscars</td>
<td>No</td>
</tr>
<tr>
<td>24</td>
<td>675</td>
<td>&lt;20/200</td>
<td>Cryotreated</td>
<td>Macular heterotopia both eyes and peripheral cryoscars</td>
<td>No</td>
</tr>
<tr>
<td>25</td>
<td>909</td>
<td>20/20</td>
<td>Mild ROP</td>
<td>Macular heterotopia worse eye and regressed ROP in the periphery</td>
<td>No</td>
</tr>
<tr>
<td>26</td>
<td>1095</td>
<td>20/25</td>
<td>Cryotreated</td>
<td>Peripheral cryoscars</td>
<td>Yes</td>
</tr>
<tr>
<td>30</td>
<td>1390</td>
<td>&lt;20/200</td>
<td>Severe untreated</td>
<td>Optic atrophy</td>
<td>Yes</td>
</tr>
<tr>
<td>28</td>
<td>1296</td>
<td>20/100</td>
<td>No ROP</td>
<td>Normal</td>
<td>Yes</td>
</tr>
<tr>
<td>33</td>
<td>1459</td>
<td>20/200</td>
<td>No ROP</td>
<td>Normal</td>
<td>No</td>
</tr>
<tr>
<td>27</td>
<td>994</td>
<td>20/200</td>
<td>No ROP</td>
<td>Normal</td>
<td>No</td>
</tr>
<tr>
<td>29</td>
<td>987</td>
<td>&lt;20/200</td>
<td>No ROP</td>
<td>Normal</td>
<td>No</td>
</tr>
</tbody>
</table>

**Abbreviations:** GA, gestational age; ROP, retinopathy of prematurity.

*All subjects had strabismus.*
ways, Olsén et al\textsuperscript{41} reported that 32\% of prematurely born children (birth weight <1750 g) have magnetic resonance imaging–verified periventricular leukomalacia, which is a known risk factor for visual dysfunction.\textsuperscript{6,9,42-44} Since magnetic resonance imaging was not routinely performed in the present study, minor neurologic lesions cannot be excluded. Furthermore, at the time of premature birth, foveal development is incompletely.\textsuperscript{49} A retinal lesion caused by a disturbance in this development, by ROP or by the preterm birth per se, may also have affected the visual outcome.\textsuperscript{36,45-48}

CROWDING

Crowding, that is, the inability to separate symbols that are presented closely together tended to be more frequent in the preterm (8.5\%) than in the control (4.1\%) group. In our study, a crowding ratio of 1.5 or more was considered to be increased, which seemed reasonable since a ratio of 1.2 is found not only in 5- to 7-year-old healthy children but also in adults with normal vision.\textsuperscript{23} Crowding is common in amblyopic eyes\textsuperscript{49} but has also been found in prematurely born children with brain lesions.\textsuperscript{5,50} Dutton and Jacobson\textsuperscript{51} stated that crowding is connected with dorsal stream dysfunction in the brain. In the present study, 39\% (7/18) of the prematurely born children with crowding had neither strabismus nor neurologic complications. However, it is uncertain whether they had experienced minor cerebral lesions in the neonatal period.

NEAR VA

Near VA was poorer in the prematurely born children than in the full-term children, according to the findings of O’Connor et al.\textsuperscript{13} Children without ROP also had poorer near VA than the controls while O’Connor et al found about the same median near VA in similar groups. Fledelius\textsuperscript{13} found no difference in near VA between prematurely born children with or without ROP, but Darlow et al\textsuperscript{44} reported a difference in the better eye. In the present study, no difference was detected between children without ROP and those with untreated ROP, while the children who had received cryotherapy had the lowest near VA than all the subgroups. However, it remains uncertain whether the reduced near VA was caused by the severe ROP per se or the cryotreatment.\textsuperscript{7} Children with neurologic disorders also had poorer near VA than those without. In these children, a reduced accommodation may contribute to an impaired near VA, but this was not evaluated in the present study. Finally, the reduction in near VA and the tendency to an increase in crowding in prematurely born children should be emphasized since this may have implications on their reading.\textsuperscript{5,50}

CONCLUSIONS

We found poorer distance and binocular near VAs in 10-year-old prematurely born children than in those born at term, this being most marked in children who had received cryotherapy and in those with known neurologic disorders. However, prematurely born children without ROP and known neurologic disorders also had a reduced VA.

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