

ORIGINAL ARTICLE

Long term outcome of neonatal meningitis

J P Stevens, M Eames, A Kent, S Halket, D Holt, D Harvey

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See end of article for authors' affiliations

Correspondence to: Dr Stevens, University of Alberta, 3A3.43 Stollery Children's Hospital, Edmonton, Alberta T6G 2B7, Canada; js20@ualberta.ca

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Objectives: To quantify long term impairment after neonatal meningitis.**Design:** Longitudinal case-control study over 9–10 years.**Subjects and methods:** A total of 111 children who had suffered neonatal meningitis were seen and compared with 113 matched controls from their birth hospital and 49 controls from general practices. Assessments included the WISC III^{UK}, movement assessment battery for children (mABC), audiometry, vision testing, and social and medical data. Statistical analysis was by multiple regression, analysis of variance, and χ^2 tests.**Results:** Some 10.8% of cases had a severe and 9% a moderate overall outcome compared with 0% and 1.8% for the hospital controls. The mean intelligence quotient (IQ) of the cases (88.8) was significantly less than that of the hospital controls (99.4) or the GP controls (99.6). The mABC score was significantly worse for the cases (7.08) than the hospital (5) or GP (4) controls. Some 3.6% of cases had sensorineural hearing loss, 2.7% had persisting hydrocephalus; no controls did. Some 5.4% of cases and 1.7% of hospital controls had treatment for seizures.**Conclusions:** Severe neurodisability and milder motor and psychometric impairment result from neonatal meningitis. Both clinical follow up and comprehensive developmental assessment are needed after this disease.

Neonatal meningitis is an uncommon but serious disease, with an incidence of 0.1–0.4 per 1000 live births.^{1,2} It can have severe long term sequelae in 12–29% of survivors,^{2–8} and milder impairment of neurological function occurs in another 15–38%.^{3–5,8} Cognitive impairment has been shown in some follow up studies of neonatal meningitis,^{3,4,6,8–10} but not in others.⁷ Other outcomes measured have included vision and hearing, although these are often not severely impaired in the absence of other severe sequelae.^{2,3,8}

Some studies have included only small numbers of patients and there has been a wide range of ages at which cases were followed up. Hence, a review with a large number of patients collected over a short period would give a clearer picture of overall outcome.

The aim of this study is to report the long term outcome of a national cohort of children who had neonatal meningitis during a defined period, 1985–1987, in England and Wales. The group was part of a cohort of infantile meningitis cases and had been followed up by questionnaire at 5 years of age.^{11,12} This follow up indicated that the neonatal cases had a worse outcome than older children. Hence, in our study the objectives were: (a) to quantify the impairment of those at the milder end of the spectrum of outcome, who may not have been identified by the earlier questionnaire follow up; (b) to compare the different infecting organisms in this age group; (c) to exclude confounding factors.

SUBJECTS AND METHODS

We examined children identified as having had neonatal meningitis (up to 28 days of life) from cases in a prospective study of meningitis in children below 1 year of age. They were collected from consultant paediatricians in England and Wales by means of a monthly reporting card between October 1985 and October 1987.¹¹ There were 166 survivors of those infected with appropriate organisms. Five died before their fifth birthday. Twenty others were lost to follow up or were duplicate cases. This left 141 with contact information, but we were unable to arrange to review 30 of these. Thus 111 cases were seen at 9–10 years of age.

Meningitis was defined as a positive cerebrospinal fluid culture. The infecting organisms considered were Lancefield group B streptococci (GBS), Gram negative bacteria (mostly *Escherichia coli*), or *Listeria monocytogenes*. Individual cases with rare organisms were not included.

Stratum matching was used to eliminate some possible confounding factors. We identified a hospital control for each child, with the closest possible birth date, matched for hospital of birth, birth weight (± 500 g), and sex. If the hospital of birth was unable to provide a control, then one was selected from children treated at Queen Charlotte's and Chelsea maternity hospital London (14 children). A further control was requested from the case's general practitioner's list (GP controls), born at term and matched only for birth date and sex, to obtain a sample typical of the general population. A total of 113 hospital controls and 49 GP controls were seen and assessed. The discrepancy in numbers of cases and controls was either due to failure to recruit children or to arrange an appointment for assessment.

Written parental consent was obtained for the examination of the children. In all cases a parent, guardian, or teacher was also present when the children were examined. The study was approved by the research ethics committee of the Royal Postgraduate Medical School (now Imperial College School of Medicine) and Hammersmith Hospitals NHS trust.

The examination was performed by a medically trained research fellow (JS) in the child's own home or, in a few cases, at their school. The examiner was not informed, until after completion of the assessment, whether the child had suffered from meningitis.

Each child was administered the WISC-III^{UK} (Wechsler intelligence scale for children). The examiner was trained and supervised by a clinical psychologist (AK), who also checked and reviewed the scoring of all the tests.

Abbreviations: GBS, group B streptococci; GP, general practitioner; WISC-III^{UK}, Wechsler intelligence scale for children; mABC, movement assessment battery for children; IQ, intelligence quotient

Table 1 Zurich neuromotor test

Subtest	No of repetitions timed
Hand pronation/supination	10
Tapping of palm on thigh	10
Alternate tapping of palm/dorsum of hand on thigh	10
Sequential apposition of thumb with each finger of the ipsilateral hand	5
Forefoot tapping	10
Alternate heel/Toe tapping	10

All subtests were performed in a sitting position. The number of hesitations was also scored.

Table 2 Characteristics of subjects

	Group		
	Cases	Hospital controls	GP controls
Birth weight (g)	2769 (81.5)	2780 (78.2)	3278 (49.9)*
Gestational age (weeks)	36.9 (3.9)	37.4 (4.2)	39.8 (1.8)*
Age at examination (years)	9.39 (0.24)	9.42 (0.22)	9.42 (0.26)

Values are mean (SD).

*GP controls differed significantly from the other two groups.

GP, General practitioner.

The movement assessment battery for children (mABC) was used to quantify motor function. This tested ball skills (visual motor integration), manual dexterity (fine motor), and static and dynamic agility (gross motor). The scores were 0–40. A score of 0 or close to it is normal; the test does not aim to quantify ability that is above average and hence gives a skewed distribution. Fine motor function and coordination was further assessed with the Zurich neuromotor test (table 1).¹³

Sweep screening of hearing, at 20, 40, and 60 dB levels, was tested using a portable audiometer with headphones. Mild hearing loss was defined as 20–40 dB, moderate as 41–60 dB, and severe as > 60 dB. When an audiometer was not available, a history of a normal sweep test at school, or other formal hearing test was considered satisfactory, provided that there was no evidence of impairment during the psychometric or clinical examination. Visual acuity was assessed with the Sonksen-Silver acuity system.¹⁴ Any previously undetected abnormality was referred to the appropriate local services. Height was measured with a portable stadiometer, and weight with one set of accurate scales on a hard surface. Head circumference and blood pressure were recorded. A standard clinical neurological examination assessed power, tone, reflexes, and cerebellar and sensory function.

Social and medical data on the children were obtained from a questionnaire, and information on acute illness was already held from the previous prospective study. Parental occupational class was defined using the UK Office of population and census survey criteria.

In addition to considering the test results individually, the overall outcome was classified as follows.

(1) Severe outcome. Severe disability or a significant functional impairment: cerebral palsy, significant learning problems (IQ < 55), global delay, special education.

(2) Moderate outcome. Moderate to mild disability or an abnormality that impairs function without significant intellectual or developmental impairment: mild cerebral palsy, mild learning problems (IQ 55–69). Sensorineural hearing loss.

(3) Mild outcome. An impairment without disability: neuro-motor signs without overt functional loss, isolated hydrocephalus, isolated epilepsy, borderline learning problems (IQ 70–80), isolated occurrence of all mABC component scores being below the 5th centile.

(4) Normal outcome.

The IQ and motor impairment scores between cases and control groups were compared using analysis of variance and a multiple regression model to take account of possible confounding variables, including birth weight, gestational age, sex, and occupational class.

A similar analysis of the index cases also included age at diagnosis of the disease and the type of infecting bacteria. The motor impairment and IQ scores in the cases were compared using the Pearson correlation coefficient to assess the degree of concordance.

mABC scores in the model were logarithmically transformed to give normally distributed data.

The categories of the overall severity of outcome were compared using a χ^2 test.

The statistical analysis was performed using STATA or SPSS 7.5. Significance was defined as $p < 0.05$ and power as 0.8.

RESULTS

We saw and examined 111 cases with 113 hospital controls and 49 GP controls. They were seen at a mean (SD) age of 9.39 (0.24) years for the cases, 9.42 (0.22) years for the GP controls, and 9.42 (0.26) years for the hospital controls. Table 2 shows the characteristics of each group. Only the birth weight and gestational age of the GP controls differed significantly from the other groups. There were no differences in occupational class between cases and controls. Table 3 shows the number of cases infected by each organism.

Overall outcome

Tables 3 and 4 show the overall outcome for cases and controls, and table 5 gives details of the impaired index cases. The details of the impaired controls are as follows. Of the two hospital controls with a moderate outcome, one had controlled absence seizures and a mild right hemiplegia, and the other had an IQ score of 60 and a motor impairment score of 24. Of the 13 hospital controls with a mild outcome, one had controlled fits, motor impairment (score 22.5), and an IQ of 82. One had all three motor impairment scores below the 5th centile and an IQ of 94. Eleven had an IQ of 70–79. Eight GP controls had a mild outcome, one with motor impairment scores below the 5th centile and 7 with an IQ of 70–79.

Table 3 Overall outcome for cases divided by infecting bacterium

Bacterium	No of children	Outcome			
		Severe	Moderate	Mild	Normal
<i>Listeria</i>	13	7.7% (1)	–	15.4% (2)	76.9% (10)
Gram -ve	7	28.0% (2)	28.0% (2)	14.0% (1)	30% (2)
<i>E coli</i>	42	4.8% (2)	9.6% (4)	21.4% (9)	64.2% (27)
GBS	49	14.3% (7)	8.1% (4)	14.3% (7)	63.3% (31)

GBS, Group B streptococci.

Table 4 Major outcome characteristics

	Group		
	Cases	Hospital controls	GP controls
IQ	88.8 (85 to 92)*	99.4 (97 to 102)	99.6 (95 to 103)
mABC	7.1 (5.9 to 8.5)*	5.0 (4.3 to 5.8)	4.0 (2.9 to 5.4)
Seizures	5.4%	1.8%	–
Overall outcome			
Severe	10.8%*	–	–
Moderate	9%*	1.8%	–
Mild	17.1%	11.5%	16%
Normal	63.1%	86.7%	84%

Values for mABC and IQ are mean (95% confidence interval).

*Cases differ from significantly from controls (details in text).

IQ, Intelligence quotient; mABC, movement assessment battery for children; GP, general practitioner.

One index case had a considerable disparity between the performance and verbal IQ score (88 and 122 respectively). This did not fall into any impairment category, however.

Children were grouped as either moderate/severe or mild/normal for analysis. When analysed the cases had a significantly worse outcome than either GP controls ($p < 0.002$) or hospital controls ($p < 0.001$). There was no significant difference between the GP and hospital controls; however, the power calculation was less than desired in this comparison. Considering the different organisms (table 3), those with *E coli* did not differ significantly from those with GBS. There were too few Gram negative or *Listeria* cases to perform a statistical analysis.

The cases with a lower birth weight had a higher incidence of poor outcomes: 12% of > 2500 g infants, 31% of 1500–2499 g, and 44% of < 1500 g infants had a moderate to severe outcome ($p = 0.016$) (table 6).

Psychometric assessment

A total of 102 cases were fully tested. Six were too severely impaired to attempt the WISC test, and there were incomplete results on three children. Almost all (110) of the hospital controls were fully tested; three children had incomplete results. All 49 GP controls were tested.

The mean full scale IQ differed between cases and controls; details are shown in table 4 and by birth weight in table 6. In the regression model, 234 children had full data sets for analysis: 93 cases, 43 GP controls, and 98 hospital controls. The two parameters that significantly influenced the IQ were the group—that is, case, hospital control, or GP control ($p < 0.001$)—and the occupational class of the parents ($p < 0.001$). These were independent of each other. A model including gestational age had 232 children with full data and did not show any effect of gestation or alter the results of the larger model.

There was a corresponding significant difference between cases and controls for the verbal and performance IQ scores. There was no disparity between verbal and performance scores in either cases or controls.

Long term educational needs were estimated using the IQ scores. Sixteen index cases had an IQ of 70–80 (borderline learning difficulty), 15 had an IQ of < 70 (moderate learning difficulty or worse), a further six were not tested because of their degree of impairment, a total of 37 cases (33% of the cohort) possibly needing educational assistance. The figures for the hospital control IQs were 12 (IQ 70–80) and 1 (IQ < 70), 11.5% of the total. There were seven GP controls with an IQ 70–80 (14.3%).

Within the index cases, the birth weight, gestational age, and age at diagnosis did not significantly affect the IQ, although there was a non-significant trend towards a lower score with decreasing birth weight, which was more pronounced in cases than controls (table 6).

There was no significant difference in IQ between the *E coli* cases: IQ 87.9 (95% confidence interval (CI) 82.3 to 93.5) and the GBS cases: IQ 88.7 (95% CI 83 to 74.4) ($p = 0.106$). There were too few cases of *Listeria* and non-*E coli* Gram negative organisms to analyse.

Hearing outcome

One case had bilateral severe sensorineural hearing loss (0.9%), having been infected with *E coli*. One had severe unilateral sensorineural loss (non-*E coli* Gram negative), and one had moderate unilateral sensorineural loss (*Listeria*); a fourth required hearing aids but was not able to be tested because of learning difficulties. This made a total of 3.6%. There was no occurrence of sensorineural loss in either control group. Nineteen cases, 22 hospital controls, and nine GP controls were assessed on history, and were normal. Eight children had no reliable details on taking a history, none of whom showed evidence of impairment when seen by the examiner.

Vision

We did not test cortical or binocular vision, but visual acuity was tested. No significant differences were noted between cases and controls. Bilateral impairment of visual acuity was found in 17% of index cases, 18.5% of hospital controls, and 8% of GP controls, and unilateral impairment was found in 9.9%, 7%, and 4% respectively. We were unable to test six index cases because of their disabilities.

Motor outcome

Means and 95% CI for the mABC were 7.08 (5.89 to 8.49) for the cases, 5.00 (4.26 to 5.82) for the hospital controls, and 4.00 (2.90 to 5.42) for the GP controls.

There was a significant difference between the total impairment scores of the index cases and the hospital controls ($p = 0.001$) and GP controls ($p = 0.003$).

Birth weight had a slightly significant effect on the motor impairment score in the model ($p = 0.033$) which was independent of the effect of meningitis. The details in table 6 illustrate this effect on both cases and controls, but with the cases having a poorer score at all birth weights except for the very low birthweight infants. There were too few cases to analyse this subgroup further.

The relation between motor impairment and the age at which meningitis was contracted or the type of infecting microbe was not significant.

The Zurich score did not differ significantly between cases and controls in terms of the scores recorded. Observation of the children, however, showed that some had more obvious difficulty in performing the tasks. As we did not score the “elegance” with which the task was performed, we were unable to determine whether cases and controls differed in this respect.

Table 5 Details of impaired index cases

	Severity category	Organism	Sex	Type of paresis	IQ WISC-III ^{UK}	Motor impairment score max = 40 (mABC)	Cerebral palsy	Hydrocephalus	Sensorineural hearing loss	Fits	Other impairments
1	1	Listeria	F	Quad	73	38	3	Yes	No	–	
2	1	<i>E coli</i>	M	–	50	34	0	No	No	–	
3	1	<i>E coli</i>	F	–	53	33	0	No	No	–	
4	1	GBS	F	Quad	nm	nm	3	No	No		Absences
5	1	GBS	M	L Hemi	nm	Can throw	2	No	No		Tonic/clonic
6	1	GBS	F	L MoNo	47	28	1	No	No	–	
7	1	GBS	M	R Hemi	47	31.5	1	No	No		Tonic/clonic
8	1	GBS	F	Quad	nm	nm	3	No	No	–	
9	1	GBS	F	–	nm	nm	0	No	No	–	
10	1	GBS	F	–	49	23.5	0	No	No	–	
11	1	Gram -ve	M	–	nm	nm	0	No	No	–	Autism
12	1	Gram -ve	F	Quad	nm	Attempted	3	No	No	–	
13	2	<i>E coli</i>	M	–	96	16.5	0	No	Bilateral severe	–	
14	2	<i>E coli</i>	F	–	59	18.5	0	No	No	–	
15	2	<i>E coli</i>	M	–	68	7	0	No	No	–	
16	2	<i>E coli</i>	F	–	61	13.5	0	No	No	–	
17	2	GBS	F	L Hemi	59	38	1	No	No		Absences
18	2	GBS	F	–	64	18.5	0	No	No	–	
19	2	GBS	M	–	67	4	0	No	No	–	
20	2	GBS	F	–	65	16.5	0	No	No	–	
21	2	Gram -ve	M	L Hemi	59	40	0	No	Unilateral severe		Drop attacks
22	2	Gram -ve	M	–	59	12	0	No			Controlled
23	3	Listeria	F	–	77	23.5	0	Yes	No	–	Absent rt forearm
24	3	Listeria	M	–	66	10.5	0	No	Unilateral moderate	–	
25	3	GBS	F	–	87	4	0	Yes	No	–	
26	3	GBS	F	–	87	23 (<5th centile)	0	No	No	–	
27	3	GBS	F	–	73	23.5 (<5th centile)	0	No	No	–	
Others	3	9 <i>E coli</i> , 4 GBS, 1 Gram -ve with isolated IQ 70–79.									

Severity: 1=severe outcome; 2=moderate outcome; 3=mild outcome.

Cerebral palsy: 0=absent; 1=mild (no loss of function); 2=moderate (loss of function); 3=severe (severe loss of function or loss of several functions).

IQ, Intelligence quotient; WISC, Wechsler intelligence scale for children; mABC, movement assessment battery for children; GBS, Group B streptococci; nm, IQ or motor impairment not measured because of child's disability; Quad, quadriplegia; L, left; R, right; hemi, hemiplegia; MoNo, monoparesis.

Table 6 Main outcome measures stratified by birth weight and comparing cases with hospital controls

	Cases	Hospital controls
Infants of birth weight ≥ 2500 g	(n=73)	(n=79)
Birth weight mean (g)	3264 (434)	3220 (383)
Gest age median (weeks)	40 (38–40)	40 (39–40)
IQ mean	90.35 (17.8)	99.89 (15.0)
mABC score median	6.5 (3.5–12.5)	4.5 (2.6–7.5)
Mod/severe outcome	12%	2.5%
Infants of birth weight 1500–2499 g	(n=29)	(n=25)
Birth weight mean (g)	1997 (306)	1949 (318)
Gest age median (weeks)	33.6 (30.8–35.2)	33.8 (31.0–37.0)
IQ mean	82.74 (25.8)	99.16 (15.7)
mABC score median	7.5 (4.6–22.3)	6.25 (3.5–11.0)
Mod/severe outcome	31%	–
Infants of birth weight ≤ 1499 g	(n=9)	(n=9)
Birth weight mean (g)	1228 (179)	1218 (181)
Gest age median (weeks)	29 (28.0–30.2)	29 (28.0–29.5)
IQ mean	85.40 (25.8)	96.55 (11.4)
mABC score mean	9.3 (7.35)	10.5 (6.1)
Mod/severe outcome	44%	–

Standard deviation is shown for means and interquartile range for medians. GP controls not included as all were term and not low birth weight.

IQ, Intelligence quotient; mABC, movement assessment battery for children; GP, general practitioner.

Seizures

Six index cases (5.4%) had a seizure disorder, and two hospital controls had absence seizures controlled with anti-convulsants, one associated with a right mild hemiplegia. The case/control difference did not reach significance.

Hydrocephalus

There were three index cases with persisting hydrocephalus requiring a shunt. One had no detectable impairments, another had pronounced motor impairment which was thought to be due to the hydrocephalus being untreated during the first two years of life. The third had motor impairment from an unrelated problem (congenital forearm absence), associated with a performance IQ of 74, the verbal IQ being 86.

Other variables

Height, weight, head circumference, and blood pressure (systolic and diastolic) did not differ between the index cases or either group of controls.

Comparing the motor and cognitive score tests for the index cases, we showed that there was a tendency for the same children to be impaired in both motor and psychometric fields. The Pearson correlation coefficient for the WISC and mABC scores was $r = -0.51$ ($p = 0.01$) for cases, $r = -0.3$ for hospital controls ($p = 0.01$), and $r = -0.25$ ($p = 0.1$) for the GP controls. This correlation is not a strong one, but is more pronounced in those children who had meningitis.

DISCUSSION

Our study has addressed many of the problems associated with long term follow up of an uncommon disease.

The children studied are part of a cohort treated over a narrow time scale, and there are a sufficient number to draw statistically valid conclusions. We used standard assessment tools based on the population as a whole. The examination was performed at an age when cooperation could be obtained from the children and hence reliable scores gained from the particular tests used. The use of controls eliminated many confounders, particularly those related to prematurity. We restricted follow up to the commoner infecting organisms to avoid the possible confounding effects of rarer infections on the general picture.

Since the time of the acute disease in our cases, mortality has improved but not morbidity.^{15 16} It is not unreasonable to assume therefore that the nature of any persisting problems will be unchanged even if the numbers of children affected has changed.

We considered the outcomes in the particular skill areas tested as well as an overall composite outcome. The overall outcomes of our cases were significantly worse than either control group. The results are similar to several reported series between 1965 and 1991.^{2 3 7 8} Severe outcomes were noted in 9–15% of survivors with moderate but significant sequelae in approximately a further 10%. There was no appreciable temporal trend towards an improvement in outcome during this period. A more recent study of infants of less than 1500 g birth weight showed that 41% had major neurological sequelae.⁹ Our own figures confirm that the smaller infants represent a much more vulnerable group. This is reflected in the overall outcomes rather than in the motor and psychometric tests, as the more severely affected infants were unable to perform these tests. The meningitis nevertheless seems to add to sequelae reported for very low birthweight infants who did not have meningitis.^{17–20}

We showed a definite impairment in cognitive function. Owing to their small numbers, previous studies did not show the same degree of significance in the IQ impairment as our series. Some studies do show a quantifiable degree of intellectual impairment occurring in about a third of survivors,^{3–5 8} but others do not.⁷ The impaired children we reviewed, for the most part, were in the mild/normal category of overall outcome, yet because of cognitive impairment, they remain at risk of educational difficulties. The study of very low birthweight infants with meningitis showed a more pronounced degree of cognitive impairment.⁹ We saw too few cases in this category to perform a similar analysis.

We showed a significant quantifiable impairment in motor function, which existed even in some of the mildly affected cases. Gross motor function was slightly more affected than fine motor function in the mABC subtests. This has not been fully assessed in other series. Impairment in visual-motor integration has been noted in those with severe sequelae by one study, with other tests of fine motor function being normal. Gross motor function was not quantified in this study.⁷ Others have not quantified motor function to any degree in those children who are clinically normal.^{2 3 5 8}

Impairment has been shown in very low birthweight infants with meningitis,⁹ and there is a trend to a poorer motor outcome in our very low birthweight infants (table 6). However, this trend is also present, to a similar degree, in the matched controls.

In our study we performed a standard clinical neurological examination. It identified children with a specific neurological deficit such as hemiparesis but did not identify functional motor impairment. The lack of difference between cases and controls with the Zurich score may be because these movements were examined individually whereas in the mABC more integration of complex movements was required. These observations highlight the need for a formalised assessment of integrated motor function, with appropriate tools, if deficits are to be identified.

Our study showed no difference in motor, intellectual, or overall outcome between GBS and Gram negative cases. In the series reported by Franco *et al*,³ the cases of GBS did worse in cognitive terms than the Gram negative cases, although there were only 19 cases examined and there was no difference in overall outcome. In another study the Gram negative cases did worse.⁴

The other outcome measures such as sensorineural hearing loss, epilepsy, and hydrocephalus were also broadly in line with other studies. They fortunately seem to occur in a very small number of cases, but need to be considered in all survivors. As we were unable to formally test the hearing of each child, a few children with mild hearing loss may not have been identified, but it is unlikely that moderate to severe impairment will have been overlooked. Visual impairment was similar to that of hospital control infants. There may be an effect of prematurity, although there were too few children to analyse fully.

Our examinations did not include a behavioural or psychological assessment, neither were the actual educational performances of the children recorded. Our estimate of a third of cases requiring additional educational support, if added together with the motor problems documented, therefore may underestimate problems.

There are potential methodological problems in our study which would be present in many large studies.

We did not recruit many GP controls relative to the number of cases and number of hospital controls. There were, however, sufficient for statistical analysis. The similarity of the hospital controls to the GP controls in their outcomes strengthens the hypothesis that our cases were impaired primarily because of their meningitis and not just because of their prematurity.

The need to recruit some hospital controls from infants born at Queen Charlotte's Hospital, rather than the hospital of an index case, introduced a possible bias. The possible bias in occupational class has been controlled for within the statistical analysis. Other scores were not skewed by these controls—for example, mean IQ for hospital controls fell to 98.6 from 99.4 when they were not included. This change did not affect the overall analysis.

A number of children were lost to follow up. The acute data we held on these children did not allow us to estimate their outcome in order to have an idea of whether they would change our conclusions. However, we considered a follow up rate of 78% of those with contact details a good number in the context of a national cohort.

Despite the observed differences between the cases and controls, the vast majority of children were regarded as normal by their families. Their functional abilities usually remained within normal ranges although skewed towards the lower end. The 89% of children not in the severe category had a good quality of life. This should be borne in mind when counselling parents in the acute situation. It remains of concern, however, that the functional problems may become socially more significant as the children become older.

We have not been able to incorporate information into our results to estimate prognosis from the acute illness, as our data

were not sufficiently detailed. Other studies have been able to consider such data, and risk scores for outcome have been produced from historical results.¹⁰ Further prospective studies would be useful.

We can conclude therefore that about 10% of neonatal meningitis survivors will need significant multidisciplinary medical, social, and developmental follow up and treatment as a result of their severe outcome. A further 10–20% will require less significant but important input for mild to moderate problems. All survivors need initial screening for treatable medical conditions such as hydrocephalus or deafness. Comprehensive developmental assessment is needed before school entry, to identify less evident but important sequelae. A purely medical follow up is not an appropriate method of continuing care for the survivors of neonatal meningitis.

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Authors' affiliations

J P Stevens, University of Alberta, 3A3.43 Stollery Children's Hospital, Edmonton, Alberta T6G 2B7, Canada

M Eames, Public Health Intelligence, Bedfordshire and Hertfordshire Health Authority, Tonman House, St Albans, Herts AL1 3ER, UK

A Kent, Department of Clinical Psychology, Hammersmith Hospital, Du Cane Road, London W12 0NN, UK

S Halket, D Holt, Karim Centre for Meningitis Research, ICSM, Department of Paediatrics and Neonatal Medicine, Queen Charlotte's and Chelsea Hospital, Ducane Road, London W12 0NN, UK

D Harvey, Department of Paediatrics and Neonatal Medicine, Hammersmith Hospital, Du Cane Rd, London W12 0NN, UK

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