

ORIGINAL ARTICLE

Prospective surveillance study of severe hyperbilirubinaemia in the newborn in the UK and Ireland

Donal Manning, Peter Todd, Melanie Maxwell, Mary Jane Platt

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See end of article for authors' affiliations

Correspondence to:
Donal Manning, Department of Paediatrics, Arrowe Park Hospital, Wirral, Merseyside CH49 5PE, UK; donal.manning@whnt.nhs.uk

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Objectives: To determine the incidence of severe hyperbilirubinaemia in the newborn, and to identify associated clinical and demographic variables, and short-term outcomes.

Design: Prospective, population-based study.

Setting: UK and Republic of Ireland, between 1 May 2003 and 31 May 2005.

Participants: Infants in the first month of life with severe hyperbilirubinaemia (maximum unconjugated serum bilirubin $\geq 510 \mu\text{mol/l}$).

Results: 108 infants met the case definition, 106 from the UK and 2 from the Republic of Ireland. The UK incidence of severe hyperbilirubinaemia was 7.1/100 000 live births (95% CI 5.8 to 8.6). Only 20 cases presented in hospital; 88 were admitted with severe jaundice. 64 (60.4%) cases were male, and 56 (51.8%) were of ethnic minority origin. 87 (80.5%) cases were exclusively breast fed. Co-morbidity included haemolysis, dehydration, infection and bruising. 14 infants showed evidence of bilirubin encephalopathy, of whom 3 died. The UK incidence of bilirubin encephalopathy was 0.9/100 000 live births (95% CI 0.46 to 1.5).

Conclusions: This is the first large, prospective, population-based study of the incidence of severe hyperbilirubinaemia in the newborn. The clinical and demographic associations, and short-term outcomes identified, are the same as those reported recently in North America and Europe.

In the past 15 years, severe hyperbilirubinaemia has been reported with increasing frequency in term and near-term infants in North America and Europe.^{1–9} Severe hyperbilirubinaemia can cause encephalopathy with important sequelae among surviving infants, including athetoid cerebral palsy, sensorineural hearing loss, paralysis of upward gaze and dental enamel dysplasia.^{1 5 6 8–10} A pilot kernicterus register established in Philadelphia in 1992 had accumulated information on 145 affected infants by 2002.⁶ In Denmark, eight cases of neonatal bilirubin encephalopathy were reported between 1994 and 2002, no cases having been reported in the preceding 20 years.^{3 9} Little is known of similar trends in the UK and Ireland, and there have been no recent published reports of bilirubin encephalopathy in mature infants.

The primary objective of this study was to determine the incidence of severe hyperbilirubinaemia in the UK and Ireland. Secondary objectives were to document clinical and demographic variables associated with severe jaundice, and the associated consequences, including the need for exchange transfusion, bilirubin encephalopathy and death.

METHOD

The study was included in the British Paediatric Surveillance Unit reporting scheme between June 2003 and June 2005 (surveying for cases seen between May 2003 and May 2005). Members of the Royal College of Paediatrics and Child Health receive a mailing every month asking whether they have encountered any of a selected number of rare diseases in the preceding month. Responders are sent an anonymised questionnaire requesting information to determine whether the reported case meets the case definition, and to collect associated clinical and demographic information.

The case definition for severe hyperbilirubinaemia was “an infant with an unconjugated serum bilirubin concentration of $\geq 510 \mu\text{mol/l}$ in the first month of life”. Information requested from paediatricians reporting cases included: the infant's sex,

ethnic origin (using the categories used by the Office for National Statistics), birth weight, gestation, mode of feeding and age at discharge from the maternity unit; the maximum unconjugated serum bilirubin concentration and the age at which this was identified; symptoms consistent with encephalopathy (impaired consciousness, hypotonia, opisthotonus and seizures); and diseases associated with jaundice. We defined probable ABO incompatibility as appropriate maternal–infant blood group permutations with positive Coombs' test, and possible ABO incompatibility as appropriate blood groups with negative Coombs' test. Otherwise we relied on the reporting paediatricians to specify associated diagnoses. Other consequences of severe hyperbilirubinaemia were recorded, including treatment by exchange transfusion, findings on MRI brain scans and death.

The denominator for calculating the incidence of severe hyperbilirubinaemia was routinely collected live births during the study period, obtained from the Office for National Statistics for England and Wales, the General Register Office for Scotland and the Northern Ireland Statistics and Research Agency. Live birth data by month were not available for the Republic of Ireland, so cases reported from there were not included in the incidence calculations. Republic of Ireland cases, however, were included in analysis of clinical and demographic variables associated with severe hyperbilirubinaemia.

We analysed the data using Stata (version 8). Where indicated, exact 95% confidence intervals were calculated.

The London multicentre research ethics committee approved the study.

RESULTS

Of 177 reports received, 108 met the case definition. There were 38 reporting errors and 25 duplicate reports, and no information was obtained in six cases. All except two cases were from the UK where, over the same time period, there were 1 500 052

Table 1 Distribution of demographic and perinatal variables. Values are numbers (%) unless otherwise stated

Variable	No. (%)
Male sex	64 (60.4)
Ethnic group	
White	52 (48.1)
Asian/Asian British	18 (16.7)
Black/black British	11 (10.1)
Mixed	11 (10.1)
Other	16 (14.8)
Birth weight (g), mean (SD)	3170 (480)
Gestational age (weeks), mean (SD)	38.2 (1.7)
Mode of delivery	
Normal vaginal	63 (58.3)
Instrumental vaginal	25 (23.1)
Caesarean section	20 (18.5)
Feeding method	
Breast	87 (80.5)
Artificial	13 (12.0)
Mixed	6 (5.5)
Associated problems	
Suspected haemolysis	49
Rhesus incompatibility	6
Probable ABO incompatibility	16
Possible ABO incompatibility	17
Glucose 6-phosphate dehydrogenase deficiency	5
Hereditary spherocytosis	3
Other causes of haemolysis	2
Dehydration	30
Bruising	7
Sepsis	4
Miscellaneous	4
No associated pathology	29

live births, giving an incidence of 7.1/100 000 live births (95% CI 5.8 to 8.6/100 000 live births). Thirteen of the UK infants had symptoms or a clinical course consistent with bilirubin encephalopathy, an incidence of 0.9/100 000 live births (95% CI 0.46 to 1.5). One further case of bilirubin encephalopathy was reported from the Republic of Ireland.

Among the cases of hyperbilirubinaemia 64 were male infants (60.4%). Fewer than half the cases were described ethnically as "white" (table 1). The mean gestational age at delivery was 38.2 weeks (range 35–42), and the mean birth weight was 3190 g (range 1.79–4.3). Eighty-eight (77.7%) cases were born vaginally, 25 (29%) of whom had instrumental deliveries. Breast feeding was the commonest mode of feeding (table 1). There was no association between severe hyperbilirubinaemia and month of birth.

The mean peak serum bilirubin concentration was 580 $\mu\text{mol/l}$ (range 510–802), and the mean age at peak serum bilirubin concentration was 4.3 days (range 1–9). At diagnosis, over a quarter of infants were dehydrated, having lost more than 10% of their birth weight. Twenty-eight (93%) of these infants had been exclusively breast fed. In nearly half of all cases, a haemolytic disease was suspected or confirmed (table 1). Other associated problems included sepsis and marked bruising in association with cephalhaematoma. Of the 29 cases with no associated problems, 26 (90%) had been exclusively breast fed.

In all, 48 infants were treated by exchange transfusion, seven of whom received more than one transfusion; 59 infants did not receive an exchange transfusion, and in one case no record was available. The median peak serum bilirubin was significantly greater in infants who were treated by exchange transfusion than in those who were not (586 $\mu\text{mol/l}$ v 544 $\mu\text{mol/l}$, respectively, $p < 0.001$). Compared with infants who were not transfused, infants receiving exchange transfusion were more

likely to have had neurological symptoms (9 (15%) v 15 (31%), $p < 0.05$, respectively) and to have had associated haemolysis (19 (32%) v 30 (62%), $p < 0.01$, respectively), and were less likely to have had no associated diagnosis (20 (34%) v 8 (16%), $p < 0.05$, respectively).

In all, 104 cases were delivered in hospital, although only 20 cases presented in hospital. The remaining infants were admitted from home, 84 being readmitted and 4 following home birth. The mean age at initial discharge for those infants readmitted with hyperbilirubinaemia was day 2 (range day 1 to day 5). We found no difference in the peak serum bilirubin concentration of those cases identified in hospital and those admitted from home, although the latter group was older at diagnosis (mean age 2.8 days v 5.0 days, respectively, $p < 0.001$). Associated haemolysis was significantly more commonly identified in infants diagnosed before discharge (16 (80%) v 33 (38%), $p < 0.001$). Twelve (60%) of infants diagnosed before discharge were treated with an exchange transfusion compared with 36 (41%) of infants presenting from home ($p = 0.08$).

Table 2 summarises the clinical, demographic, biochemical and outcome findings for infants with bilirubin encephalopathy. Two infants presented while still in hospital, nine were readmitted, and three had been born at home. All three infants with infection died. Postmortem examination was conducted in two cases, and both showed kernicterus. Only one infant with encephalopathy had no identified associated pathology. This infant had been breast fed. Four infants with bilirubin encephalopathy did not receive exchange transfusion—one with overwhelming infection, two with dehydration and one with no associated diagnosis. Four of the surviving infants at 12-month follow-up had typical sequelae, including sensori-neural hearing impairment and athetoid cerebral palsy. Three of these infants underwent brain MRI, which showed increased signal in the globus pallidus on T2-weighted imaging, as described previously in bilirubin encephalopathy.¹¹ Three survivors were reported to have normal development at one year, two had neurodevelopmental problems felt to be unrelated to bilirubin encephalopathy and two were lost to follow-up.

Compared with jaundiced infants without encephalopathy, the infants with features suggesting encephalopathy were more likely to be boys (12 (85%), $p = 0.037$); more likely to be black/British black (6 (43%), $p < 0.001$); had significantly higher peak serum bilirubin concentrations (mean 627 $\mu\text{mol/l}$ v 573 $\mu\text{mol/l}$ in jaundiced infants without encephalopathy, $p = 0.037$); were more likely to have a coexistent infection (3 (21%), $p = 0.007$); and were significantly more likely to be treated with an exchange transfusion (10 (66%) v 38 (40%) jaundiced infants without encephalopathy, $p = 0.046$). A multiple logistic regression model demonstrated that ethnic group (black) and glucose 6-phosphate dehydrogenase deficiency independently increased the risk of encephalopathy in infants with hyperbilirubinaemia (table 3).

DISCUSSION

Between May 2003 and May 2005, the incidence of severe neonatal hyperbilirubinaemia in the UK was 0.07/1000 live births, and the incidence of bilirubin encephalopathy was about 1/100 000 live births. Associations with both severe hyperbilirubinaemia and bilirubin encephalopathy included male sex, ethnic minority origin, breast feeding and comorbidity, including dehydration, marked bruising, haemolytic diseases and infection. Most infants were admitted to hospital for management of jaundice after earlier discharge or a home birth.

Although severe jaundice and bilirubin encephalopathy have been extensively reported in North America in the past 15

Table 2 Clinical, demographic, biochemical and outcome data for infants with bilirubin encephalopathy

Case no.	Sex	Ethnic origin	Gestation (weeks)	Birth weight (kg)	Mode of feeding	Clinical features	Maximum SBR ($\mu\text{mol/l}$)	Age at maximum SBR (days)	Associated pathology	Outcome at 12 months
1	Male	Black	41	3.34	Artificial	↓ LOC, ↓ tone, opisthotonus, seizures	709	3	Klebsiella septicaemia	Died
2	Male	White	37	2.94	Breast	↓ LOC, ↓ tone, opisthotonus, seizures	613	8	Unspecified haemolysis	Hearing loss
3	Male	Black	36	2.35	Breast	↓ LOC, ↓ tone	649	4	Omphalitis, possible ABO incompatibility	Died
4	Male	Asian	36	1.79	Artificial	↓ LOC, ↓ tone, opisthotonus, seizures	663	8	G6PD deficiency	Athetosis, severe hearing loss
5	Male	South Asian	39	2.83	Breast	↓ LOC, ↓ tone, opisthotonus	563	3	Dehydration, possible ABO incompatibility	Normal
6	Female	Middle Eastern	40	3.24	Breast	↓ LOC, seizures	802	3	G6PD deficiency	Normal
7	Male	White	36	3.0	Artificial	↓ tone, seizures	561	4	Cephalhaematoma	Incidental hemiparesis
8	Male	White	39	4.01	Unknown	Opisthotonus, seizures	587	4	Dehydration, spherocytosis	Lost to follow-up
9	Male	Black	39	3.12	Breast	↓ LOC, opisthotonus, seizures	742	4	G6PD deficiency	Athetosis, epilepsy
10	Male	Black	37	3.06	Breast	Opisthotonus	541	8	Dehydration	Normal
11	Female	White	41	4.3	Breast	↓ LOC, ↓ tone	597	3	Rhesus incompatibility	Lost to follow-up
12	Male	Black	40	Unknown	Unknown	↓ LOC, ↓ tone	699	4	Omphalitis	Died
13	Male	Black	37	2.73	Breast	↓ LOC, seizures, opisthotonus	547	5	ABO incompatibility	Severe hearing loss, cerebral palsy
14	Male	White	38	2.77	Breast	↓ LOC, opisthotonus	511	5	None identified	Incidental visual delay

↓ LOC, impaired consciousness; G6PD, glucose 6-phosphate dehydrogenase; SBR, serum bilirubin.

years,^{1-4 6 8} there has been little information on current trends in the UK and Ireland. In Wirral, the incidence of moderate hyperbilirubinaemia (total serum bilirubin $\geq 340 \mu\text{mol/l}$) increased markedly from 2.4/1000 live births in 1991 to 5.5/1000 in 2001.¹² Ours, however, is the first prospective, population-based study of the incidence of severe neonatal jaundice, and bilirubin encephalopathy, in the UK.

Little is known of the incidence of severe neonatal jaundice in other Western countries. Lee *et al* reported nine infants with a serum bilirubin concentration $\geq 510 \mu\text{mol/l}$ in Ontario between 1992 and 1994, an incidence of 0.38/1000 live births.³ Newman *et al* reported that 0.1/1000 infants born in 1995-6 in a health maintenance organisation catchment area in California had a serum bilirubin concentration $\geq 30 \text{ mg/dl}$ ($513 \mu\text{mol/l}$).⁴ In both these studies the total serum bilirubin concentration was used, whereas we used unconjugated serum bilirubin, as we wished to exclude infants with severe liver disease or cholestasis. In infants in the first week of life without such disease, the conjugated serum bilirubin concentration is negligible,⁹ so our findings are comparable with those of Lee *et al* and Newman *et al*. The incidence of severe hyperbilirubinaemia cannot be said to be lower in the UK than in North

America, however, because their studies were conducted a decade ago, and the incidence may have fallen following clinical and public health measures taken after the "epidemic" of bilirubin encephalopathy was reported.

There are no national estimates of the incidence of bilirubin encephalopathy for North America, but Ebbesen *et al* reported eight cases in Denmark between 1994 and 2002, during which time 582 600 live term or near-term infants were born: an incidence of 1.4/100 000 live term or near-term births.⁹ This compares with our calculated incidence of 1/100 000 total live births.

The clinical and demographic associations with severe hyperbilirubinaemia that we identified are similar to those reported in North America and Europe. Most infants reported were breast fed.^{1 2 4 13 14} A male preponderance has been described^{9 14} and near-term infants^{1 4 7 8 12 14} and infants of ethnic minority origin^{8 15} have been disproportionately represented. Precise data on the ethnic origin of all live births in Britain and Ireland are not available, but more than half the affected infants in our study were of ethnic minority origin. Finally, the re-emergence of severe neonatal jaundice in North America has coincided with an increasing trend to early discharge of infants from the birth hospital.^{3 13}

Hyperbilirubinaemia can be aggravated by dehydration due to lactation failure,^{1 5 6 8 9} but it can also occur in the presence of successful lactation.¹⁵ In our study almost all the infants with no associated diagnosis had been breast fed. Infants of ethnic minority origin may be vulnerable for two reasons: first, clinical evaluation of the severity of jaundice may be difficult and second, some ethnic minority groups have a high prevalence of haemolytic diseases such as glucose 6-phosphate dehydrogenase deficiency. Finally, near-term infants may be vulnerable because of relative difficulty in establishing lactation, and relative immaturity of hepatic uptake and conjugation of bilirubin. In addition to dehydration, the other diseases and

Table 3 Multivariate logistic analysis of risk factors for encephalopathy, UK and Ireland, 2003-5

Variable	Odds ratio	Confidence interval	p Value
Female sex	0.37	0.06 to 2.21	0.27
Black/black British	19.0	2.5 to 144.7	0.004
Infection	9.0	0.38 to 210.0	0.17
Glucose 6-phosphate dehydrogenase deficiency	28.2	2.6 to 307.7	0.006

All odds ratios were mutually adjusted for the other variables in the table.

What is already known on this topic

- In the past 15 years, severe hyperbilirubinaemia and bilirubin encephalopathy have been reported in term and near term infants in the developed world.

What this study adds

- This is the first prospective, population-based study of severe neonatal hyperbilirubinaemia in the UK and Ireland.
- It provides a robust estimate of the current incidence of severe hyperbilirubinaemia and bilirubin encephalopathy in term and near-term infants.

problems associated with severe hyperbilirubinaemia in our study (haemolysis, infection and marked bruising) have also been identified in North America and Denmark.^{5 6 8 9}

The infants with bilirubin encephalopathy shared many clinical and demographic features with those who have severe hyperbilirubinaemia without encephalopathy, including male preponderance and ethnic minority origin. An interesting feature of this group was that 3/14 were born at home. Whether these infants received less intensive midwifery surveillance during the first week than infants born in hospital is not known, but presumably they were considered to be at low risk.

A limitation of our study is that the case definition may have excluded infants with bilirubin encephalopathy at serum bilirubin concentrations below our case definition. Of 125 infants reported to the Philadelphia kernicterus registry, 19 had bilirubin encephalopathy at bilirubin concentrations below 30 mg/dl (513 µmol/l).⁸ Possibly our study failed to identify comparable infants in the UK and Ireland. Our case definition may also have excluded some infants with encephalopathy associated with severe conjugated hyperbilirubinaemia.¹⁶ Also, because the focus of our study was primarily epidemiological and could not collect comprehensive clinical information on individual infants, we may have under-identified mild bilirubin encephalopathy. The calculated incidence of bilirubin encephalopathy should be regarded, therefore, as a minimum.

The strengths of our study include its prospective design, and the comprehensive national coverage of paediatric and maternity units in Britain. Almost all consultant paediatricians in the UK are members of the Royal College of Paediatrics and Child Health and therefore receive a monthly mailing from the British Paediatric Surveillance Unit. The mean response rate to this is 92%,¹⁷ and for many cases we received duplicate reports from colleagues. Under-ascertainment, therefore, is likely to be minimal.

It is of concern that 59 infants with severe hyperbilirubinaemia did not undergo exchange transfusion. This group of infants had lower median serum bilirubin concentrations, and less frequent associated haemolysis, than infants receiving exchange transfusion. Our study was not designed to examine treatment decisions, but we speculate that in some cases intensive phototherapy and rehydration resulted in rapid reduction in serum bilirubin and deferral of exchange transfusion. Neurological symptoms, such as impaired conscious level and hypotonia, may in some infants have been attributed to associated morbidity such as infection and dehydration.

Arguably, however, such symptoms in the presence of severe hyperbilirubinaemia warrant urgent exchange transfusion.

Our findings have important implications. We have shown that severe hyperbilirubinaemia and bilirubin encephalopathy, which have been reported with increasing frequency in North America and Europe, have also occurred in the UK and Ireland. We have also shown that the same clinical, pathological and demographic associations are relevant here. These findings are important, not just for paediatricians and neonatologists, but also for midwives, general practitioners, public health professionals and commissioners of primary care services. The "kinder, gentler" approach to the investigation and management of neonatal jaundice which was advocated in the 1980s and 1990s should be re-evaluated.¹⁸ Unfortunately, clinical practice in surveillance and treatment of neonatal jaundice varies widely,¹⁹ probably because many aspects of such management are not supported by a firm evidence base.²⁰

Nonetheless, some cases of severe hyperbilirubinaemia and bilirubin encephalopathy may be preventable. Severe jaundice often presents after the infant has been discharged from the birth hospital, and sometimes after home delivery. Careful community-based surveillance of all infants who are discharged early, supplemented by laboratory measurement of serum bilirubin and other investigations as appropriate, is essential. Particular vigilance is required for near-term infants and infants of ethnic minority origin, and clinical assessment should include assessing the adequacy of lactation. As severe jaundice also presented in hospital in 20 cases, the same principles apply to infants cared for on postnatal wards. Finally, parents of newborn infants should be given comprehensive information about neonatal jaundice and the possible consequences (albeit uncommon) of delay in establishing successful breast feeding.

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Authors' affiliations

Donal Manning, Peter Todd, Department of Paediatrics, Arrowe Park Hospital, Wirral, Merseyside, UK

Melanie Maxwell, Clinical Practice Research Unit, Arrowe Park Hospital, Wirral, Merseyside, UK

Mary Jane Platt, Division of Public Health, University of Liverpool, Liverpool, UK

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