Visual disability in childhood: findings from the national observational study of British childhood visual impairment and blindness (BCVIS2)

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Abstract

Background

The WHO's *Vision 2020* global initiative against blindness, launched in 2000, prioritises children. Progress has been hampered by the global paucity of epidemiological data about childhood visual disability. The British Childhood Visual Impairment and Blindness Study 2 (BCVIS2) was undertaken to address this evidence gap.

Methods

UK-wide prospective population-based observational study of all those aged under 18 years newly diagnosed with visual impairment or blindness between Oct 1, 2015 and Nov 1 2016. Eligible children were notified simultaneously but independently by their managing ophthalmologists and paediatricians via the two national active surveillance schemes, the British Ophthalmic and Paediatric Surveillance Units. Standardised detailed data were collected at diagnosis and one year later. Incidence estimates and relative rates by key sociodemographic factors were calculated. Descriptive analyses were undertaken of underlying ophthalmic disorders and non-ophthalmic comorbidities.

Findings

Of 784 cases, 72% had additional non-ophthalmic impairments/disorders and 4% died within the year. Annual incidence was highest in the first year of life, 5·2 per 10,000 (95% CI 4·7-5·7) with cumulative incidence by 18 years of 10·0 per 10,000 (95% CI 9·4 to 10·8). Rates were higher for those from any ethnic minority group, the lowest quintile of socio-economic status, born preterm or with low birthweight. Only 44% had a single ophthalmic condition: disorders of the brain/visual pathways affected 48% overall. Prenatal or perinatal aetiological factors accounted for 84% of all conditions.

Interpretation

BCVIS2 provides a contemporary snapshot of the heterogeneity, multi-morbidity and vulnerability associated with childhood visual disability in a high income country, and the arising complex needs. These findings will facilitate developing and delivering healthcare and planning interventional research. They highlight the importance of including childhood visual disability as a sentinel event and metric in global child health initiatives.

Funding

Fight for Sight, National Institute for Health Research, Ulverscroft Foundation.

Introduction

Most people intuitively recognise the potentially profound impact of losing one's eyesight in adult life.[1,2] Few will have given thought to being born or growing up with impaired vision. An expanding literature is revealing the vital importance of normal vision to all aspects of child development[3] at a time when optimising early childhood development, particularly as the foundation of adult health and well-being, is a global priority.[4] There is also growing recognition of the diverse and deep potential impact of impaired vision on physical and mental health, quality of life, and social outcomes of the affected child and the adult she becomes.[3,5,6]

Childhood-onset visual disability arguably confers a greater burden than adult-onset visual impairment (mainly occurring in late adult life), in terms of 'years of sighted life' lost and associated financial and opportunity costs of care and loss of potential productivity.[7] Childhood visual disability was prioritised in '*VISION 2020*'[8] the World Health Organisation's global initiative to eliminate avoidable blindness by 2020. However, as recognised in the WHO's 'Universal Eye Health' Global Action Plan,[9] progress has been hampered by the global paucity of robust epidemiological intelligence about childhood visual disability to inform primary, secondary or tertiary preventive health care, policies and strategies. The British Childhood Visual Impairment and Blindness Study (BCVIS)[10] was undertaken in 2000, as *Vision 2020* launched, to address this evidence gap for the United Kingdom *per se* and as an example of an industrialised country setting. It employed national active surveillance methods for the first time in this arena, to understand the epidemiology of childhood *blindness,* the 'tip of the iceberg' of the full spectrum of impaired vision. In response to the continuing lack of alternative data sources to inform planning and provision of services and policies, we built on the proof of methods and the national collaborative

research network that enabled us to undertake that study, to carry out the research reported here, the BCVIS2 - a national epidemiological study of incident childhood *full-spectrum* visual disability (ie spanning visual impairment to blindness), characterising this population and identifying their specific needs within the broader context of child health.

Methods

Study design

A prospective UK-wide, cross-sectional study establishing an inception cohort of newly diagnosed children.

Case definition / Eligibility criteria

Any child/young person aged ≤18 years and newly diagnosed with any condition causing impaired acuity to a level of 0·50 LogMAR or worse (worse than 6/18 Snellen) in each eye, or equivalent vision as assessed by standard qualitative measures.[10,11]

Within ICD 10, visual impairment (VI) comprises acuity between 0·5 and 1·0 (6/19 to 6/60 Snellen) and severe visual impairment/blindness (SVI/BL) comprises a narrower range of acuity of 1·01 LogMAR or worse, including no perception of light. As a benchmark, in the UK the minimum threshold for a standard driving licence is 0·3 LogMAR (6/12 Snellen), and 0·5 LogMAR is a conventional threshold for anticipating additional educational support such as low vision aids or large print.

Case ascertainment

In the UK multidisciplinary assessment of children newly diagnosed as visually impaired/blind is recommended,[12] and a proportion of children will first present to a

paediatrician.[10] Therefore to maximise ascertainment of eligible cases *and* completeness of data collection, eligible children were identified simultaneously but independently, through the two long-standing national active surveillance schemes in the UK for research on rare conditions in ophthalmology and in paediatrics, the British Ophthalmological Surveillance Unit (BOSU) and the British Paediatric Surveillance Unit, respectively. In both schemes, comprising **all** UK consultant/'attending' ophthalmologists (ie general and specialist paediatric) and paediatricians, respectively, reporting clinicians use a monthly reporting card to either notify any new cases *or* confirm they have no cases to report. Despite the overarching recommendation, in practice, children with the most severe impairment (SVI/BL) usually see a paediatrician around the time of diagnosis, but those with less severe impairment (VI) may not. Thus ophthalmologists reported all eligible children (VI/SVI/BL) and paediatricians reported those with SVI/BL. Cases were ascertained in a 12 month period ending 1st November 2016 with follow-up data collection completed into 2018.

Data collection

Data were collected at diagnosis and one year later using standardised proformas developed with our multi-disciplinary clinical research network, the British Childhood Visual Impairment and Blindness Study Group (BCVISG). Data collected at diagnosis comprised: sociodemographic characteristics (age, sex, ethnicity and family postcode/zipcode) alongside detailed ophthalmic and systemic clinical information using ICD-10 definitions, and information about early management comprising diagnostic tests and treatments. The disorders/condition(s) causing VI/SVI/BL were categorised using the modified WHO dual taxonomy we used previously[10] i.e. by both anatomical site(s) affected and aetiological factors (by timing

of action). Identifiers were used to match cases, exclude duplicate reports, and merge data obtained through both sources. Follow-up data were used to review/confirm eligibility, including confirmation that the visual disability was permanent, and collect additional information about management and outcomes. This included status with respect to certification of sight impairment, the process by which individuals visual impairment are offered inclusion in their local social care register to assist in accessing support and Governmental financial assistance.[13] .All incoming data returned by the managing consultant (attending) clinician were reviewed for completeness by a senior ophthalmologist (ALS). Reporting clinicians were contacted about missing data or for clarification, as required.

The UK Health Research Authority (ref 14/LO/1809) approved the study, with Section 251 exemption from individual consent for use of data from the UK Confidentiality Advisory Group on the grounds of Public Interest.

Statistical Analysis

Children were grouped by age at diagnosis of VI/SVI/BL (<1yr, 1-4y, 5-9y,10-15y 16-18y), and also by absence/presence of other significant non-ophthalmic impairments or conditions, referred to as VI/SVI/BL *'isolated' or 'plus'* respectively for brevity hereafter. Socioeconomic status was categorised using the Index of Multiple Deprivation (IMD), the standard UK measure derived from postal (zip) code[14], with the 'lowest' quintile comprising the most deprived group. Child population at risk denominators were obtained from the UK Office of National Statistics (2016). Descriptive analyses are presented as frequencies and proportions (%). Cumulative incidence (risk) and annual age-group specific incidence (rate) of *permanent* VI/SVI/BL (i.e. confirmed at follow up), with 95% confidence intervals, were

calculated using person-time analysis (Breslow and Day).[15] The denominator for the youngest age-group (under the age of 1 year) was total number of live births.[16] Data were analysed using STATA statistical software (version 14·2, StataCorp LLC, College Station Texas). P ≤0·05 was considered to be statistically significant.

Role of the funding source

The study funders had no role in study design, data collection, data analysis, data interpretation, or writing of the report. LT, ALS and JSR had full access to all study data. JSR had final responsibility for the decision to submit for publication.

Results

Study sample

Of 845 eligible children initially notified, 61 children were ineligible at follow up due to improved vision after treatment. Thus the study sample comprised 784 children with permanent newly-diagnosed all-cause VI/SVI/BL.

Despite the surveillance schemes being independent, some ophthalmologists and paediatricians collaborated. This improved data completeness and quality but precluded use of capture-recapture analysis to estimate completeness of ascertainment of the subset of SVI/BL cases. No alternative data source existed for capture-recapture analysis of VI cases. Due to missing data for some sociodemographic variables, denominators are reported individually.

Socio-demographic characteristics

55% (427/783) of all children were boys, 63% (437/689) were White, and 34% (264/772) were from the most deprived quintile for IMD score. Fifty-two (7%) were

twins and two children (0·3%) were from triplet births, proportions that are 4·7 and 12 fold higher than the proportion of twin and triplet maternities in the U.K[16] respectively in the study year.

Multi-morbidity

72% (559/778) children had significant non-ophthalmic impairments or conditions i.e. childhood visual disability 'plus'.

Mortality

Twenty eight (4%) of all children died within the year after diagnosis of visual disability - all had underlying systemic disorders. A quarter of these were infants – an 'infant mortality rate' for children with VI/SVI/BL of 17·4 per 1000 infants (95% CI: 8·3-36·5) whilst the overall national infant mortality rate (2018) of 3.8/1000.[17]

Incidence

Table 1 shows that 51% of all children (54% 'plus', 45% 'isolated') were diagnosed in the first year of life, with only 23% diagnosed after five years of age. Incidence of visual disability in the first year of life was 5·19 per 10,000 (95% CI 4·71-5·72), at least ten-fold higher than in any other age-group. Variation in incidence by age-group was similar for the two subpopulations with "isolated" and "plus" VI/SVI/BL. Overall cumulative incidence (or 'lifetime' risk) increased from 5·19 per 10,000 by age 1 year to 10·02 per 10,000 (95% CI 9·35-10·76). The cumulative incidence of visual disability 'plus' was considerably higher (7·15/10,000) than of 'isolated' (2·8/10,000).

One year after diagnosis, 644 (82%) of children had been certified as sight impaired/severely sight impaired. Certification had been deferred by the health professionals or the parents in the majority of the remaining children.

Variations in incidence by key socio-demographic factors

Incidence rates varied significantly by key sociodemographic factors potentially related to early life adversity (Table 2). Children from any ethnic minority group, and notably South Asians, had significantly higher rates than White children. Incidence increased with decreasing socio-economic status. There were gradients of increasing incidence with decreasing gestational age and with lower birthweight.

Disorder(s) causing VI/SVI/BL

Only 44% (345) of children had a single 'anatomical site' affected: 37% (288) had two and 19% (151) three or more. The specific disorders are shown in Table 3. Disorders of the brain and visual pathways (a heterogeneous group of conditions grouped under the umbrella term of cerebral visual impairment, CVI,) affected 48% of all children. Disorders of the retina, mainly hereditary retinal dystrophies and albinism affected 37% - including 4% (31) of children with retinopathy of prematurity, of whom 52% (16) also had CVI. Disorders of the optic nerve affected 28% of children, predominantly optic nerve hypoplasia and optic atrophy.

There were striking differences in the relative importance of different anatomical sites between the two subpopulations of children with 'plus' and 'isolated' visual disability, for example visual pathways and cortex accounting for 64% versus 8% respectively, as shown in Figure 1.

Aetiological factors causing VI/SVI/BL

The underlying aetiological factors (where known) are shown in Table 4. Factors 'acting' prenatally accounted for 70% of all cases (Figure 2.). Specifically, known hereditary conditions affected 62% of children. The relative importance of hereditary factors varied somewhat by ethnicity, affecting 65% of South Asian (Pakistani, Bangladeshi or Indian) compared to 54% of White children (difference 11% [p=0·01, 95% CI: 3 to 20]) and 56% of Black, 50% of mixed ethnicity and 68% of other ethnic groups.

Non-ophthalmic disorders or impairments associated with VI/SVI/BL

Table 5 shows the diverse significant impairments and major non-ophthalmic conditions affecting 72% children. Overall 13% had hearing and 21% had speech and language impairments.

Discussion

We report the first national population-based epidemiological study of incident **full-spectrum** all-cause childhood visual disability. Although the underlying disorders are uncommon, the cumulative incidence (lifetime risk) of all-cause childhood visual disability is at least 10 per 10,000 by 18 years. Half of all children are affected from birth or during infancy. Incidence is strikingly higher amongst those from socio-economically disadvantaged backgrounds, any ethnic minority group and those born preterm or with low birthweight. Almost three quarters have significant additional impairments or disorders and the distributions of underlying disorders and aetiological factors in this group differs significantly from those with 'isolated' childhood visual disability. Overall, disorders of the brain and visual pathways (collectively "cerebral visual impairment") account for almost half of all childhood

visual disability. Amongst known aetiological factors, genetic or environmental influences acting prenatally or in the perinatal/neonatal periods predominate. The striking complexity and heterogeneity of visual disability illustrates a constellation of complex needs, underlined by the high proportion of children dying within the year following diagnosis.

We used the well-established national active surveillance schemes in ophthalmology and paediatrics in the UK, to identify a representative study sample. Ascertainment was maximised by implementing the study through the BCVISG, established initially in 2000 and now comprising over 150 paediatric ophthalmologists and paediatricians. Given extant national guidance[12], it is highly unlikely that eligible children were managed by clinicians not in the BCVISG. In the absence of any alternative, equivalent and independent data source, formal estimation of ascertainment using capture-recapture analysis was not possible. However a larger number of children with incident SVI/BL *specifically* were ascertained than in BCVIS[10] in 2000, supporting high ascertainment. Moreover the cumulative incidence estimate of VI/SVI/BL is considerably higher than the most recent estimate of sight impairment certification rates.[13] Nevertheless we report *minimum* estimates of incidence of childhood visual disability in the UK. There were low levels of missing data, apart from about birthweight and gestation and for both these variables the gradient ('dose response') of relative rates is plausible and consistent with the disorders observed. Thus findings regarding groups with highest rates, disorders causing impaired vision and aetiological patterns are unlikely to be biased. As this is a study of all-cause visual disability ie an outcome rather than a study of any individual disorders. Since this outcome reflects both risk of disorder per se as well as risk of worse outcome in both eyes, and since all children with the same

conditions but resulting in unilateral disease or with mild/visual impairment were not eligible for the study, and there are no 'controls' ie children without any eye disease, multivariable analysis to estimate the role and contribution of potential 'risk factors' is not appropriate. We do appropriately report estimations of relative rates where population denominators are available.

There are no studies of **full-spectrum** (encompassing visual impairment, severe visual impairment and blindness) all-cause incident childhood disability with which we can compare *directly* our findings. As described earlier, we previously conducted what remains the only national study of incident severe visual impairment and blindness in 2000[10] ie a subgroup of the population studied in BCVIS2**,** direct comparisons of incidence or causes is not appropriate, given the significantly different eligibility. It is also not possible to compare directly our findings about *incident* childhood visual disability with studies of prevalent visual disability[18,19], given the populations studied in the latter reflect both survival/mortality and cohort effects in underlying risk factors. Our study was necessary precisely because of this paucity of contemporary data required to characterise this population and provide a baseline for future monitoring and as the basis for developing and evaluating policies and services to meet their health needs. However 'counting' - in the form of certification - of sight impairment has a long history in Britain[13] as in some other high income countries. These systems were implemented primarily to address unmet social care and educational needs by 'flagging' affected individuals to relevant services, and therefore sit 'outside' and unconnected to generic health information systems. Even in settings with well-established universal health and social care provision and comprehensive health information systems, the impressive national level linking of administrative, social care and health care data excludes the registers of visual

impairment.[20] Given its purpose, certification in the UK is influenced by the perceived needs of the child, evidenced by an increasing certification of children with impaired visual *processing* rather than impaired visual function (acuity or visual fields), to facilitate appropriate educational support.[13] Additionally, certification requires attribution to *one* ophthalmic disorder and no additional information, for example about non-ophthalmic conditions, is collected which our study shows is inappropriate for children. Recent improvements in the British system relevant to children include adoption of the adapted WHO taxonomy for disorders used in the present study (developed for BCVIS[10]) and inclusion of offer of certification to eligible individuals as part of quality standards for paediatric ophthalmologists.[12] Unlike adults, childhood certification rates are not a Public Health England indicator.[21] Some of these recent changes may account for the higher proportion of children certified within a year of diagnosis in BCVIS2 than in 2000.[10] Nevertheless, 'counting' childhood visual disability in isolation is not enough: our findings illustrate the need for health intelligence that permits 'understanding' in the context of child health.

The socio-demographic patterning, multi-morbidity, long-term complex care needs and truncated life expectancy observed in BCVIS2 identify that childhood visual disability epitomises all the challenges to child health articulated in recent influential national and international child health initiatives and policies.[4] Why then, rather than being an exemplar for developing models for '*investing in children's health for lifelong intergenerational and economic benefits',*[4] is consideration of visual disability lacking in the key strategic documents? We suggest this is attributable to three factors. Firstly, the lack of data necessary to understand the specific needs of this population: for example, children with visual disability are distributed throughout the analysis of mortality and each category of morbidity (communicable conditions, non-

communicable conditions and injuries) in children and adolescence in the Global Burden of Diseases Injuries and Risk Factors 2017 Study[22] and are subsumed within the under 50 years group in the WHO's global vision database.[23] Secondly, the inadvertent 'sequestering' of children with visual impairment away from the 'lens' of child health by virtue of clinical management sitting within specialist ophthalmology/eye care services. Thirdly, the paradox that the potential impact of visual impairment is so self-evident as to be overlooked in most child health research.[22] The findings of our study address some of these gaps. We suggest that they also identify the value of inclusion of visual disability as a 'sentinel' (ie key health of the population indicator) child health event, and 'target condition' in national and international child health research as well as strategies and policies.

The WHO-UNICEF-Lancet commission "*A Future for the World Children*" rightly articulates the vital importance of optimising early childhood in a life course perspective of human development.[4] Since Nobel prize-winning research on vision was instrumental to our current understanding of brain plasticity and neurogenesis,[24] it is regrettable that vision impairment has only recently been acknowledged to be a 'developmental emergency'.[3] This ill serves children with visual disability, of whom half, according to our study, are affected from birth or during the first year of life. Although multidisciplinary assessment of children newly diagnosed with visual impairment is advocated,[12] practices and provision of vision-specific developmental support vary substantially, possibly reflecting structural boundaries between clinical specialties and primary and secondary/tertiary healthcare. The UK National Health Service Long Term Plan[25] makes ambitious pledges to children's health but the sole commitment relating to vision is to 'eyesight' services (comprising specialist optometric/optician assessment) for children with learning disabilities. Whilst

welcome, our study shows this is relevant to around a fifth of all children with visual disability, and does not address the significant wider multi-morbidity evidenced by BCVIS2.

The associations of all-cause childhood visual disability with socio-economic disadvantage and ethnic minority status observed in our study reflect differences in risk of specific conditions and/or access to health services and/or outcomes of treatment. Nevertheless these variations amplify the growing awareness of inequalities in childhood visual health - important in their own right and as the basis for inequalities in adult life visual health[6] – and closely mirroring inequalities in other domains of child health. Since these disparities exist in the UK despite the universal, publicly funded, cost-free at the point of use health care system in a high income country, they can be reasonably assumed to exist elsewhere. As such, widening of visual health inequalities can be anticipated as part of the aftermath of the COVID-19 pandemic on children's health and well-being[26]. Globally, the key child healthcare impact indicators are the under-five childhood mortality (U5MR) and stunted growth rates. Given our findings and prior evidence that prevalence of childhood vision impairment aligns with U5MR, we suggest that childhood visual disability could be usefully used as a sensitive and meaningful metric of the effectiveness of all policies and programmes to reduce child health inequalities, particularly in neurodevelopmental outcomes.[4,9]

The observed relative importance of different disorders in BCVIS2 reflects an evolution over time. A decline in preventable conditions, such as corneal scarring due to ophthalmia neonatorum and preventable prenatal infections such as rubella,

occurred in tandem with improved outcomes through screening and treatment for key disorders such as retinopathy of prematurity and congenital cataract.[27,28]

The predominance of disorders affecting the brain and visual pathways (CVI) broadly echoes reports from other sources in similar settings.[18,19] Some of this is attributable to neonatal encephalopathy due to birth trauma or hypoxia, recognised to be a growing issue,[22] underlining the value of including vision outcomes in interventional research in this area. Equally, the significantly increased rate of childhood visual disability amongst those born preterm in the present study illustrates the importance of visual disability as a key metric in the substantial global efforts to prevent poor outcomes for the more than 1 in 10 children who are 'born too soon' globally.[29]

Finally, the observed contribution of congenital ocular anomalies echoes their importance in child health. Together these findings illustrate that effective interventions to reduce the current burden of childhood visual disability in the UK and similar populations are most likely to emerge by interfacing better ophthalmology and paediatrics.

To better identify priorities and develop and implement integrated national eye health policies, plans and programmes, there is a need to think more radically and consider new models of integrated 'live' registers of childhood visual disability through clinician-patient/family partnerships. The ideal model would comprise a register able to 'pull through' and 'push out' the key high fidelity data from health, education and social care. The promise of the transformational changes in health care through implementation of electronic medical records has yet to be fully realised but certainly offers a means of ensuring health information is both complete and up-to-date, capturing key information from all clinical specialties. Importantly, such a new model could also capture the perspectives of children and young people and their families,

including through the use of vision patient reported outcome measures (PROMs) as these become integrated into routine clinical practice,[30] to enhance their value in affording opportunities for health economics analyses.

The BCVIS2 provides a contemporary snapshot of childhood visual disability in a high income country useful for developing and delivering healthcare and health policies and for planning interventional research. The longitudinal investigation underway of clinical, social and educational outcomes of this unique inception cohort will afford further novel insights. But this study has already demonstrated that childhood visual disability is a marker of significant vulnerability and should now be considered as a sentinel child health event. This requires a paradigm shift from the current model of exceptionalism created by health service structures and clinical boundaries. Without this childhood visual disability will remain simultaneously self-evidently important but invisible in national and international monitoring processes and thus absent in our global ambitions for the future of children.[4]

Research in context

Evidence before this study

The World Health Organisation's 'Universal Eye Health' Global Action Plan articulates the global paucity of epidemiological data on childhood visual disability which has resulted in children being subsumed within the subgroup of people aged under 50 years in its WHO's global vision database. Thus data are lacking for planning primary, secondary and tertiary preventive strategies.

Our search (key words child*, vis* impairment, blind*) of bibliographic databases (PUBMED, EMBASE) for papers in any language published up to the start of study in 2015 did not identify any national population-based epidemiological studies of incident full-spectrum childhood visual disability. The British Childhood Visual Impairment and Blindness Study (BCVIS), undertaken in 2000 investigated solely the epidemiology of childhood *blindness*, the subgroup at the worst end of the full spectrum of visual disability.

Added value of this study

This study provides annual age-specific and cumulative incidence of all-cause full-spectrum childhood visual disability in a high income country setting and demonstrates variations in incidence by key sociodemographic metrics of disadvantage and early life adversity. The predominance of aetiological factors operating prenatally or perinatally is demonstrated. The underlying ophthalmic conditions, two or more in most children, are described. The complex multi-morbidity, comprising diverse non-ophthalmic impairments/disorders experienced by this vulnerable population is described, including truncated life expectancy.

Implications of all the available evidence

The findings of this study should aid planning, implementation and evaluation of clinical and public health services and health policies. Progress in reducing the burden of childhood visual disability will require better integration of visual disability into child health strategies and policies. This would be facilitated by considering visual disability a sentinel child health event and key metric in child health monitoring systems.

Contributors

Study conceptualised by JSR and designed by ALS and JSR. Data collected by LJT, ALS with oversight by JSR. All authors were involved in data analysis. The manuscript was drafted by LJT, ALS, and JSR, and all authors approved the final version of the manuscript.

Declaration of Interests

All authors declare no competing interests. The funding organizations had no role in the design or conduct of this research. This paper presents independent research. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health and Social Care.

Acknowledgments

This work was funded directly by a Fight for Sight grant (1525/26) and was supported by funding from the Ulverscroft Foundation for the Ulverscroft Vision Research Group. AL Solebo received support from the National Institute for Health Research Biomedical Research Centre (NIHR BRC) based at Moorfields Eye Hospital NHS Foundation Trust and UCL Institute of Ophthalmology, and an NIHR Lectureship, and is supported by an NIHR Clinician Scientist award (CS-2018-18-ST2-005). JS Rahi is supported in part by the NIHR BRC based at Moorfields Eye Hospital NHS Foundation Trust and UCL Institute of Ophthalmology, and an NIHR Senior Investigator award. This work was undertaken at UCL Institute of Child Health / Great Ormond Street Hospital for children which received a proportion of funding from the Department of Health's NIHR Biomedical Research Centres funding scheme.

The funding organizations had no role in the design or conduct of this research. This paper presents independent research. The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health and Social Care.

Data sharing

Individual patient data were collected and processed with section 251 support from the Confidentiality Advisory Group (CAG). We do not have permission to share these identifiable data.

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Tables & Figures

Table 1· Annual age group specific incidence (IR) and cumulative incidence of VI/SVI/BL per 10,000

	VI plus† (N=559)		VI isolated‡ (N=219)		AFI (N=784)		Total UK Population^ (1000s)
Age (y)	**n (%)**	**IR (95%CI)**	**n (%)**	**IR (95%CI)**	**n (%)**	**IR (95%CI)**	
<1	299 (54)	3·86 (3·45-4·32)	99 (45)	1·28 (1·05-1·56)	402* (51)	5·19 (4·71-5·72)	774·5
1-4	151 (27)	0·47 (0.40-0.55)	48 (22)	0·15 (0·11-0·20)	200[1] (26)	0·62 (0·54-0·71)	3231·8
5-9	57 (10)	0·14 (0.11-0.18)	42 (19)	0·10 (0·08-0·14)	99 (13)	0·25 (0·20-0·30)	4037·4
10-15	43 (8)	0·10 (0·07-0·13)	25 (11)	0·06 (0·04-0·09)	69[2] (9)	0·16 (0·13- 0·20)	4338·3
16-18	9 (2)	0·04 (0.02-0.08)	5 (2)	0·02 (0·01-0·05)	14 (2)	0·06 (0·04- 0·10)	2262·1
0-18	559 (100)	0·38 (0·35-0·41)	219 (100)	0·15 (0·13-0·17)	784 (100)	0·54 (0·50-0·57)	14644·2
Cumulative	**n**	**Cumulative IR**	**n**	**Cumulative IR**	**n**	**Cumulative IR**	
1	299	3·86 (3·45-4·32)	99	1·28 (1·05-1·56)	402*	5·19 (4·71-5·72)	··
5	450	5·73 (5·22-6·28)	147	1·87 (1·59-2·20)	602[1]	7·67 (7·08-8·30)	··
10	507	6·44 (5·90-7·02)	189	2·39 (2·07-2·76)	701	8·89 (8·26-9·58)	··
16	550	7·03 (6·47-7·64)	214	2·74 (2·40-3·13)	770[2]	9·85 (9·17-10·57)	··
18	559	7·15 (6·58-7·77)	219	2·80 (2·46-3·1)	784	10·03 (9·35-10·76)	··

Values are incidence per 10,000 (95% CI). †VI/SVI/BL plus= children with an additional major non-ophthalmic disorder or impairment
VI/SVI/BL isolated‡= children with isolated visual loss (no major non-ophthalmic disorder or impairment)
≈Includes 6 children with unknown VI plus or isolated status
*includes 4 children with unknown VI plus or isolated status,
[1] includes 1 child with unknown VI plus or isolated status,
[2] includes 1 child with unknown VI plus or isolated status
^Using mid-year 2016 UK population estimates (ONS) by single year of age

Table 2· Relative incidence rates of VI/SVI/BL by sociodemographic characteristics

	All cases (N=784)	Total UK pop (1000s)	Annual incidence†	Relative rate (95% CI)
Ethnic group (n=689)				
White	437 (63%)	12289·3	0·4 (0·3-0·4)	Reference
South Asian*	162 (24%)	999·3	1·6 (1·4-1·9)	4·6 (3·8-5·5)
Pakistani	86 (11%)	462·6	1·9 (1·5-2·3)	5·2 (4·2-6·6)
Indian or Bangladeshi	50 (6%)	536·7	0·9 (0·7-1·2)	2·6 (2·0-3·5)
Black	32 (5%)	636·6	0·5 (0·4-0·7)	1·4 (1·0-2·0)
Mixed	36 (5%)	668·6	0·5 (0·4-0·7)	1·5 (1·0-2·1)
Other	22 (3%)	171·2	1·3 (0·8-2·0)	3·6 (2·4-5·6)
Sex (n=783)				
Female	356 (45%)	7143·7	0·5 (0·5-0·6)	Reference
Male	427 (55%)	7508·5	0·6 (0·5-0·6)	1·1 (1·0-1·3)
Deprivation (IMD) quintile (n=772)				
IMD Quintile 1 (Least deprived)	112 (15%)	2930·4	0·4 (0·3-0·5)	Reference
IMD Quintile 2	110 (14%)	2930·4	0·4 (0·3-0·5)	1·0 (0·8-1·3)
IMD Quintile 3	112 (15%)	2930·4	0·4 (0·3-0·5)	1·0 (0·8-1·2)
IMD Quintile 4	174 (23%)	2930·4	0·6 (0·5-0·7)	1·6 (1·3-1·9)
IMD Quintile 5 (Most deprived)	264 (34%)	2930·4	0·9 (0·8-1·0)	2·4 (2·0-2·8)
Country of residence (n=784)				
England[2]	712 (91%)	12434·2	0·6 (0·53-0·62)	··
Scotland	33 (4%)	665·2	0·3 (0·21-0·42)	··
Wales	31 (4%)	1092·7	0·5 (0·33-0·66)	··
Northern Ireland	8 (1%)	460·1	0·2 (0·09-0·35)	··
Birthweight‡ (n=387)				
≥2500g (Normal)	267 (69%)	686·3	3·9 (3·4-4·4)	Reference
1500-2499g (LBW)	71 (18%)	44·61	15·9 (12·6-21·1)	4·1 (3·1-5·4)
<1500g (VLBW)	49 (13%)	7·52	65·2 (49·2-86·2)	16·8 (12·4-22·8)
Gestation at birth‡ (n=531)				
Normal (≥37 weeks)	383 (72%)	688·65	3·3 (5·0-6·1)	Reference
Moderate **to late (32-3**6 **weeks)**	88 (17%)	48·29	18·2 (14·8-22·5)	3·3 (2·6-4·1)

Very (28-31 weeks)	233 (6%)	5·92	55·7 (39·6-78·4)	10·0 (7·0-14·3)
Extreme (<28 weeks)	27 (5%)	3·33	81·1 (55·6-118·2)	14·6 (9·9-21·6)

†Values are yearly incidence per 10,000 children aged 0-18 years, except for birthweight and preterm: which is yearly incidence per 10,000 live births·

‡Birthweight and Preterm birth excludes cases from Northern Ireland as the denominator is unknown. Values are yearly incidence per 10,000 children <1 year old·

*Includes 15 South Asian children of 'Asian Other' ethnicity.

[2]Including 1 child from Guernsey and 1 child from the Isle of Man

Table 3· Disorders causing VI/SVI/BL grouped by anatomical site or sites affected (n=784)

[1]Subtotals represent the number of children with each ophthalmic site affected. This will be less than the sum of individual disorders as some children had multiple disorders per site so were counted more than once.

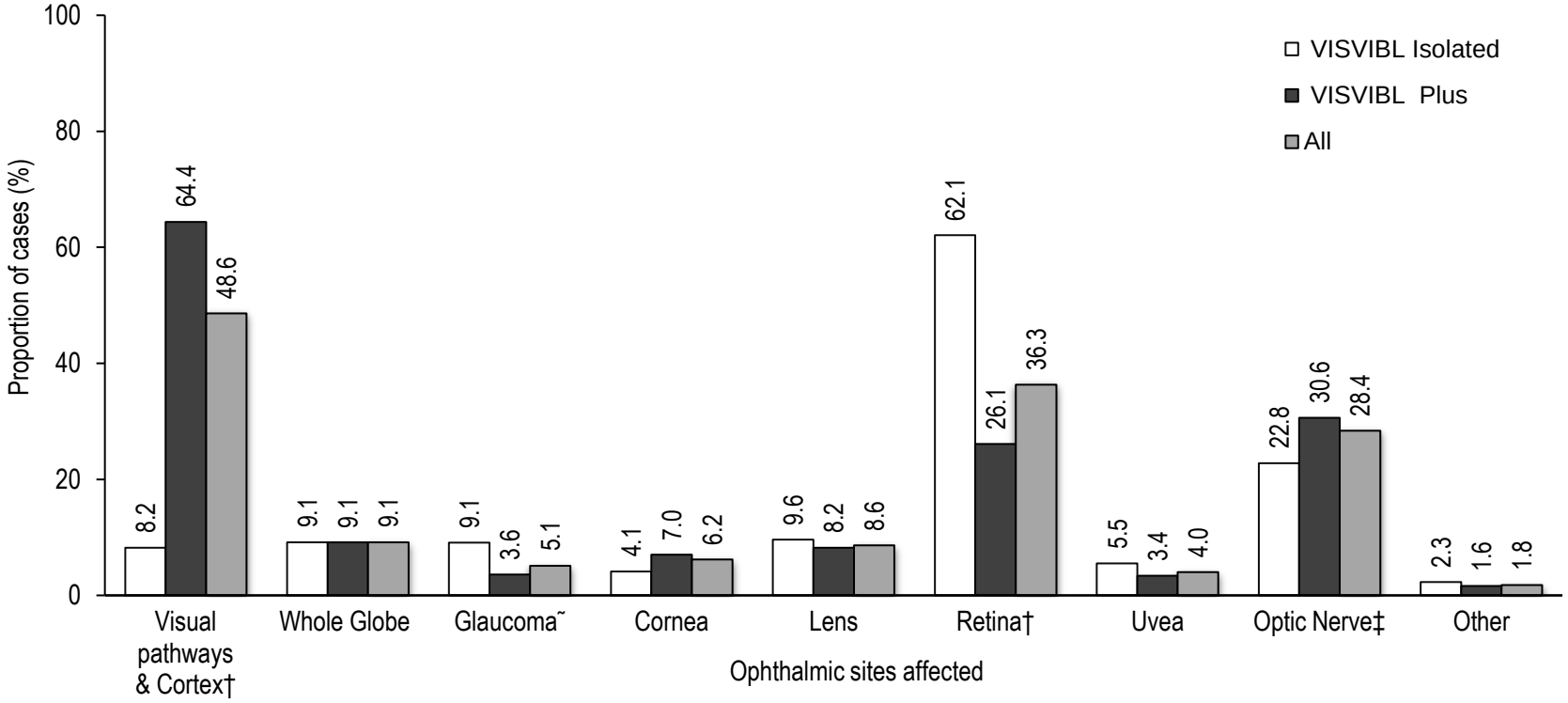
	Children with site affected[1]
Cerebral / visual pathways (CVI)	**378 (48·2%)**
Hypoxic/ischaemic encephalopathy	118 (15%)
Structural abnormalities	113 (14%)
Non-accidental injury	9 (<1%)
Neurodegenerative disorders	24 (3%)
Tumour	23 (3%)
Metabolic	16 (2%)
Infection	21 (3%)
Unknown disorder but evidence of CVI	60 (8%)
Whole globe and anterior segment	**95 (12·1%)**
Microphthalmia/Anophthalmia	40 (5%)
Anterior segment dysgenesis	24 (3%)
Multiple site coloboma	14 (2%)
Disorganised globe	*7 (<1%)*
Buphthalmos	*4 (<1%)*
Phthisis	*6 (<1%)*
Glaucoma	**42 (5·4%)**
Primary congenital (PCG)	*10*
Secondary	*32*
Cornea	**50 (6·4%)**
Opacity	29 (4%)
Dystrophy	2 (<1%)
Other	19 (2%)
Uvea	**30 (3·8%)**

Aniridia	17 (2%)
Coloboma (single site)	4 (<1%)
Uveitis	4 (<1%)
Other	5 (<1%)
Lens	**67 (8·6%)**
Cataract/aphakia	58 (7%)
Other	9 (1%)
Retina	**286 (36·5%)**
ROP	31 (4%)
Retinal and macular dystrophies	125 (16%)
Cone	28
Cone-rod	34
Leber's amaurosis	5
Stargardt's disease	11
Storage disorder (CLN)	4
CSNB	8
Retinitis Pigmentosa	13
Unspecified macular dystrophy	14
Unspecified retinal dystrophy	6
Retinoschisis	2
Oculocutaneous albinism	60 (8%)
Retinitis	4 (<1%)
Retinal detachment	36 (5%)
Retinoblastoma	3 (<1%)
Other	17 (2%)
Myelination of retina	1
Other retinopathy	1
Single site coloboma	2
Vitreoretinal dysplasia	4
Foveal hypoplasia	9
Optic Nerve	**222 (28·3%)**
Hypoplasia	116 (15%)
SOD	32

Isolated	84
Atrophy	89 (11%)
Primary	32
Secondary	57
Neuritis/neuropathy	17 (2%)
Other	8 (<1%)
Demyelinated optic nerve	1
Morning glory anomaly	2
Dysplasia	2
Aplasia	1
Optic nerve astrocytoma	1
Coloboma single site	1
Other	**14 (1·8%)**
Isolated nystagmus	9 (<1%)
Isolated high refractive error*	4 (<1%)
Stickler syndrome	1
Blepharophimosis syndrome	1 (<1%)

*High refractive error was considered to be equal or greater than 5·5 dioptres in the worse eye

Figure 1· Disorders by anatomical sites (all, VI/SVI/BL 'plus', and VI/SVI/BL 'isolated')* (N=778)



^Other: Idiopathic (isolated) nystagmus or High RE (not isolated but primary reason for loss of vision)
*Totals exceed 100% and some children had multiple sites
†: p<0·0001 for difference in proportions test between VI isolated and plus: ‡p=0·031 ˜p=0.0016

Table 4· Aetiological factors causing VI/SVI/BL (grouped by timing of effect) for all cases (N=784)

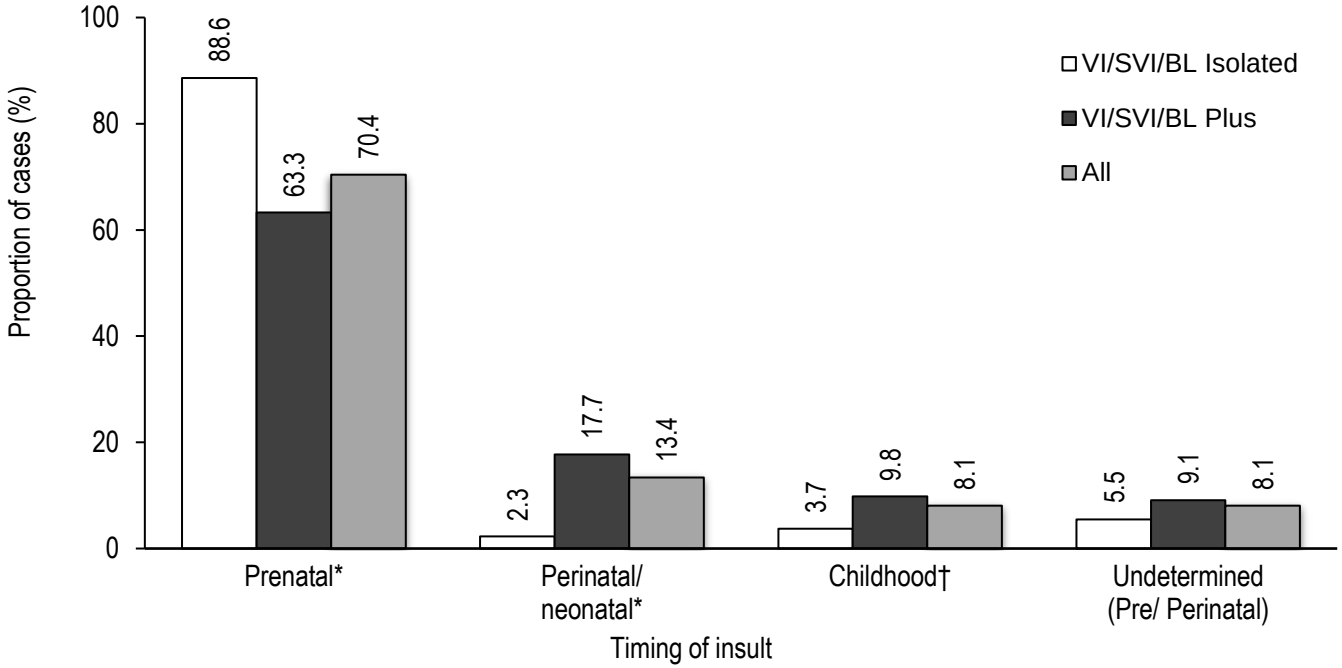
[1]Total of some subcategories for each aetiological factor exceeds 100% as some children had multiple factors

PRENATAL	**n=553 (71%)**
Hereditary	482 (61%)
Autosomal recessive	162
Autosomal dominant	46
X-linked	18
Chromosomal	29
Maternal inheritance	10
Sporadic/Uncertain	217
Hypoxia Ischaemia	14 (2%)
Infection in pregnancy	19 (2%)
Cytomegalovirus	3
Rubella	2
Toxoplasmosis	2
Herpes Simplex	1
Hepatitis C	1
Group B Streptococcus	7
HIV	1
Unknown / not specified	2
Maternal drug use*	9 (1%)
Other	2 (<1%)
Twin-twin transfusion syndrome	1
Neonatal immune thrombocytopenia	1
Unknown (congenital, no further information)	53 (7%)
PERINATAL/NEONATAL	**n=105 (13%)**
Hypoxia Ischaemia	69 (9%)

Infection	19 (2%)
Group B Streptococcus	8
Herpes Simplex	1
Pneumococcal	1
Other	9
Unspecified Meningitis	5 (<1%)
Non-accidental injury	2 (<1%)
Other	13 (2%)
Hydrocephalus	8
Epileptic encephalopathy	2
Neonatal hyper/hypoglycaemia	3
Unknown	18 (2%)
CHILDHOOD (post neonatal)	**n=63 (8%)**
Tumour	21 (3%)
Astrocytoma	2
Glioma	6
Medulloblastoma	1
Neuroblastoma	2
Craniopharyngioma	3
Tectal plate glioma	1
Rhabdomyosarcoma	2
Ependymoma	2
Prolactinoma	1
Unspecified brain tumour	1
Non-accidental injury	9 (1%)
Systemic disorders	5 (<1%)

Homocystinuria	1
Acute lympoblastic lymphoma	1
Graft vs Host disease	1
Erythema multiforme	1
Sickle cell disease	1
Hypoxia ischaemia	9 (<1%)
Hydrocephalus/raised intracranial pressure	3 (<1%)
Infection	3 (<1%)
Epstein Barr virus	1
Group B Streptococcus	1
Unknown	1
Accidental injury	5 (<1%)
Near drowning	2
Accidental physical trauma	2
Laser eye injury	1
Nutritional (Vitamin A) deficiency	1
Unknown	12 (2%)
UNCONFIRMED TIMING (either prenatal or perinatal)	**n=63 (8%)**

Figure 2· Timing of insult leading to VI/SVI/BL for all cases (N=778), VI/SVI/BL isolated (n=219), VI/SVI/BL plus (n=559)



*p<0·0001 †p=0·0044 for difference in two proportions test ^Percentage totals exceed 100% due to multiple aetiologies in some cases
Children in the 'undetermined' category had insults arising from either the prenatal or perinatal period, but the timing could not be reliably ascribed to a single aetiological category with information provided

Table 5· Non-ophthalmic impairments and conditions for children with VI/SVIBL (for all cases N= 784)

Impairments – key categories	%
Hearing	13·4
Learning	22·5
Speech & Language	21·3
Mobility	26·0

Main non-ophthalmic conditions	%
Seizures or epilepsy	22·6
Developmental delay (including global delay)	20·0
Feeding	12·4
Cerebral palsy	9·2
Microcephaly	7·9
Hydrocephalus	4·6
Other neurological	8·6
Respiratory	5·7
Sleep related	4·0
Cardiac	3·7
Behavioural	2·3
Autism spectrum	1·8