Longterm oculomotor and visual function in spina bifida cystica: a population-based study

Elizabeth Caines,[1] Margareta Dahl[2] and Gerd Holmström[1]

[1]Department of Ophthalmology, University Hospital, Uppsala, Sweden
[2]Department of Paediatrics, University Hospital, Uppsala, Sweden

ABSTRACT.

Purpose: **To document and describe the development from birth of visual and oculomotor functions in a group of children with spina bifida cystica (myelomeningocele and myeloschisis [MMC]). The emphasis in this study is on findings at 12–14 year follow-up.**

Methods: **Twenty children aged 12–14 years with myelomeningocele and Chiari-related malformations were examined by an orthoptist and a paediatric ophthalmologist. A further child who did not wish to participate actively in the study is also reported. Visual acuity for near and distance, refractometer readings in cycloplegia, the presence of ocular motility disorders and nystagmus were recorded. Accommodation, convergence, colour vision and stereo acuity were assessed and the fundus and media were examined.**

Results: **Six children (29%) in the study group had subnormal vision, although no child was visually impaired. Eleven (52%) showed manifest strabismus and 17 (81%) had a significant refractive error. Near visual acuity was normal in nearly all the children, but accommodation was defective in 10. Nine children had nystagmus and two had optic atrophy. No visual field defects were found.**

Conclusions: **The high incidence of ocular disturbances in children with spina bifida highlights the importance of regular ophthalmological investigation and follow-up.**

Key words: Arnold Chiari – myelomeningocele (MMC) – hydrocephalus – spina bifida cystica – visual function

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Introduction

Spina bifida cystica (myelomeningocele and myeloschisis [MMC]) is a complicated malformation leading to various disabilities, which may include ophthalmological complications. The complex clinical picture resulting from neurological dysfunction includes impaired urinary bladder innervation, paralysis and reduced sensibility of the legs, weakness of the hands and 'failure to thrive' due to difficulty in swallowing (Biglan 1990). Some 80–90% of children born with MMC develop hydrocephalus (Clements & Kaushal 1970; Biglan 1990; Ziya 1995) and many require insertion of a shunt to regulate intracranial pressure. Magnetic resonance imaging (MRI) reveals that more than 90% have Chiari II malformation, with caudal displacement of the cerebellum, lower brainstem and fourth ventricle through the foramen magnum (Samuelsson et al. 1987). Increased intracranial pressure, underdevelopment or dysfunction of cranial nerve nuclei and/or a tethered cord may explain why more than 50% of children with MMC also have ocular disturbances such as strabismus and gaze palsies (France 1975; Maloley et al. 1977; Gilbert et al. 1986; Biglan 1990; Lennerstrand et al. 1990; Mercuri et al. 1997; Dickman et al. 2001).

In 1988 a multidisciplinary prospective study was initiated of all infants born with MMC during 1988–90, in the area served by University Hospital, Uppsala, Sweden (Dahl et al. 1995). The catchment area population at the time was 1.2 million. The main intention was to document and describe the clinical course of neurological dysfunction above cele level during the first 4 years of life. Oculomotor and visual disturbances were described in a separate study (Caines & Dahl 1997). The present investigation, a follow-up at age 12–14 years, was undertaken in order to form a comprehensive picture of the children's visual function. To our knowledge, no previous study has documented visual and oculomotor development from birth in a group of children with this specific, complicated neurological malformation.

Materials and Methods

The original study comprised 22 infants (14 girls, eight boys). Twenty showed ventricular dilatation; 15 required the insertion of a shunt. The level of herniation/motor level of paralysis varied considerably. Chiari II malformation was documented in 19 infants, six of whom had serious Chiari-related brainstem dysfunction with multiple malformations of the central nervous system. Neurosurgical decompression was necessary in three cases. One infant with severe brainstem symptoms died aged 3 months; decompression surgery was not performed because it was considered too risky.

The surviving 21 children (14 girls, seven boys) and their parents were asked to participate in the study. One family declined, but permitted us to use data from a recent orthoptic/ophthalmic examination of the child at the age of 12 years, 6 months. Mean age at examination of the remaining 20 children was 13 years, 4 months (range 12 years to 14 years, 10 months).

Twenty children were examined by an orthoptist and an ophthalmologist. Nineteen children were examined by the author (EC) at the Department of Ophthalmology, Uppsala University Hospital, while attending the Folke Bernadotte Rehabilitation Centre in Uppsala, or at their local ophthalmic clinic. One child had moved and was seen by a local orthoptist. The fundus and media of 11 patients were examined by a paediatric ophthalmologist in Uppsala; those of the remaining nine subjects were examined by an ophthalmologist at each child's local hospital. Data pertaining to the child who did not actively participate in the study were obtained from the ophthalmologist and orthoptist at the child's local ophthalmic department. Unfortunately, accommodation and colour vision had not been documented in this case. One other child, who was in poor general health, would not co-operate in some of the tests. No data regarding her accommodation, convergence or colour vision were therefore obtained. Monocular and binocular distance visual acuity (VA) was tested with optimal refractive correction using Snellen's linear chart. One child was unable to complete the test; VA was therefore determined using a picture chart. Near VA was tested with Jaeger charts. Refractometer readings were taken in cycloplegia, obtained by instilling drops containing cyclopentholate (0.85%) and phenylephrine (1.50%). In this investigation, significant refractive error was defined as: hypermetropia ≥ 3.0 D; astigmatism ≥ 1.0 D; myopia ≥ 1.0 D and anisometropia ≥ 1.0 D. Cover test for near and distance fixation, with glasses when usually worn, was carried out in all cases. Ocular motility was examined and particular note made of any nystagmus. Incomittance and A and V patterns were determined by prism and cover test measurements in five directions of gaze. Convergence and accommodation were measured using the Royal Air Force near point rule (Neely 1956). Accommodation was tested with the N_5 text. The children wore full spectacle correction and each eye was measured three times to detect the presence of accommodative fatigue. Normal accommodation was deemed as 10–14 D. The Lang stereo (Lang 1983) and Titmus test were used to determine stereo acuity, as appropriate. Colour vision was tested with the Hardy, Rand and Rittler (HRR) test (Bailey 2004) and visual fields estimated using Donder's confrontation method.

Results

Visual acuity

Distance VA in all 21 cases was ≥ 0.3 D in both eyes (Table 1) (i.e. no child was classified as visually impaired). Fifteen children had VA = 1.0 in the better eye; of the remaining six, five had latent and/or side-pocket nystagmus, and one had high hypermetropia combined with astigmatism. Six of the 21 children had amblyopia, with an interocular difference of ≥ 2 Snellen lines; of these, four had strabismic amblyopia and two anisometropic amblyopia. Near VA was normal in one or both eyes in the 20 patients who completed the test. Only three children showed a slight monocular reduction; all three had strabismic amblyopia with distance VA ≤ 0.8 in the amblyopic eye.

Refractive errors

The results of cycloplegic refraction from 3 months of age onward are presented in Table 2. In the present investigation (at 12–14 years) a significant refractive error was found in 17 (81%) of the study group. Six children (29%) had hypermetropia ≥ 3.0 D in both eyes; in three of them this was combined with astigmatism ≥ 1.0 D; four of the six were esotropic and four anisometropic. Only small changes in refractive errors were found from the age of 3 months to follow-up at 12–14 years.

Strabismus

Strabismus at various ages is presented in Table 3. At 12–14 years, manifest or intermittent strabismus was found in 11 children (52%), of whom 10 (91%) had shunt-regulated hydrocephalus. Eight children had convergent strabismus of varying degrees. Of 10 children with esotropia at the age of 4 years, two had undergone surgery that resulted in a change from manifest to latent deviation. Three children had manifest or intermittent exotropia; in one child the deviation had remained constant since birth. The other two cases of divergent deviation were intermittent divergent squints of divergence excess type that had earlier been only latent. Six of the children with manifest or intermittent strabismus had A pattern; three were esotropic and three exotropic. Five of the children with A pattern showed overaction of the superior oblique muscles. V pattern was found in two of the children with manifest or intermittent

Table 1. Distance visual acuity better/worse eye ($n = 21$) tested with optimal refractive correction.

< 0.3 < 20/60		0.3–0.99 ≥ 20/60 to < 20/20		1.0 20/20	
Better eye	Worse eye	Better eye	Worse eye	Better eye	Worse eye
0	0	6	11	15	10

Table 2. Cycloplegic refraction (both eyes).

	Hypermetropia ≥ + 3 D		Astigmatism ≥ 1 D		Myopia ≥ 1 D	
Age	RE	LE	RE	LE	RE	LE
3 months	5	5	5	5	0	0
4 years	8	8	8	8	1	1
12–14 years	6	6	8	10	1	1

RE = right eye; LE = left eye.

Table 3. Ophthalmological findings in study group ($n = 21$). Figures for manifest or intermittent strabismus are presented.

Age	Esotropia	Exotropia	A + V syndrome	Nystagmus
3 months	4	1	1	2
4 years	10	1	2	5
12–14 years	8	3	8	9

strabismus, neither of whom showed overaction of the inferior oblique muscles. Latent strabismus was present in eight children; five had exophoria and three an esophoria of > 4 prism dioptres. Stereo acuity tested with the Lang test was positive in nine cases. Two children found it difficult to recognize the symbols but responded positively to the Titmus fly, pictures and rings.

Accommodation

Accommodation was tested in 19 children. According to our criteria, nine children showed normal results in both eyes, seven had defects bilaterally and three had normal accommodation in one eye only. Two of the eyes with poorer accommodation were amblyopic. No cases of accommodative fatigue were observed.

Nystagmus, colour vision, visual fields, optic atrophy

Nystagmus of varying amplitude was evident in nine cases (43%). Three of these were side-pocket type, one of which was combined with latent nystagmus. Three children had vertical nystagmus on elevation, which in two cases was combined with latent nystagmus in the primary position. The remaining three children had latent nystagmus only. Four of the children with latent nystagmus had VA ≤ 0.5 in one or both eyes. Optic atrophy was found in the right eye in two children, both of whom had VA = 0.5 in the affected eye, latent nystagmus, esotropia and a high level of herniation. Colour vision and visual fields were normal in all cases tested (19 and 20, respectively).

Three children had undergone decompression surgery at an early age. Two of these had a manifest strabismus with side-pocket nystagmus and a significant refractive error. One also had optic atrophy. Two children underwent neurosurgery to release a tethered cord; they both had latent deviation and low degrees of hypermetropia and astigmatism. Distance VA in this group with severe brainstem dysfunction was reduced in one or both eyes in four of the five cases. Multiple shunt revision had been necessary in all cases. On the day of examination, one child was extremely depressed and was referred to the paediatric department for further care. Three children with a significant refractive error complained of recurring headaches; investigation for shunt dysfunction did not lead to any revision; glasses were prescribed. One seriously myopic child did not wear her glasses but was recommended to do so. Two children with slight uncorrected hypermetropia were also prescribed glasses.

Discussion

In this study of 21 children aged 12–14 years, with MMC, 29% had subnormal VA, 52% strabismus, 43% nystagmus and 81% a significant refractive error (according to our definitions). Fourteen children (67%) were wearing their prescribed spectacles. Three had previously undergone strabismic surgery. The prospective design of our study also allowed us to monitor the course of ophthalmological changes not previously reported in other studies. Many authors have assessed ocular findings in children with hydrocephalus, but few have reported on those with MMC and related Chiari malformation (Rothstein et al. 1973; Biglan 1990; Lennerstr Gallo 1990; Pinello et al. 2003).

Visual acuity

Visual acuity was normal (1.0) in the better eye in 15 (71%) of the children examined at the age of 12–14 years; none of them were classified as visually impaired (VA < 0.3). At the age of 4 years, only five infants had normal VA, defined at this age as ≥0.8 in the better eye. The improved VA at 12–14 years indicates delayed visual maturation in these children. The good VA observed here concurs with the results of Lennerstrand & Gallo (1990) and Pinello et al. (2003). This is encouraging because children with MMC have many disabilities to contend with and rely on their vision for orientation.

Refractive errors

We found significant refractive errors in 17 (81%) of our study group. Lennerstrand & Gallo (1990) reported an incidence of 54% in a retrospective study in patients with MMC, and, more recently, Pinello et al. (2003) reported 59%; hence a higher proportion of significant refractive errors was recorded in our material despite the fact that our criteria were more stringent. The differing prevalences may be partly attributable to the varying ages of patients in the other studies (4–34 years and 5 months to 26 years, respectively). Larsson et al. (2003) found that 7.8% of normal 10-year-old Swedish children had a significant refractive error. The criteria they used were similar to those applied in the present study. Refractive errors would therefore seem to be far more common in children with MMC than in a normal population, emphasizing the need for follow-up. Astigmatism, often combined with hypermetropia, was the predominant refractive error in our study. The prevalence of astigmatism was especially high, as has

been noted in children with Down's syndrome and others with intellectual difficulties (Haugen et al. 2001; Warburg 2001). The normal process of emmetropization, which includes a decrease in astigmatism, appears not to have taken place.

Children with MMC are frequent patients at hospital departments. Headaches may be the cause in some cases (Clancy et al. 2005), although shunt dysfunction, migraine and obstructive sleep apnoea are the three chief reasons (Hanigan 2004; Matta & Carod-Artal 2004). Uncorrected refractive errors may give similar symptoms. This study has shown that spectacles for the correction of small refractive errors can alleviate symptoms. Retinoscopy in cycloplegia is a quick and inexpensive way to determine a child's refraction and should not be disregarded.

Strabismus

Manifest or intermittent strabismus was found in 11 children (52%) in our study population, indicating a prevalence similar to previous findings (40–50%) in children with MMC (Biglan 1990; Gaston 1991; Dickman et al. 2001; Pinello et al. 2003), but very different from that in the normal population. Recently Holmström et al. (2006) found manifest strabismus in 3.2% of healthy 10-year-old Swedish children. In the present study, eight (73%) of the children with strabismus were esotropic, a finding that largely agreed with those of other authors (Clements & Kaushal 1970; Rothstein et al. 1973; Pinello et al. 2003). Exotropia was less common in these studies as it was in the case of the present study ($n = 3$, 14%). We found congenital esotropia in only four patients. The high prevalence of strabismus has been attributed in most cases to hydrocephalus (Stanworth 1970; France 1975; Maloley et al. 1977). All the children with manifest strabismus ($n = 11$) had developed the deviation during the first 4 years of life; of these, 10 had hydrocephalus requiring shunt insertion. As the level of herniation in seven of the 10 cases was high, it appears that hydrocephalus combined with high-level herniation predisposes to the development of strabismus in patients with MMC, as was also concluded by Lennerstrand et al. (1990). It has been suggested that strabismus associated with hydrocephalus and MMC is a consequence of lateral rectus palsy (Clements & Kaushal 1970). Our study cannot support this hypothesis, however, as we diagnosed only one case of lateral rectus weakness throughout the follow-up period.

Lesions of the cerebellum and brainstem can cause various defects in ocular motility, including weakness of oblique muscles that results in A and V patterns. The presence of the A pattern in connection with hydrocephalus was first reported by France (1975). Maloley et al. (1977) found an incidence of 60% of A syndrome in 18 patients with MMC, which was decidedly higher than in a normal population of strabismic individuals. In our study, 73% of the children with strabismus showed an A or V pattern. Follow-up at 12–14 years of age revealed six more cases of A and V pattern than testing at 4 years of age. The more accurate prism and cover test measurements, practicable in the older patient group, may account for this increase.

Accommodation

Accommodation was reduced in half our children. Although accommodative problems have previously been attributed to various neurological disorders and brain damage, there are few studies on accommodation and near VA in children with MMC. Of the seven with bilateral accommodative defects, three had been prescribed an anticholinergic drug. In one case poor accommodation may have resulted from tiredness. All seven patients had normal near VA, possibly because near VA was tested early in the examination, whereas accommodation was tested toward the end. Another possibility is that near VA was tested at a distance of 33 cm, and therefore did not require full accommodation. Cregg et al. (2001) noted poor accommodation regardless of refractive error in a group of children with Down's syndrome and concluded that defective neural control could be the cause. We recommend measurement of accommodation in children with MMC, as it may lead to the prescribing of additional spectacle correction for close work, where appropriate.

Nystagmus

Nystagmus was found in nine children (43%) in the study group, three (14%) of whom had side-pocket type, an ocular finding often present in Chiari deformity (Amal Al-Awami et al. 2005). All those with nystagmus had shunted hydrocephalus, but levels of herniation varied. Various forms of nystagmus are often associated with neurological disorders and in MMC have been correlated with Chiari malformation (Biglan 1990; Salman et al. 2005). Tubbs et al. (2004) recently showed a direct correlation between the severity of nystagmus and the degree of tectal beaking, but emphasized that this may not be the sole cause.

Optic atrophy

Only two cases of optic atrophy were diagnosed in this study, although the condition has been reported as common in children with MMC (Rabinowic 1974; Gaston 1985). More recent studies have not corroborated this finding (Mankinen-Heikkinen & Mustonen 1987; Caines & Dahl 1997). Early intervention and surgical correction of hydrocephalus may account for the low prevalence of optic atrophy in our study.

Colour vision

A red–green disturbance in colour vision was found in a cohort of hydrocephalic children when tested with HRR charts (Mankinen-Heikkinen & Mustonen 1987). In our study, colour vision was normal in all cases tested, including those with optic atrophy, suggesting adequate functioning of the optic nerve.

Visual fields

Using the confrontation method, Gaston (1991) reported visual field defects in 5% of children with MMC and hydrocephalus. No major visual field defects on confrontation were found in our group, although smaller restrictions could not be ruled out, as more detailed investigation of the visual fields was not performed.

Children born with spina bifida cystica and related Chiari malformation may have various ocular disturbances. The present study suggests that children with a high level of herniation,

together with shunt-regulated hydrocephalus, are at increased risk of developing multiple ophthalmological defects. Although our study population was small, children with MMC have demonstrably more ocular problems than the general population. Fortunately, modern techniques now enable these children to grow to adulthood. It is therefore especially important that all their senses are allowed to develop fully and that a multidisciplinary approach to the needs and care of these children is adopted. Orthoptic and ophthalmological investigations provide a comprehensive picture of their visual functions. The information obtained may be of great importance to both teaching staff and family members, and if acted upon, will improve the quality of life of the children themselves. The need for regular ophthalmic monitoring and the initiation of treatment when necessary must be emphasized.

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Correspondence:
Elizabeth Caines
Department of Ophthalmology
University Hospital
751 85 Uppsala
Sweden
Tel: + 46 18 611 5118
Fax: + 46 171 473095
Email: elizabeth.caines@akademiska.se