Optic nerve hypoplasia: Risk factors and epidemiology.

Tornqvist, Kristina; Ericsson, Anders; Källén, Bengt

Published in:
Acta Ophthalmologica Scandinavica

DOI:
10.1034/j.1600-0420.2002.800313.x

2002

Optic nerve hypoplasia: Risk factors and epidemiology

Kristina Tornqvist[1], Anders Ericsson[2] and Bengt Källén[3]

[1]Department of Ophthalmology, University Hospital of Lund, Lund, Sweden
[2]Epidemiological Centre, National Board of Health, Stockholm, Sweden
[3]Tornblad Institute, University of Lund, Lund, Sweden

ABSTRACT.
Objectives: **To study the epidemiology of optic nerve hypoplasia.**
Design and Methods: **Children with optic nerve hypoplasia and visual impairment were identified through the Swedish Register of Visually Impaired Children. Pre- and perinatal characteristics were obtained from the Medical Birth Registry and by scrutinizing pregnancy and delivery records. Clinical characteristics of children with optic nerve hypoplasia are described. The following risk factors were studied: maternal age, parity, maternal smoking, gestational duration, birth weight, delivery method, Apgar score, maternal disease during pregnancy, drugs used in early pregnancy.**
Results: **Young maternal age, first parity, maternal smoking, preterm birth and factors associated with preterm birth were risk factors for optic nerve hypoplasia. There was an indicated association with the use of fertility drugs and antidepressant drugs.**
Conclusions: **Optic nerve hypoplasia is apparently associated not only with other anomolies, notably of the central nervous system, but also with signs of general disturbance in fetal development.**

Key words: optic nerve hypoplasia – epidemiology – risk factors – maternal age – smoking – drugs – **prematurity**

Acta Ophthalmol. Scand. 2002: 80: 300–304

Optic nerve hypoplasia is a non-progressive congenital abnormality associated with a reduced number of axons in one or both optic nerves (Mosier et al. 1978). It can be bilateral or unilateral and is clinically characterized by a small optic disc, often surrounded by a peripapillary halo bordered by a dark ring of pigment. In addition, increased tortuosity of the retinal vessels as well as few branching points can be seen (Hellström et al. 1999). The pathogenesis is not fully understood, but the disorder can result from a number of still unidentified adverse events occurring during development of the visual pathways. The condition has been considered rare, but an increasing incidence has been reported during the last decades (Hoyt & Good 1992). The age-specific prevalence of visual impairment due to optic nerve hypoplasia in the Swedish population of 0–19 years is 6.3/100 000 (Blohmé & Tornqvist 1997c).

The clinical picture reflects varying functional reduction ranging from very mild or no visual impairment to blindness (Björk et al. 1978; Lambert et al. 1987; Zeki & Dutton 1990). Optic nerve hypoplasia may occur as an isolated event or in association with other developmental anomalies, most often cerebral malformations (De Morsier 1956; Skarf & Hoyt 1984; Burke et al. 1991).

A number of aetiological factors such as drugs (McKinna 1966; Chan et al. 1978; Hoyt & Billson 1978; Good et al. 1992), maternal diabetes (Patel et al. 1975; Peterson & Walton 1977; Donat 1981; Kim et al. 1989; Landau et al. 1998), and alcohol (Strömland 1987; Chan et al. 1991; Strömland & Pinazo-Duran 1994) have been associated with the development of optic nerve hypoplasia. Viral infections have also been implicated (Bistner et al. 1973).

Hitherto, however, no thorough investigation concerning risk factors for optic nerve hypoplasia in a nationwide population has been performed. In this study, we have explored possible risk factors responsible for the development of optic nerve hypoplasia in all Swedish children identified with this diagnosis and with a disease severe enough to cause visual impairment.

Material and Methods

Individuals with bilateral optic nerve hypoplasia severe enough to cause visual impairment were identified by inventory of the Swedish Register of Visually Impaired Children (Blohmé & Tornqvist 1997a). The analysis was restricted to individuals born during 1979–97.

The Swedish Register of Visually Impaired Children

This database includes data on all visually impaired children aged between 0 and 19 years in the country, with visual acuity (VA) of ≤ 0.3 and/or a simultaneous visual field defect. The Register was originally established by collecting data obtained from the medical records of low vision clinics and departments of ophthalmology throughout Sweden and is now continuously updated by reporting from these sources. Data obtained on each child are recorded on a standardized

form and subsequently entered into a database. Each record contains information on name, sex, date of birth, treating ophthalmologist and low vision clinic, county, ophthalmological diagnosis, systemic diagnosis, aetiological factors, additional impairments, classification of visual impairment, visual field defects, refraction, near vision, and family history.

Suggested aetiological factors are divided into four main categories according to the system used in previous Nordic studies (Rosenberg et al. 1992; Blohmé & Tornqvist 1997b), as follows:

(1) prenatal;
(2) peri/neonatal;
(3) infantile/juvenile, and
(4) unknown.

Classification of visual impairment is made according to WHO (World Health Organisation) definitions. Ophthalmological diagnoses are classified according to a Californian version of ICD-9 (International Classification of Diseases, 9th version) (Riise et al. 1992; Hansen et al. 1992; Blohmé & Tornqvist 1997c).

On December 31, 1999 the database included data on 2774 individuals aged between 0 and 19 years. The total Swedish population aged between 0 and 19 years was then 2.25 million out of an entire population of 8.86 million. Among infants with a diagnosis of optic nerve hypoplasia, infants with Down syndrome and infants with incomplete personal identification numbers were excluded.

The Medical Birth Registry

Cases with a complete personal identification number were matched with the Medical Birth Register for 1977–97. This register was started in 1973 and contains data on antenatal care, delivery, and the paediatric examination of newborn children (Cnattingius et al. 1990). Since 1982, it has been based on copies of the original medical records, computerized by the National Board of Health, Stockholm.

Information on drug use in early pregnancy was obtained from the records of the 100 women whose antenatal care records could be retrieved. The same form is used throughout Sweden. Pregnant women are interviewed by their attending midwife early in their antenatal care (usually in weeks 10–12), and are asked about smoking habits and drug use during the pregnancy, among other issues.

Statistical analysis

Various risk factors were compared between cases and between all infants born ($n = 2\,109\,316$). Risk estimates were determined as odds ratios (OR) using Mantel-Haenszel procedure after various stratifications, and 95% confidence intervals (95% CI) were estimated using Miettinen's test-based method. In order to study a putative trend in maternal age distribution, a weighted linear regression analysis of the log (OR) was carried out.

The following risk factors were studied:

(1) maternal age and parity;
(2) maternal smoking in early pregnancy;
(3) gestational duration;
(4) birth weight and birth weight for pregnancy week;
(5) maternal diabetes;
(6) maternal pre-eclampsia;
(7) drug use in early pregnancy;
(8) fetal presentation;
(9) delivery method, and
(10) low Apgar score at 5 min.

Birth weight for each pregnancy week was expressed as standard deviations (SD) of the expected birth weight at each week according to a sex and parity specific normal growth curve (Källén 1995). Infants with a birth weight less than 2 SD below the expected mean were regarded as small for gestational age (SGA).

No information on drug use among women with normal infants was retrieved in the study. Comparisons were instead made with data from the Medical Birth Registry, where records of drug use in early pregnancy have been computerized since 1994. This information is based on the same source as that used in the present study, and at least crude comparisons can be made.

Results

A total of 156 individuals (72 male and 84 female; sex ratio 0.86, 95% CI = 0.62–1.17) with optic nerve hypoplasia were found in the database of visually impaired children. Among these, 63 (40%) had an isolated optic nerve hypoplasia without any systemic diagnosis. A total of 39 had reported congenital cerebral malformations, and of these 13 displayed septo-optic dysplasia and another six showed other mid-line deficiencies such as agenesis of the corpus callosum. Additionally 28 had diagnoses such as encephalopathy or cerebral palsy, indicating associated cerebral damage. Altogether, 43% of subjects showed signs of cerebral involvement.

As expected, prenatal aetiologies were by far the most commonly suggested ones and occurred in 125 of the individuals. Of these, 104 were aetiologically classified 'prenatal unspecified'. The aetiological classification in 26 cases was peri/neonatal, and in five cases it was unknown (Table 1). Additional impairments occurred in 98 individuals (63%), for whom a combination of mental and motor impairment was the most frequently occurring (27%) (Table 2). Reduction in visual acuity varied considerably (Table 3). A total of 17 individuals (11%) had no light perception, whereas 42% of cases fell into WHO category 1 or had VA of 0.3. The proportion of blindness according to WHO criteria was 32%.

Records for a total of 125 children with optic nerve hypoplasia matched with data obtained from the Medical Birth Registry and could be analysed. Matching proved impossible in 23 cases because the subjects did not have complete identification numbers in the Registry of Visually Impaired Children (due to registration routines in one particular area of Sweden). The children in the remaining cases had either not been registered in the Medical Birth Register (occurs in 1–2% of all infants born) or had not been born in Sweden but had immigrated or had been adopted from abroad.

Among the matched children, there were three twins (1.6%) and thus 122 singleton births.

Table 4 shows ORs for maternal age, parity and maternal smoking, with each factor stratified for year of birth and the other two factors. There is an increased risk for low maternal age (independent of parity) and a statistically significant declining trend with age ($p < 0.01$) and for first parity (independent of age), compared with higher parity. There is also an increased risk for parity 4+, although this does not reach statistical significance. Maternal smoking in early pregnancy is a risk factor and a dose-dependency is indicated. The effects of smoking were analysed in infants with a birth weight below 2500 g and infants with a birth weight of 2500 g or more. In the latter group, the effect of smoking was further increased: OR = 1.73 (95% CI 1.10–2.72) for any smoking and OR = 2.19 (95% CI 1.23–3.88) for smoking 10 or more cigarettes

per day. No risk increase was noted for any smoking in low birth weight infants (OR = 0.86, 95% CI 0.35–2.13).

Preterm birth (< 37 completed weeks) among singletons showed an OR of 3.47 (95% CI 2.25–5.35) and low birth weight (< 2500 g) an OR of 4.96 (95% CI 3.27–7.52). The OR for being SGA was 2.63 (95% CI 1.42–4.86). All these ORs were stratified for year of birth, maternal age, parity, and smoking habits.

Only one woman was diagnosed with diabetes. The expected number was 0.4. Four women reported a period of subfertility before the pregnancy. Maternal pre-eclampsia occurred in only four women with singleton births.

The OR for having a caesarean section (based on 32 cases) *versus* non-instrumental vaginal delivery in singleton deliveries was 2.98 (95% CI 2.02–4.40), but after stratification for gestational duration, the OR decreased to 2.55 (95% CI 1.63–3.99). Instrumental vaginal delivery *versus* non-instrumental vaginal delivery showed an OR of 1.00 (95% CI 0.43–2.34) after stratification for gestational week.

Among singleton vaginal deliveries, only four were breech deliveries. Breech *versus* head presentation (stratifying for gestational week) showed an OR of 1.55 (95% CI 0.54–4.45) (this analysis was restricted to the period 1982–97 for technical reasons).

Low Apgar scores (< 7 at 5 min) were noted in eight singletons. The OR *versus* Apgar score ≥ 7 was 3.90 (95% CI 1.96–7.75).

According to the antenatal records for the 100 women whose records were scrutinized, drug use was reported by 37 women, and included a total of 45 drugs (see Table 5). Among these, the following can be commented upon.

One women used an antifungal drug (griseofulvin). Three women had become pregnant after drug treatment for infertility: bromocriptine (1), cyklofenil (1), and clomifene (1). Four women used drugs related to manic-depressive disease: lithium (1), clomipramine (2), and citalopram (1). All drugs used are accounted for in Table 5.

In the course of scrutiny of antenatal records, it was found that one infant had two previous sibs with microcephaly and another infant had a previous sib with a mid-line defect.

Table 1. Distribution of suggested aetiological factors among 156 children/adolescents with bilateral optic nerve hypoplasia.

Aetiological groups and subgroups	Number
Prenatal aetiology	125
Genetic without chromosomal cytogenetic abberation	5
Genetic with chromosomal cytogenetic abberation	8
Infectious disease, prenatal	4
Intoxication	2
Other prenatal influence, specified	2
Other prenatal influence, unspecified	104
Peri/neonatal aetiology	26
Maturity with asphyxia	10
Maturity, other peri-neonatal complications	6
Prematurity with dysoxygenation	5
Prematurity with other complications	5
Unknown time and cause	5

Table 2. Distribution of additional impairments among 156 Swedish children/adolescents with bilateral optic nerve hypoplasia.

Impairments	Number	Percentage
Mental (exclusively)	24	(15%)
Mobility (exclusively)	12	(8%)
Hearing (exclusively)	3	(2%)
Mental and mobility	42	(27%)
Mental and hearing	5	(3%)
Mobility and hearing	1	
Mental, mobility and hearing	1	
Other impairments	10	(6%)
Total additional impairments	98	(63%)

Table 3. WHO classification of visual impairment and the distribution of visual acuities among 156 Swedish children/adolescents with bilateral optic nerve hypoplasia.

Category	Vision		Number of individuals
1	Low vision	0.1–0.3	56
2		0.05–0.1	21
3	Blindness	0.02–0.05	5
4		< 0.02	28
5		No light perception	17
9	Unknown		19
> = 0.3			10

Discussion

Our study identified a number of risk factors for optic nerve hypoplasia. Low mat-

Table 4. Odds ratio (OR) with 95% confidence intervals (95% CI) for some maternal characteristics to have a child with optic nerve hypoplasia. Each variable is stratified for year of birth and the other two variables.

Maternal characteristic	OR	95% CI
Age		
19	1.46	0.70–3.02
20–24	1.50	1.02–2.21
25–29	0.88	0.60–1.27
30–34	0.85	0.54–1.35
35–39	0.49	0.21–1.13
40–	0.99	
Parity		
1	1.73	1.16–2.58
2	0.55	0.36–0.84
3	0.90	0.51–1.59
4 +	1.36	0.67–2.75
Smoking		
None	1.00	reference
< 10 cigs/day	1.42	0.87–2.33
≥ 10 cigs/day	1.84	1.08–3.14
All smoking	1.61	1.08–2.41

ernal age (irrespective of parity) and low parity (irrespective of age) were both risk factors. Maternal smoking was an independent risk factor. Among the risk factors reflected by infant characteristics are preterm birth, low birth weight and being small for gestational age. Analysis of drugs used during pregnancy indicated risk associated with fertility drugs and antidepressant drugs.

The characteristics of the infants with optic nerve hypoplasia in the present material mainly agree with those found in smaller published studies. Our study found the condition to occur at a rate of seven per 100 000 births, higher than the 1.8–6.3 per 100 000 births described in the literature (Jan et al. 1977; Blohmé & Tornqvist 1997c). However, it has been suggested pervasively that the disease may be more prevalent than previously thought (Lambert et al. 1987). The actual occurrence of the condition is certainly still higher than that shown here, as our study was restricted to serious cases involving visual impairment (Table 3). Infants with milder forms of optic nerve hypoplasia may either not have any visual impairment, or the condition may be unilateral.

Optic nerve hypoplasia is characterized in the literature as a congenital malformation of prenatal origin (Taylor & Stout 1997). It is often seen together with septo-optic dysplasia and other cerebral malformations (De Morsier 1956; Skarf & Hoyt 1984; Burke et al. 1991). We found a high proportion of infants (63%) with additional impairments, although this is not surprising given the high rate of associated cerebral involvement. Burke et al. (1991) found neuro-developmental handicaps in 32 of 46 children (70%) with optic nerve hypoplasia, but described structural central nervous system abnormalities in 90% of them.

Our study found a sex ratio of 0.87, thus a predominance of females. The sex ratio does not differ significantly from that in the age-specific population (1.06), but it differs from that previously reported by Zion (1976), who found a sex ratio of 1.5 in a review of the existing significant literature in English on the subject.

As stated earlier, some aetiological factors have been suggested in the literature, notably maternal diabetes and maternal alcoholism. Landau et al. (1998) found that 8.8% of children of mothers with diabetes had optic nerve hypoplasia. In our study, only one mother was diabetic. Children of diabetic mothers present superior segmental hypoplasia with normal or very limited decrease in visual function (Peterson & Walton 1977; Kim et al. 1989) and the material we present consists of children with visual impairment. We have no data on maternal alcoholism, but none of the medical histories of the 100 cases scrutinized contained notes on alcohol or drug abuse. Optic nerve hypoplasia has been estimated to occur in as many as 48% of infants with fetal alcohol syndrome (FAS) (Strömland 1987). Given an incidence of FAS of 1/600 (Olegård et al. 1979), this would mean that the rate of optic nerve hypoplasia associated with FAS would be 80 per 100 000 births, a rate which does not seem realistic even if mild forms are included.

We found an increased risk of optic nerve hypoplasia in infants born of smoking women. The association between maternal smoking and infant congenital malformation is much debated but, at least for some conditions, association exist which are probably causal (Källén 2001). The association between maternal smoking and optic nerve hypoplasia is dose-dependent and remains after stratification for birth weight, indicating a direct toxic effect.

Some authors have suggested that maternal drug use can cause optic nerve hypoplasia, generally based on single case reports. In our study, we found relatively rare drugs occurring more than once for two groups: drugs used for treatment of infertility (three cases) and drugs used for treatment of depressive disease (four cases). These findings may be random, but if not, they explain only a small number of cases. During 1995–99, antidepressant drug use in early pregnancy was reported by seven per 1000 pregnant women; the finding that three mothers of infants with optic nerve hypoplasia used antidepressants during pregnancy is therefore noteworthy, but more data are needed in order to verify or reject an association. One woman reported the use of the antifungal drug griseofulvin, which has been associated with birth defects. In the 1995–99 Medical Birth Registry, only one woman reported use of griseofulvin. Table 5 shows exposures for commonly used drugs such as antibiotics, anti-asthmatics, and analgesics that mirror their use in the general population.

Other maternal characteristics found to be risk factors for optic nerve hypoplasia include young maternal age (irrespective of parity) and low parity (irrespective of age). Some previous studies, all of which were smaller than the present study, have also observed that young maternal age and first parity may be over-represented (Elster & McAnarney 1979; Purdy & Friend 1979; Margalith et al. 1984; Robinson & Conry 1986). Young maternal age is a risk factor for a few congenital malformations, the most well-known of which is probably gastroschisis (Källén & Lindham 1982). Optic nerve hypoplasia may be a malformation to be added to this list.

Preterm birth, low birth weight, SGA, low Apgar scores, and caesarean section are all associated with an increased risk for optic nerve hypoplasia. Assuming that the condition does not originate during birth, but is a congenital malformation formed much earlier, these associations could be due to unfavourable conditions during development, affecting fetal growth, general fetal development and the risk of malformation. Early fetal maldevelopment might be associated with an increased risk of peri-neonatal complication.

Another possibility is that optic nerve hypoplasia actually results from preterm birth and the complications associated with such births. Optic nerve atrophy might be more commonly expected, as a result of neonatal ischaemia. It is possible that some misclassification has occurred, but it can hardly be significant enough to account for the results seen here.

Apart from causing visual impairment, optic nerve hypoplasia can be associated with endocrine disturbances (Hoyt et al. 1970; Skarf & Hoyt 1984; Brodsky &

Table 5. Drug use recorded in antenatal medical records for 100 women whose children developed optic nerve hypoplasia.

Drug category	Number of drugs	Number of women
Gastrointestinal drugs	3	3
Insulin	2	1
Antifungal drugs	1	1
Bromocriptine	1	1
Oral contraceptives	1	1
Ovulation stimulator	2	2
Antibiotics	7	6
Muscle relaxants	1	1
Analgesics	9	8
Lithium	1	1
Antidepressants	3	3
Common cold drugs	5	3
Anti-asthmatic drugs	7	4
Anti-nausea drug	1	1
Eye drops	1	1

Glasier 1993). Sudden death in children with septo-optic dysplasia has been reported (Brodsky et al. 1997) and it is thus of vital importance that optic nerve hypoplasia is recognized and that appropriate further investigation is performed. The increasing incidence and the intriguing pathogenesis illuminates the importance of epidemiological studies and the evaluation of possible risk factors as part of preventive work.

Acknowledgements

This study was supported by the Foundation for the Visually Impaired in the former country of Malmöhs and a donation from Malin Mårtensson.

References

Bistner S, Rubin L & Aguine G (1973): Development of the bovine eye. Am J Vet Res **34**: 7–12.

Björk Å, Laurell CG & Laurell U (1978): Bilateral optic nerve hypoplasia with normal visual acuity. Am J Ophthalmol **86**: 524–529.

Blohmé J & Tornqvist K (1997a): Visual impairment in Swedish children. I. Register and prevalence data. Acta Ophthalmol Scand **75**: 194–198.

Blohmé J & Tornqvist K (1997b): Visual impairment in Swedish children. II. Aetiological factors. Acta Ophthalmol Scand **75**: 199–205.

Blohmé J & Tornqvist K (1997c): Visual impairment in Swedish children. III. Diagnoses. Acta Ophthalmol Scand **75**: 681–687.

Brodsky MC, Conte FA, Taylor D, Hoyt CS & Mrak RE (1997): Sudden death in septo-optic dysplasia. Report of 5 cases. Arch Ophthalmol **115**: 66–70.

Brodsky MC & Glasier CM (1993): Optic nerve hypoplasia. Clinical significance of associated central nervous system abnormalities on magnetic resonance imaging (published erratum appears in Arch Ophthalmol 111: 491). Arch Ophththalmol **111**: 66–74.

Burke JP, O'Keefe M & Bowell R (1991): Optic nerve hypoplasia, encephalopathy, and neurodevelopmental handicap. Br J Ophthalmol **75**: 236–239.

Chan T, Bowell R, O'Keefe M & Lanigan B (1991): Ocular manifestations in fetal alcohol syndrome. Br J Ophthalmol **75**: 524–526.

Chan CC, Fishman M & Egbert PR (1978): Multiple ocular anomalies associated with maternal LSD ingestion. Arch Ophthalmol **96**: 282–284.

Cnattingius S, Ericson A, Gunnarskog J & Källén B (1990): A quality study of a medical birth registry. Scand J Soc Med **18**: 143–148.

De Morsier G (1956): Agénésie du septum lucidum avec malformation du tractus optique. La dysplasie septo-optique. Schweiz Arch Neurol Neurochir Psychiatr **77**: 267–292.

Donat JFG (1981): Septo-optic dysplasia in an infant of a diabetic mother. Arch Neurol **38**: 580–591.

Elster AB & McAnarney ER (1979): Maternal age re: septo-optic dysplasia. J Pediatr **94**: 162.

Good WV, Ferriero DM, Golabi M & Kobori JB (1992): Abnormalities of the visual system in infants exposed to cocaine. Ophthalmol **99**: 341–346.

Hansen E, Flage T, Rosenberg T, Rudanko SL, Viggósson G & Riise R (1992): Visual impairment in Nordic children. III. Diagnoses. Acta Ophthalmol **70**: 597–604.

Hellström A, Wiklund L, Svensson E, Albertsson-Wikland K & Strömland K (1999): Optic nerve hypoplasia with isolated tortuosity of the retinal veins. Arch Ophthalmol **117**: 880–884.

Hoyt CS & Billson FA (1978): Maternal anticonvulsants and optic nerve hypoplasia. Br J Ophthalmol **62**: 3–6.

Hoyt C & Good W (1992): Do we really understand the difference between optic nerve hypoplasia and atrophy. Eye **6**: 201–204.

Hoyt WF, Kaplan SL, Grumbach MM & Glaser J (1970): Septo-optic dysplasia and pituitary dwarfism. Letter. Lancet **2**: 893–894.

Jan JE, Robinson GC, Kinnis C & MacLeod PJM (1977): Blindness due to optic-nerve atrophy and hypoplasia in children: an epidemiological study. Dev Med Child Neurol **19**: 353–363.

Källén B (1995): A birth weight for gestational age standard based on data in the Swedish Medical Birth Registry 1985–89 Europ J Epidemiol **11**: 601–606.

Källén K (2001): Maternal smoking and congenital malformations. Fetal Maternal Med Rev **13**: 63–86.

Källén B & Lindham S (1982): A women's birth cohort effect on malformation rates. Int J Epidemiol **11**: 398–401.

Kim RY, Hoyt WE, Lessell S & Narahara MH (1989): Superior segmental optic nerve hypoplasia: a sign of maternal diabetes. Arch Ophthalmol **107**: 1312–1315.

Lambert SR, Hoyt CS & Narahara MH (1987): Optic nerve hypoplasia. Surv Ophthalmol **32**: 1–9.

Landau K, Djahanschahi Bajka J & Kirchschlõger BM (1998): Topless optic disks in children of mothers with type 1 diabetes mellitus. Am J Ophthalmol **125**: 605–611.

Margalith D, Jan JE, McCormick AQ, Tze WJ & Lapointe J (1984): Clinical spectrum of optic nerve hypoplasia: a review of 51 patients. Dev Med Child Neurol **26**: 311–322.

McKinna AJ (1966): Quinine induced hypoplasia of the optic nerve. Can J Ophthalmol **1**: 261–265.

Mosier MA, Lieberman MF, Green WR & Knox DL (1978): Hypoplasia of the optic nerve. Arch Ophthalmol **96**: 1437–1442.

Olegård R, Sabel KG, Aronsson M et al. (1979): Effects on the child of alcohol abuse during pregnancy - retrospective and prospective studies. Acta Paediatr Scand Suppl **275**: 112–121.

Patel H, Tze WJ, Crichton JU, McCormick AQ, Robinson GC & Dolman CL (1975): Optic nerve hypoplasia with hypopituitarism. Am J Dis Child **129**: 175–180.

Peterson RA & Walton DS (1977): Optic nerve hypoplasia with good visual acuity and visual field defects: a study of infants of diabetic mothers. Arch Ophthalmol **95**: 254–258.

Purdy F & Friend JCM (1979): Maternal factors in septo-optic dysplasia. J Pediatr **95**: 661.

Riise R, Flage T, Hansen E, Rosenberg T, Rudanko SL, Viggósson G & Warburg M (1992): Visual impairment in Nordic children. I. Nordic registers and prevalence data. Acta Ophthamol **70**: 145–154.

Robinson GC & Conry RF (1986): Maternal age and congenital optic nerve hypoplasia: a possible clue to aetiology. Dev Med Child Neurol **28**: 294–298.

Rosenberg T, Flage T, Hansen E, Rudanko SL, Viggósson G & Riise R (1992): Visual impairment in Nordic children. II. Aetiological factors. Acta Ophthalmol **70**: 155–164.

Skarf B & Hoyt CS (1984): Optic nerve hypoplasia in children. An association with anomalies of the endocrine and CNS. Arch Ophthalmol **102**: 62–67.

Strömland K (1987): Ocular involvement in the fetal alcohol syndrome. Surv Ophthalmol **31**: 277–284.

Strömland K & Pinazo-Duran MD (1994): Optic nerve hypoplasia: Comparative effects in children and rats exposed to alcohol during pregnancy. Teratology **50**: 100–111.

Taylor D & Stout A (1997): Optic nerve: congenital anomalies. In: Taylor, D (ed). Pediatric Ophthalmology, 2nd edn. Blackwell Science Ltd, London. 660–700.

Zeki SM & Dutton GN (1990): Optic nerve hypoplasia in children. Br J Ophthalmol **74**: 300–304.

Zion V (1976): Optic nerve hypoplasia. Ophthalm Seminars **1**: 171–196.

Received on March 19th, 2001.
Accepted on February 26th, 2002.

Correspondence:
Kristina Tornqvist, MD
Department of Ophthalmology
University Hospital of Lund
SE-221 85 Lund
Sweden
Tel: +46 46 17 20 74
Fax: +46 46 21 15 074
e-mail: kristina.tornqvist@oft.lu.se