Risk factors for permanent childhood hearing impairment

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ABSTRACT

Objective: While several perinatal risk factors for permanent childhood hearing impairment (PCHI) are known, association with gestational length remains unclear. We hypothesised that shorter gestational length predicts higher PCHI risk.

Design: 19504 participants from UK Millennium Cohort Study (born 2000-2002, prior to newborn screening).

Methods: Multivariable discrete-time survival analysis to examine associations between parent-reported PCHI by age 11 years and gestational length, plus other pre-specified factors.

Results: PCHI affected 2.1 per 1000 children (95% CI: 1.5-3.0) by age 11, however gestational length did not predict PCHI risk (hazard ratio, 95% CI: 1.00, 0.98-1.03 per day increase). Risk was increased in those with neonatal illness, with or without admission to neonatal care (6.33, 2.27-17.63 and 2.62, 1.15-5.97, respectively), of Bangladeshi or Pakistani ethnicity (2.78, 1.06-7.31), or born to younger mothers (0.92, 0.87-0.97 per year).

Conclusion: Neonatal illness, rather than gestational length, predicts PCHI risk. Further research should explore associations with ethnicity.

INTRODUCTION

Accurate knowledge of permanent childhood hearing impairment (PCHI) incidence and risk factors is needed to inform universal newborn hearing screening (UNHS) policies, particularly for identification of high-risk children that require targeted surveillance or specialised screening. Joint Committee for Infant Hearing (JCIH) guidelines highlight several perinatal PCHI risk factors, including spending five or more days in NIC (neonatal intensive care or special care baby units).[1] Risk of PCHI is proposed to also be associated with other factors, including low birthweight, prenatal maternal smoking, maternal age, lower socio-economic status and south Asian ethnicity. These factors could either directly impact on auditory development or reflect proxy measures of suboptimal prenatal and perinatal conditions.

Shorter gestation length (a measure of prenatal and perinatal conditions) may predict PCHI risk and is currently used as an indicator of specialised screening in some UNHS programmes. However, current evidence on the association between PCHI and gestational length is inconclusive and mostly limited to high-risk samples with short follow-up.[2,3] Using data from a prospective UK-wide child cohort, we investigated whether shorter gestational length predicts PCHI risk by age 11 years, independently of other risk factors. We also investigated the independent associations of other pre-specified demographic and perinatal risk factors with PCHI.

METHODS

Study population

We included 19504 participants with available hearing data from the Millennium Cohort Study (MCS), a nationally representative UK sample of children born between September 2000 and January 2002 before UNHS implementation. Main-carer interviews were undertaken when children were aged 9 months, 3, 5, 7 and 11 years.

Outcome

We classified children as having PCHI if they exhibited all of the following:

1. Parent-reported hearing impairment that did not resolve by their final attended interview

2. Parent-reported treatment with a hearing aid or cochlear implant at one or more sweeps

3. No parent-reported glue ear at any sweep

PCHI could be of any severity or cause, and unilateral or bilateral.

Predictors

Gestational length was treated as a continuous variable and calculated in days, using information from hospital records if available, otherwise from maternal report. Implausible values (<168 or >301 days) or invalid responses were treated as missing.

Other early life predictors reported by main respondents included: child ethnicity (categorised using 2001 Census categories: White, Mixed, Indian, Pakistani/Bangladeshi, Black/Black British, or other); child sex; maternal age (years) at birth of the child, neonatal illness (none, present without NIC, or present with NIC); maternal report of prenatal smoking (yes or no); and birthweight (age- and sex-standardised z-score using UK 1990 standards and excluding values <5 or >5). Mother's highest educational qualification was treated as a time-varying covariate and categorised as per Table 1.

Statistical analysis

Univariable discrete-time survival analysis models were constructed to investigate predicted PCHI risk, followed by a multivariable model including all variables. We excluded children with missing predictor data in univariable and multivariable analyses. Sensitivity analyses included analyses treating gestational length as categorical and excluding children with glue ear (*n*=1184). Analyses were performed using Stata version 13 (Stata Corporation, Texas, USA), with sampling weights and adjustment of variance estimates for the stratified cluster-sampling design.

Ethics approval

Ethics approval was obtained for the original cohort study.

RESULTS

Study sample

The study sample comprised 19504 children (10011 boys, 15977 white), 1785 of whom had been admitted to NIC and 6702 exposed to prenatal maternal smoking (Table 1). Geometric mean gestational length was 39 weeks (95% confidence interval [CI]: 39-39 weeks) and mean birthweight z-score 0.0 (standard deviation [SD]: 1.0). Most mothers were educated to NVQ level 2 or higher (*n*=14805). Mean maternal age at birth was 28 (SD: 6) years.

PCHI incidence

By age 11 years, 44 children met the study PCHI case definition (Table 1), giving a cumulative PCHI incidence of 2.1 (95% CI: 1.5-3.0) per 1000 children. Risk of PCHI onset was highest by 9 months of age (*n*=18, 40% of PCHI conditions identified by this age), but persisted throughout childhood.

Risk factors for PCHI

Shorter gestational length, whether treated as continuous or categorical, did not predict increased PCHI risk. Higher PCHI risk by age 11 years was independently predicted by neonatal illness with or without NIC, younger maternal age at birth, and being of Pakistani or Bangladeshi ethnicity (Table 2).

DISCUSSION

Key findings

Risk of PCHI was highest between birth and age 9 months, and continued throughout early childhood. Our findings suggest that gestational length is not an independent predictor of PCHI risk, whereas experiencing neonatal illness with or without NIC admission, being of Pakistani or Bangladeshi ethnicity, or being born to a younger mother were. These findings are generalisable to the UK child population born before UNHS implementation.

Strengths and limitations

A key strength of our study is the use of data from a large prospective population-based cohort study with repeated questions on ear or hearing problems rather than a selective sample of preterm or low birthweight babies. We used robust statistical methods to account for multiple covariates, including time-varying covariates, and adjust for sample attrition. Gestational length was available from hospital records in most children and maternal report was deemed to be accurate to within 1 week for children without hospital records.

Limitations were that we relied on parental report rather than objectively measured HI, though we included treatment in the case definition to reduce misclassification. Although audiometric measures and information about aetiology would have allowed more accurate classification, these were not available for the cohort. Additionally, the small number of children with PCHI limited statistical power.

Interpretation

Our estimate of PCHI incidence over the first 11 years of life is comparable to similar studies in Australia,[4] and provides further information on early and persisting risk of PCHI across childhood. Our findings exclude gestational length as a predictor of PCHI, and identify neonatal illness, maternal age and ethnicity as important predictors in a mutually adjusted model.

Neonatal illness and admission to NIC are recognised predictors of PCHI, potentially mediated through infections, hyperbilirubinaemia, hypoxia, or exposure to ototoxic drugs.[1] We were unable to explore assocations with duration of NIC admission or other specific JCIH risk factors as this information was not available. Although it has been suggested that consanguinity may be one factor contributing to PCHI risk in British Bangladeshi childen, we did not have information on this and the causal mechanisms associating ethnicity and maternal age with PCHI require further investigation.[5]

IMPLICATIONS AND CONCLUSION

Our findings suggest that gestational length does not predict PCHI risk and underline the importance of neonatal illness, as well as ethnicity and younger maternal age. As UNHS was introduced after the birth of this cohort, age at PCHI onset in this study may not reflect current patterns in age at diagnosis. However, our findings highlight that risk of PCHI persists throughout childhood, providing support for continued vigilance and monitoring after the newborn period. Further research is required to explain the specific causal mechanisms underlying the association of PCHI with ethnicity, maternal age and neonatal illness.

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9 months: http://dx.doi.org/10.5255/UKDA-SN-4683-3;

3 years: http://dx.doi.org/10.5255/UKDA-SN-5350-3

5 years: http://dx.doi.org/10.5255/UKDA-SN-5795-3

7 years: http://dx.doi.org/10.5255/UKDA-SN-6411-5

11 years: http://dx.doi.org/10.5255/UKDA-SN-7464-2

CONTRIBUTORS
All authors contributed to the study conception and the analytic plan. EB designed and conducted the analyses, and wrote the first draft of the paper. All authors interpreted the results and implications, commented on the manuscript at all stages, and approved the final submitted version.

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COMPETING INTERESTS
None to declare.

DATA SHARING STATEMENT

This study uses data from the Millennium Cohort Study, which is available on the UK Data Archive.

WHAT IS ALREADY KNOWN ON THIS SUBJECT?

Permanent childhood hearing impairment (PCHI) risk is increased among children exposed to adverse perinatal events.

The association between PCHI and shorter gestational length remains unclear.

WHAT THIS STUDY ADDS?

PCHI risk is not predicted by shorter gestational length.

Children of Pakistani or Bangladeshi ethnicity or born to younger mothers are at increased risk of PCHI.

REFERENCES

1. JCIH. Year 2007 position statement: Principles and guidelines for early hearing detection and intervention programs. *Pediatrics* 2007;120(4):898-921. doi: 10.1542/peds.2007-2333
2. van Dommelen P, Verkerk PH, Van Straaten HL, et al. Hearing loss by week of gestation and birth weight in very preterm neonates. *The Journal of Pediatrics* 2015;166(4):840-43. e1.
3. Moore T, Hennessy EM, Myles J, et al. Neurological and developmental outcome in extremely preterm children born in England in 1995 and 2006: the EPICure studies. *BMJ (Clinical Research Ed)* 2012; 345: e7961. doi: 10.1136/bmj.e7961 [published Online First: 2012/12/06]
4. Russ SA, Poulakis Z, Barker M, et al. Epidemiology of congenital hearing loss in Victoria, Australia. *International Journal of Audiology* 2003; 42(7): 385-90.
5. Bajaj Y, Sirimanna T, Albert DM, et al. Causes of deafness in British Bangladeshi children: a prevalence twice that of the UK population cannot be accounted for by consanguinity alone. *Clinical Otolaryngology:* 2009; 34(2): 113-9. doi: 10.1111/j.1749-4486.2009.01888.x

TABLES

Table 1. Characteristics of children with or without PCHI by age 11 years

	Children with PCHI, *n*=44	**Children without PCHI, *n*=19460**
Mean gestational length, weeks (95% CI)*	38.7 (37.4-40.0)	39.3 (39.2-39.3)
Missing (n)	3	941
Mean birthweight, z-score (95% CI)	-0.2 (-0.5-0.2)	0.0 (0.0-0.0)
Missing (n)	3	941
Sex (n, %)		
Male	22 (47.5)	9989 (51.3)
Female	22 (52.5)	9471 (48.7)
Missing	0	0
Ethnicity (n, %)		
White	29 (76.9)	15948 (87.3)
Mixed	<5	601 (3.2)
Indian	<5	500 (1.8)
Pakistani or Bangladeshi	9 (12.1)	1348 (3.9)
Black or Black British	<5	740 (2.7)
Other	0	305 (1.2)
Missing	0	18
NIC admission (n, %)		
No neonatal/perinatal illness	13 (27.2)	10229 (52.5)
Neonatal/perinatal illness without NIC admission	16 (45.5)	6764 (38.0)
Neonatal/perinatal illness with NIC admission	12 (27.3)	1773 (9.5)
Missing	3	694
Maternal prenatal smoking (n, %)		
Non-smoking	28 (73.9)	12017 (65.9)
Smoking	13 (26.1)	6687 (34.1)
Missing	3	756
Highest maternal education level by end of follow-up (n, %)		
NVQ level 1, equivalent to leaving school <16 years	<5	1395 (7.0)
NVQ level 2, equivalent to age-16 leaving school	11 (28.4)	4968 (26.0)
NVQ level 3, equivalent to age-18 leaving school	<5	2808 (14.6)
NVQ level 4, equivalent to university education	10 (27.4)	5498 (31.8)
NVQ level 5 (highest), equivalent to university education including postgraduate qualifications	5 (15.9)	1448 (8.2)
Other	12 (19.4)	3225 (12.4)
Missing	0	118
Mean maternal age at cohort child's birth, years (95% CI)*	26.5 (24.9-28.1)	28.9 (28.7-29.1)
Missing	0	96

CI: confidence intervals; NIC: neonatal care unit including neonatal intensive care & special care baby unit; NVQ: national vocational qualifications; PCHI: permanent childhood hearing impairment. Percentages are adjusted for sample design.
*Geometric mean after natural log transformation

Table 2. Discrete-time survival analysis for risk of PCHI up to age 11 years

	Univariable analysis, HR (95% CI)	Multivariable analysis, HR (95% CI)
Gestational length, per day	0.99 (0.96-1.01)	1.00 (0.98-1.03)
Birthweight, per unit z score	0.84 (0.59-1.20)	0.95 (0.72-1.24)
Ethnicity*		
White	Reference	Reference
Mixed	0.66 (0.17-2.50)	0.38 (0.06-2.59)
Indian	3.74 (0.68-20.73)	3.56 (0.58-21.71)
Pakistani or Bangladeshi	3.67 (1.59-8.48)	2.78 (1.06-7.31)
Black or Black British	1.58 (0.38-6.68)	2.04 (0.42-9.97)
Maternal education level		
NVQ level 1 or equivalent	Reference	Reference
NVQ level 2 or equivalent	1.19 (0.35-4.08)	1.23 (0.35-4.38)
NVQ level 3 or equivalent	0.13 (0.01-1.07)	0.13 (0.01-1.14)
NVQ level 4 or equivalent	1.00 (0.29-3.48)	0.98 (0.23-4.12)
NVQ level 5 or equivalent	1.07 (0.14-7.97)	1.32 (0.16-10.87)
Other	1.78 (0.50-6.34)	1.61 (0.44-5.94)
Maternal age at birth, per year increase	0.93 (0.89-0.97)	0.92 (0.87-0.97)
Maternal report of smoking before or during pregnancy	0.71 (0.32-1.57)	0.57 (0.23-1.42)
Neonatal illness and/or NIC admission		
No neonatal/perinatal illness	Reference	Reference
Neonatal/perinatal illness without NIC admission	2.30 (0.96-5.52)	2.62 (1.15-5.97)
Neonatal/perinatal illness with NIC admission	5.51 (2.16-14.08)	6.33 (2.27-17.63)
Female sex	1.15 (0.57-2.33)	1.12 (0.54-2.31)

HR: hazard ratio; NIC: neonatal care unit including neonatal intensive care and special care baby units; NVQ: national vocational qualifications; PCHI: permanent childhood hearing impairment. HRs adjusted for sample design. *no children with PCHI were of the 'other' ethnicity so HRs could not be calculated. Analyses exclude children with missing predictor data for the relevant variables included in each model.