

# Factors associated with fall in neonatal intubation rates in the United Kingdom – prospective study

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**Objective** To investigate the trend of neonatal resuscitation by intubation or mask ventilation over time and to assess its association with changes in prevalence of caesarean section and use of general anaesthesia in labour.

**Methods** All women booking pregnancy at any of 15 maternity units, analysed using logistic regression.

**Design** Prospective study.

**Setting** UK hospital-based maternity units (15 centres).

**Population** A total of 221 322 first singleton births of babies weighing 200 g or more in the St Mary's Maternity Information System cohort, 1988–2000, covering the North West Thames area of London.

**Main outcome measures** Prevalence of intermittent positive-pressure ventilation (IPPV) (by intubation or mask) by calendar year.

**Results** Overall use of IPPV decreased markedly (two-sided  $P < 0.01$ ) over the course of the study, and this decrease was evident by all modes of delivery. Adjusted mean prevalence of intubated IPPV decreased from 0.51% (95% CI 0.44–0.58) in 1988 to 0.07% (95% CI 0.06–0.09) in 2000. There was a similar decrease in the prevalence of IPPV by mask. However, despite substantial increases in prevalence of caesarean sections and reductions in the use of general anaesthesia over the course of the study, adjusting for these variables made little difference to the temporal trends in intubation or use of mask ventilation.

**Conclusions** There has been a marked reduction in the prevalence of infants given resuscitation by positive-pressure ventilation that cannot be explained by changes in the prevalence of caesarean section or use of general anaesthesia in labour.

**Keywords** Analgesia, caesarean section, intubation, neonatal resuscitation, pregnancy.

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## Introduction

Many neonatologists in Western countries have observed an apparent decline in the number of newborn babies needing resuscitation over the last two decades. For example, Wu *et al.*<sup>1</sup> have reported that the diagnosis of birth asphyxia in California decreased by 91% from 14.8 to 1.3 per 1000 live births during the years 1991–2000. They could not explain this decrease by an increase in related diagnoses and speculated that an increase in the caesarean section rate, by limiting the stress in labour to which foetuses are exposed, might be one causal factor. This suggestion is supported by reports from Canada, the Netherlands and the UK, demonstrating falls of two-thirds or more in indices of poor condition at birth in babies in breech presentation following the adoption

of the recommendation of the Term Breech Trial group that all these babies should be delivered by caesarean section, and anecdotal observations by one of the authors (T.L.).<sup>2–4</sup> We therefore analysed the North West Thames database of 585 291 pregnancies to assess whether there had been a significant fall in the incidence of babies in poor condition at birth, and whether this was associated with any change in the rate of caesarean section, correcting for other confounding variables.

The most objective measure of the child's condition at birth is the need for resuscitation by positive-pressure ventilation (intermittent positive-pressure ventilation [IPPV]). This can be done by endotracheal tube (intubated IPPV) or by face mask. These, particularly intubated IPPV, are major interventions in neonatal medicine and therefore are in general readily recognised by all staff and appropriately coded for in the

clinical record and associated databases. Despite its importance, there are relatively few studies that have examined the trends of IPPV over time.<sup>5–10</sup> Most of these show reductions in its use. However, these studies were mainly of small<sup>8</sup> or selected populations (e.g. of very preterm or low birthweight deliveries,<sup>5,6,9,10</sup> or breech presentations<sup>7</sup>) and did not provide convincing explanations of why the reduction in IPPV had occurred. In contrast, the present study is of a very large population-based cohort over a continuous period of 13 years. Because of the hypothesis<sup>1</sup> that changes in the prevalence of intubation and birth asphyxia may be due to changes in the type of delivery, and in particular the increased use of caesarean section and the reduction in the use of general anaesthesia for delivery in recent years, both these variables were examined to assess their impact on the changes in prevalence of intubation over time.

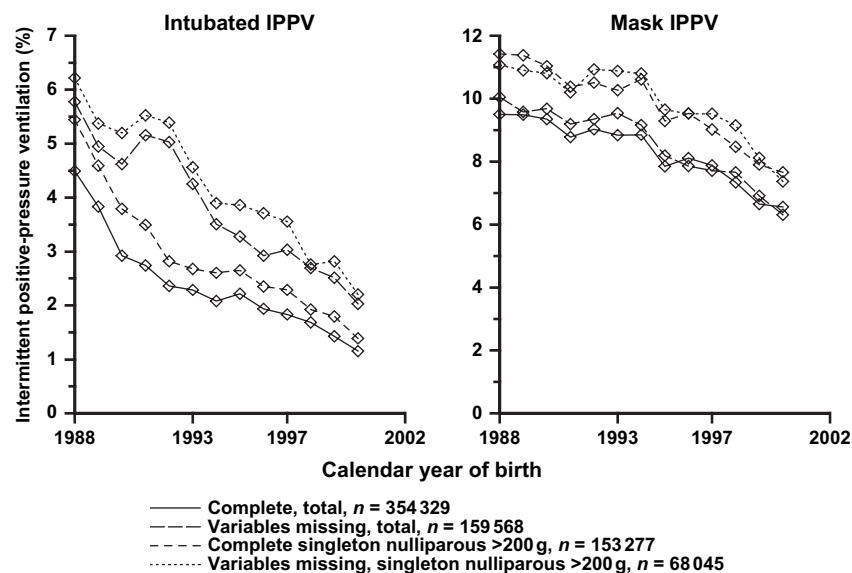
## Methods

### Data source

Since 1988 there has been prospective data collection on all pregnancies booked into nearly all the maternity units in the North West Thames region of London using the St Mary's Maternity Information System (SMMIS). Initially, data were collected from 17 separate maternity units, but this decreased to 15 over time because of amalgamations and rationalisation. However, the geographical coverage of women delivering and recorded on the system remained essentially unchanged. From 1988 until 2000, SMMIS registered data from 585 291

pregnancies, of which 513 897 progressed far enough to have the use of intubation (IPPV) after delivery recorded. Extremely preterm pregnancies, with a birthweight less than 200 g, where the baby was not considered viable, have been excluded from this analysis. Data were entered by trained clerks (first antenatal visit) or midwives (first antenatal clinic, and all deliveries) with online validation (for example cross-checks between data items that might be mutually exclusive), standard definitions for a range of clinical measurements (excluding implausible values, and challenging unlikely ones) and high quality of data collection (the data were used to generate clinical reports and discharge summaries, and so great efforts were made to ensure its accuracy).<sup>11</sup> We restricted the study to 222 614 singleton births of babies weighing 200 g or more among nulliparous mothers to ensure that only one delivery was included for each woman (varying numbers of deliveries to the same woman can introduce bias if for example women of high parity are more likely to have complications and also introduce analytic complications since the separate events [births] are not then statistically independent). However, we present in Figure 1 the data for all 513 897 births in this data set with information on calendar year of birth and intubation status so as to document the overall trend of intubation in the total population.

In addition to intubation or need for mask ventilation, data recorded on SMMIS include calendar year of birth, mother's ethnic group (based on self-classification in discussion with the midwife), smoking, maternal height (m), weight (kg) and age at booking (years), presence of meconium-stained amniotic



**Figure 1.** Percentage prevalence of intubated and mask IPPV and calendar year of birth and availability of principal regression variables (maternal ethnic group, smoking habits, maternal height, maternal weight, maternal age at booking, meconium-stained amniotic fluid, birthweight, weeks of gestation, method of delivery, Apgar score at 5 minutes, Carstairs' index, parity, number of infants in delivery, general anaesthetic at delivery) ( $n = 354\,329$  all variables available,  $n = 159\,568$  one or more variables missing), and the same for singleton nulliparous births, birthweight  $\geq 200$  g ( $n = 153\,277$  all variables available,  $n = 68\,045$  one or more variables missing).

fluid at delivery, mode of delivery, type of anaesthesia if needed and the child's Apgar score at birth (at 1 and 5 minutes after birth). Carstairs' score, an index of deprivation based on small area census data, derived from the mother's residential postcode,<sup>12</sup> was calculated, as was the mother's body mass index (BMI, kg/m<sup>2</sup>) at her first antenatal visit, which occurred on average at 14.9 weeks of gestation (range 5–44). (The last variable was only used for the descriptive analyses presented in Table 1.)

### Ethical approval

The use of the SMMIS database for this research was approved by the St Mary's National Health Service Trust Local Research Ethics Committee.

### Statistical methods

Log-linear logistic models were fitted by maximum likelihood techniques<sup>13</sup> to explore the relationship of IPPV with calendar year. These relationships were adjusted for mother's ethnic group, smoking habits, age at booking, Carstairs' score, maternal height and weight, birthweight, meconium-stained amniotic fluid, Apgar score at 5 minutes and (for all except Figures 1 and 2) mode of delivery. The variables used were chosen *a priori* to control for what are known to be the major socio-demographic factors associated with resuscitation and to facilitate comparison with previous studies of this data set.<sup>14</sup> For certain analyses (those of Figure 2), we also adjusted for the use of general anaesthesia during delivery. Birthweight was also adjusted for because of the (well-known) strong relationship between birthweight and IPPV (results not shown) and the trend of birthweight to increase over time. Mode of delivery also very strongly influences the need for intubation, and as the mix of modes of delivery has been changing over time, this also was adjusted for. It was judged *a priori* that Apgar score at 5 minutes, an independent measure of neonatal outcome, should be adjusted for in order to control for possible variation in case mix at delivery. Likewise, it was judged *a priori* that meconium-stained amniotic fluid should be adjusted for in order to control for any changes in practice of intubation associated with this condition and thereby more accurately assess temporal changes in the underlying condition of the baby. Although there have been substantial declines in the proportion of births with low Apgar scores over time (M. P. Little, M.-R. Järvelin and D. E. Neasham, unpubl obs.), little difference was made to the results by adjustment for this variable: temporal trends were diminished in magnitude but still highly statistically significant. Because the need for neonatal intubation might vary over a time as a result of variation in the distribution of weeks of gestation at delivery (possibly as a result of variation in the distribution of modes of delivery over time, but for other reasons as well), for certain analyses we also adjusted for weeks of gestation at delivery. Bootstrap methods<sup>15</sup> were

used to evaluate the confidence intervals (CI) on the fitted parameters and to assess statistical significance. 95% CI were evaluated using 999 bootstrap samples in Figures 2–5. The chi-square test for heterogeneity in Table 1 was evaluated using 9999 bootstrap samples. The analyses include only those records with complete data in the model as appropriate. All *P* values are two sided.

## Results

Prevalence rates for unadjusted IPPV by tube and by mask selected variables are shown in Table 1. Statistically significant ( $P \leq 0.05$ ) differences in intubated IPPV prevalence were observed between the categories of mother's ethnic group, cigarette smoking, mother's BMI, age at booking, Carstairs' score, year of birth, meconium-stained amniotic fluid, birthweight, mode of delivery and Apgar score at 5 minutes, and for prevalence of IPPV by mask, statistically significant ( $P \leq 0.05$ ) differences were observed for all these except Carstairs' score ( $P = 0.3950$ ).

Table 2, which reports the regression coefficients from fits of a logistic model to intubation data (intubated IPPV and IPPV by mask separately), shows that elective caesareans increase the prevalence of intubated IPPV by 40% (95% CI 10–80) and a slightly greater increase, by 122% (95% CI 96–152), is associated with emergency caesareans; use of general anaesthesia in labour increases the rate of IPPV even more, by 145% (95% CI 115–178%), and a similar increase is observed for general anaesthesia combined with other forms of analgesia in labour (increase of 132%, 95% CI 69–214). The analogous figures for IPPV by mask are 25% (95% CI 13–38), 50% (95% CI 41–60), 109% (95% CI 94–126) and 120% (95% CI 82–159).

The potential influence of missing data is explored in Figure 1; it shows that there is little difference in the trend of IPPV by calendar year depending on whether cases with any missing data are excluded or not, although there is some difference in the absolute level of intubation.

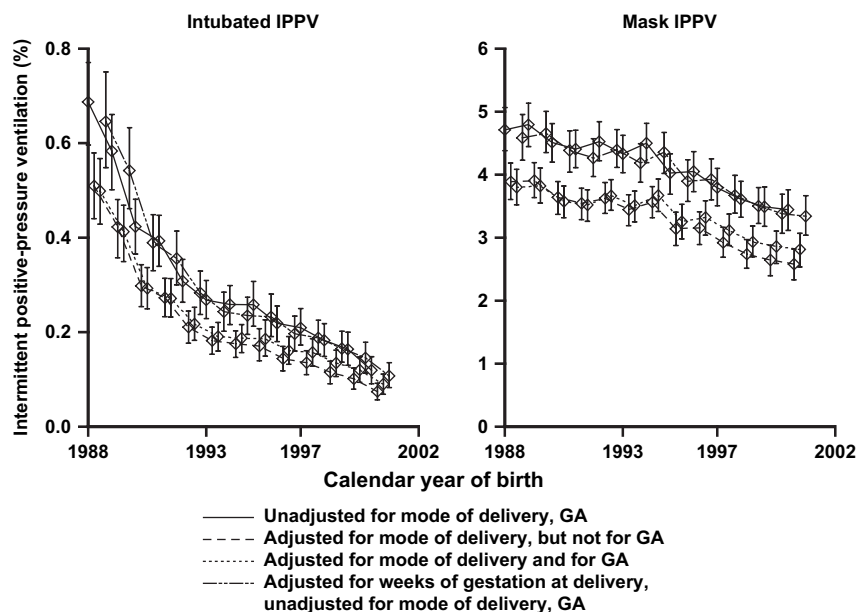
Figure 2 shows that there was a marked and highly statistically significant reduction in prevalence of IPPV over the course of the study, from 0.69% (95% CI 0.60–0.77) in 1988 to 0.12% (95% CI 0.09–0.15) in 2000. Very little of this fall could be explained by changes in the mode of delivery, in particular by the caesarean section rate: after adjustment for mode of delivery, the mean prevalence of intubated IPPV exhibited a substantial decrease from 0.51% (95% CI 0.44–0.58) in 1988 to 0.07% (95% CI 0.06–0.09) in 2000. Additional adjustment for use of general anaesthesia during delivery, which has decreased substantially over this period, made very little difference to this trend: even with adjustment for this variable, the mean prevalence of intubated IPPV decreased from 0.50% (95% CI 0.43–0.57) in 1988 to 0.09% (95% CI 0.07–0.11) in 2000. Adjustment for weeks of

**Table 1.** Prevalence rates of neonatal IPPV (by intubation or mask) at birth by maternal and birth characteristics in a cohort of 221 322 first singleton births in the North West Thames region in London (and *P* values of heterogeneity [ $\chi^2$ ] statistic evaluated using 9999 bootstrap samples)

| Variable                                              | IPPV by intubation percent (number of cases) |                   | IPPV by mask percent (number of cases) |                   |
|-------------------------------------------------------|----------------------------------------------|-------------------|----------------------------------------|-------------------|
| <b>Mother's ethnic group*</b>                         |                                              |                   |                                        |                   |
| White European                                        | 2.69 (3110)                                  | <i>P</i> < 0.0005 | 9.90 (11 458)                          | <i>P</i> < 0.0005 |
| Black African                                         | 6.75 (273)                                   |                   | 12.04 (487)                            |                   |
| Black Caribbean                                       | 5.65 (224)                                   |                   | 11.75 (466)                            |                   |
| Indian, Pakistani, Bangladeshi                        | 3.35 (614)                                   |                   | 10.16 (1864)                           |                   |
| Oriental                                              | 3.68 (92)                                    |                   | 8.51 (213)                             |                   |
| Mediterranean                                         | 4.32 (154)                                   |                   | 9.62 (343)                             |                   |
| Other                                                 | 3.02 (154)                                   |                   | 9.58 (488)                             |                   |
| <b>Mother's smoking (cigarettes per day)*</b>         |                                              |                   |                                        |                   |
| 0                                                     | 2.94 (3714)                                  | <i>P</i> < 0.0005 | 9.89 (12 501)                          | <i>P</i> < 0.0005 |
| 1–9                                                   | 3.20 (481)                                   |                   | 10.01 (1503)                           |                   |
| 10–19                                                 | 3.43 (318)                                   |                   | 10.75 (996)                            |                   |
| 20+                                                   | 4.06 (108)                                   |                   | 12.00 (319)                            |                   |
| <b>Mother's BMI at first pregnancy check (kg/m²)*</b> |                                              |                   |                                        |                   |
| <20                                                   | 2.53 (516)                                   | <i>P</i> < 0.0005 | 8.91 (1816)                            | <i>P</i> < 0.0005 |
| 20–24.99                                              | 2.88 (2508)                                  |                   | 9.65 (8396)                            |                   |
| 25+                                                   | 3.48 (1597)                                  |                   | 11.13 (5107)                           |                   |
| <b>Mother's age at booking (years)*</b>               |                                              |                   |                                        |                   |
| 0–24                                                  | 2.80 (1387)                                  | <i>P</i> < 0.0005 | 9.98 (4947)                            | <i>P</i> = 0.0028 |
| 25–29                                                 | 2.83 (1611)                                  |                   | 9.87 (5617)                            |                   |
| 30–34                                                 | 3.24 (1155)                                  |                   | 9.90 (3536)                            |                   |
| 35+                                                   | 4.22 (468)                                   |                   | 11.00 (1219)                           |                   |
| <b>Carstairs' quintiles**</b>                         |                                              |                   |                                        |                   |
| 1 (most affluent)                                     | 2.37 (752)                                   | <i>P</i> < 0.0005 | 9.91 (3149)                            | <i>P</i> = 0.3950 |
| 2                                                     | 2.59 (869)                                   |                   | 9.92 (3330)                            |                   |
| 3                                                     | 3.03 (1144)                                  |                   | 10.01 (3779)                           |                   |
| 4                                                     | 3.34 (1015)                                  |                   | 9.89 (3009)                            |                   |
| 5 (most deprived)                                     | 4.27 (829)                                   |                   | 10.38 (2018)                           |                   |
| <b>Year of birth*</b>                                 |                                              |                   |                                        |                   |
| 1988–90                                               | 4.58 (1742)                                  | <i>P</i> < 0.0005 | 11.27 (4283)                           | <i>P</i> < 0.0005 |
| 1991–93                                               | 2.99 (1326)                                  |                   | 10.39 (4601)                           |                   |
| 1994–96                                               | 2.53 (841)                                   |                   | 9.91 (3291)                            |                   |
| 1997–2000                                             | 1.88 (712)                                   |                   | 8.32 (3144)                            |                   |
| <b>Meconium-stained amniotic fluid*</b>               |                                              |                   |                                        |                   |
| No                                                    | 1.59 (1970)                                  | <i>P</i> < 0.0005 | 8.79 (10 872)                          | <i>P</i> < 0.0005 |
| Yes                                                   | 8.96 (2651)                                  |                   | 15.03 (4447)                           |                   |
| <b>Birthweight (g)*</b>                               |                                              |                   |                                        |                   |
| <1500                                                 | 51.32 (545)                                  | <i>P</i> < 0.0005 | 15.63 (166)                            | <i>P</i> < 0.0005 |
| 1500–2000                                             | 13.38 (229)                                  |                   | 21.20 (363)                            |                   |
| 2000–2500                                             | 4.42 (304)                                   |                   | 15.67 (1077)                           |                   |
| 2500–3000                                             | 2.44 (725)                                   |                   | 9.95 (2960)                            |                   |
| 3000–3500                                             | 2.35 (1422)                                  |                   | 9.02 (5458)                            |                   |
| 3500–4000                                             | 2.52 (1032)                                  |                   | 9.53 (3910)                            |                   |
| >4000                                                 | 2.95 (364)                                   |                   | 11.23 (1385)                           |                   |
| <b>Apgar score at 5 minutes*</b>                      |                                              |                   |                                        |                   |
| 0–3                                                   | 75.14 (269)                                  | <i>P</i> < 0.0005 | 17.32 (62)                             | <i>P</i> < 0.0005 |
| 4–6                                                   | 45.77 (920)                                  |                   | 46.12 (927)                            |                   |
| 7–10                                                  | 2.27 (3432)                                  |                   | 9.49 (14 330)                          |                   |
| <b>Mode of delivery*</b>                              |                                              |                   |                                        |                   |
| Spontaneous                                           | 1.55 (1440)                                  | <i>P</i> < 0.0005 | 7.44 (6917)                            | <i>P</i> < 0.0005 |
| Emergency caesarean                                   | 9.22 (1969)                                  |                   | 16.91 (3610)                           |                   |
| Elective caesarean                                    | 2.11 (107)                                   |                   | 9.75 (494)                             |                   |
| Instrumental                                          | 2.92 (960)                                   |                   | 12.18 (4006)                           |                   |
| Breech                                                | 14.17 (145)                                  |                   | 28.54 (292)                            |                   |

\*Among 153 290 singleton nulliparous births  $\geq 200$  g with information on mother's ethnic group, smoking habits, maternal height, maternal weight, calendar year, meconium-stained amniotic fluid, mother's age at booking, mode of delivery, Carstairs' score and Apgar score at 5 minutes.

\*\*Among 152 938 singleton nulliparous births  $\geq 200$  g with information on mother's ethnic group, smoking habits, maternal height, maternal weight, calendar year, meconium-stained amniotic fluid, mother's age at booking, mode of delivery, Carstairs' score, Carstairs' quintile and Apgar score at 5 minutes.

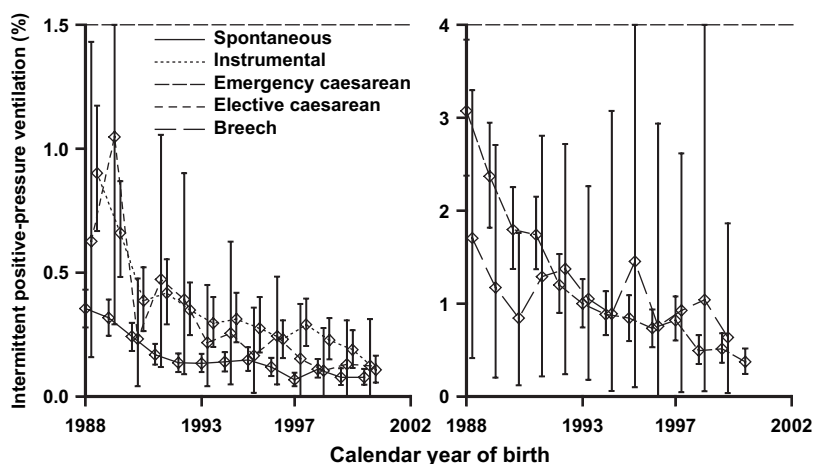


**Figure 2.** Percentage prevalence of intubated and mask IPPV (+95% CI) and calendar year of birth, adjusted and unadjusted for mode of delivery, adjusted and unadjusted for use of general anaesthesia (GA) in delivery or adjusted for weeks of gestation at delivery ( $n = 153\,291$ ).\*

\*Singleton nulliparous births  $\geq 200$  g, adjusted for mother's ethnic group, smoking habits, maternal height, maternal weight, birthweight, meconium-stained amniotic fluid, mother's age at booking, Carstairs' score and Apgar score at 5 minutes.

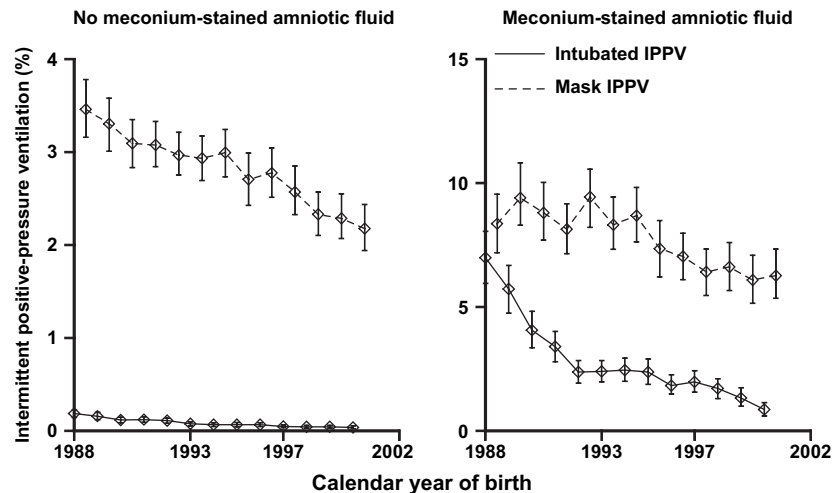
gestation at delivery also made little difference to this trend: even following adjustment, the mean prevalence of intubated IPPV decreased from 0.65% (95% CI 0.55–0.75) in 1988 to 0.11% (95% CI 0.08–0.14) in 2000. There was a similar, although less marked, decrease in prevalence of IPPV by mask, which after adjustment for mode of delivery was 3.89% (95% CI 3.61–4.19) in 1988 and 2.58% (95% CI 2.33–2.82) in 2000. Again, adjustment for use of general anaesthesia in delivery, or weeks of gestation at delivery, made

very little difference to this trend. As Figure 3 shows, this decrease is seen for all the main modes of delivery, although it is less for some modes of delivery (e.g. spontaneous) than for others. Figure 4 shows that the decrease, whether in IPPV by mask or by intubation, is also seen in women with meconium-stained amniotic fluid. Figure 5 shows that the decrease in intubated IPPV is also evident in most birth-weight groups; although the trend is less strong for the smallest babies, those weighing less than 1500 g, it is



**Figure 3.** Percentage prevalence of intubated IPPV (+95% CI) by mode of delivery (spontaneous, instrumental, emergency caesarean, elective caesarean, breech) and calendar year of birth ( $n = 153\,290$ ).\*

\*Singleton nulliparous births  $\geq 200$  g, adjusted for mother's ethnic group, smoking habits, maternal height, maternal weight, birthweight, meconium-stained amniotic fluid, mother's age at booking, Carstairs' score and Apgar score at 5 minutes.



**Figure 4.** Percentage prevalence of intubated and mask IPPV by meconium staining of amniotic fluid (+95% CI) and calendar year of birth ( $n = 153\,290$ ).\*

\*Singleton nulliparous births  $\geq 200$  g, adjusted for mother's ethnic group, smoking habits, maternal height, maternal weight, birthweight, mother's age at booking, Carstairs' score, Apgar score at 5 minutes and mode of delivery.

statistically significant in this and all other birthweight groups (two-sided  $P < 0.01$ ).

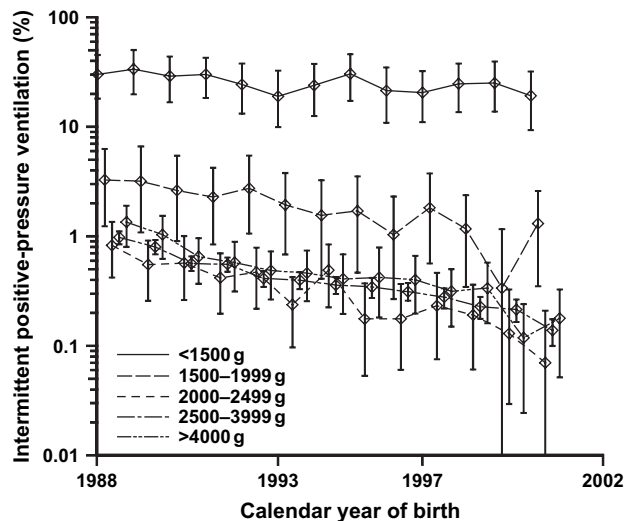
## Discussion and conclusions

We have documented a marked decrease in the prevalence of IPPV over the 13 years covered by the study. Similar decreases were observed both for intubated IPPV and for IPPV by mask. This decrease was evident for all modes of delivery and for

women with and without meconium-stained amniotic fluid. The decrease in the prevalence of IPPV was observed in all birthweight groups, although less marked for those with birthweights less than 1500 g, presumably because many of these babies were electively intubated for long-term respiratory support even when their condition at birth is good. However, there was no fall in the proportion of babies with low birthweight that might have accounted for the fall in IPPV. Our findings of reductions in prevalence of intubation over time are consistent with most other studies, in particular those of Lumley *et al.*,<sup>5</sup> Lashen *et al.*,<sup>7</sup> Allwood *et al.*<sup>8</sup> and Rich *et al.*,<sup>9</sup> although a contrary trend was observed in the study of Anthony *et al.*<sup>10</sup> These are generally small<sup>8</sup> studies that examined selected populations (e.g. of very preterm or low birthweight deliveries,<sup>5,6,9,10</sup> or breech presentations<sup>7</sup>) and so are not comparable with the large, effectively population-based study presented here.

The reduction in prevalence of IPPV over time that we found was not due simply to the marked increase in the caesarean section rate over the period, which rose from 12.0% in 1988 to 23.0% in 2000 in our database. Adjustment for method of delivery made little difference to our findings (Figure 2). Likewise, the reduction of prevalence of IPPV was not substantially affected by the reduction in use of general anaesthesia in labour, which fell from 6.9% in 1988 to 2.5% in 2000 (Figure 2).

There may well have been a gradual and unrecognised change in the attitude to IPPV over the study period, as we found falls in the rate of IPPV even after adjustment for meconium staining of the amniotic fluid and for Apgar score at 5 minutes. Although there have recently been substantial alterations in guidelines relating to the birth of babies with meconium-stained amniotic fluid, these have largely occurred



**Figure 5.** Percentage prevalence of intubated IPPV (+95% CI) and calendar year of birth by birthweight ( $n = 153\,290$ ).\*

\*Singleton nulliparous births  $\geq 200$  g, adjusted for mother's ethnic group, smoking habits, maternal height, maternal weight, meconium-stained amniotic fluid, mother's age at booking, Carstairs' score, Apgar score at 5 minutes and mode of delivery.

**Table 2.** Principal regression coefficients (logistic relative risks and 95% CI evaluated by 999 bootstrap samples) in fit of logistic model to data on neonatal IPPV (by intubation or mask) at birth\*

| Variable                                      | IPPV by intubation coefficient | IPPV by mask coefficient |
|-----------------------------------------------|--------------------------------|--------------------------|
| <b>Mother's ethnic group</b>                  |                                |                          |
| White European                                | 1**                            | 1**                      |
| Black African                                 | 2.00 (1.66–2.38)               | 1.19 (1.07–1.31)         |
| Black Caribbean                               | 1.84 (1.49–2.21)               | 1.28 (1.14–1.43)         |
| Indian, Pakistani, Bangladeshi                | 1.00 (0.88–1.14)               | 0.94 (0.89–1.00)         |
| Oriental                                      | 1.36 (1.02–1.71)               | 0.82 (0.71–0.96)         |
| Mediterranean                                 | 2.00 (1.60–2.41)               | 1.03 (0.91–1.16)         |
| Other                                         | 1.24 (1.00–1.51)               | 0.99 (0.89–1.10)         |
| <b>Mother's smoking (cigarettes per day)</b>  |                                |                          |
| 0                                             | 1**                            | 1**                      |
| 1–9                                           | 1.10 (0.97–1.24)               | 0.99 (0.93–1.06)         |
| 10–19                                         | 0.98 (0.84–1.14)               | 1.02 (0.95–1.10)         |
| 20+                                           | 1.11 (0.84–1.41)               | 1.16 (1.01–1.33)         |
| <b>Mother's height (m)</b>                    | 0.88 (0.48–1.61)               | 0.20 (0.15–0.26)         |
| <b>Mother's weight (kg)</b>                   | 1.00 (1.00–1.01)               | 1.00 (1.00–1.01)         |
| <b>Mother's age at booking (years)</b>        |                                |                          |
| 0–19                                          | 1.11 (0.95–1.29)               | 1.05 (0.99–1.13)         |
| 20–24                                         | 1.02 (0.93–1.13)               | 1.05 (1.01–1.10)         |
| 25–29                                         | 1**                            | 1**                      |
| 30–34                                         | 1.12 (1.02–1.23)               | 0.98 (0.93–1.03)         |
| 35–39                                         | 1.28 (1.12–1.48)               | 1.02 (0.95–1.10)         |
| 40+                                           | 1.27 (0.87–1.74)               | 1.00 (0.84–1.19)         |
| <b>Meconium-stained amniotic fluid</b>        |                                |                          |
| No                                            | 1**                            | 1**                      |
| Yes                                           | 9.13 (8.48–9.89)               | 1.61 (1.54–1.68)         |
| <b>Birthweight (g)</b>                        |                                |                          |
| <1500                                         | 49.29 (40.18–60.05)            | 0.81 (0.65–0.99)         |
| 1500–2000                                     | 5.76 (4.75–7.11)               | 1.74 (1.50–2.00)         |
| 2000–2500                                     | 1.65 (1.39–1.92)               | 1.61 (1.50–1.74)         |
| 2500–3000                                     | 1.02 (0.91–1.13)               | 1.10 (1.05–1.15)         |
| 3000–3500                                     | 1**                            | 1**                      |
| 3500–4000                                     | 0.94 (0.85–1.03)               | 1.02 (0.98–1.07)         |
| >4000                                         | 0.83 (0.72–0.97)               | 1.11 (1.04–1.19)         |
| <b>Mode of delivery</b>                       |                                |                          |
| Spontaneous                                   | 1**                            | 1**                      |
| Emergency caesarean                           | 2.22 (1.96–2.52)               | 1.50 (1.41–1.60)         |
| Elective caesarean                            | 1.40 (1.10–1.80)               | 1.25 (1.13–1.38)         |
| Instrumental                                  | 1.84 (1.69–2.03)               | 1.72 (1.65–1.80)         |
| Breech                                        | 2.89 (2.21–3.69)               | 3.53 (3.02–4.13)         |
| <b>Apgar score at 5 minutes</b>               |                                |                          |
| 0–3                                           | 233.89 (161.76–349.16)         | 2.25 (1.63–3.12)         |
| 4–5                                           | 99.20 (81.90–124.98)           | 7.51 (6.29–8.93)         |
| 6                                             | 38.23 (32.29–45.55)            | 14.09 (12.12–16.23)      |
| 7–9                                           | 3.06 (2.84–3.34)               | 3.23 (3.11–3.35)         |
| 10                                            | 1**                            | 1**                      |
| <b>Carstairs' index</b>                       | 1.02 (1.01–1.04)               | 1.00 (1.00–1.00)         |
| <b>Use of general anaesthetic in delivery</b> |                                |                          |
| None                                          | 1**                            | 1**                      |
| General anaesthesia only                      | 2.45 (2.15–2.78)               | 2.09 (1.94–2.26)         |
| General anaesthesia and other analgesic       | 2.32 (1.69–3.14)               | 2.20 (1.82–2.59)         |

\*Among 153 290 singleton nulliparous births  $\geq 200$  g with information on mother's ethnic group, smoking habits, maternal height, maternal weight, calendar year, meconium-stained amniotic fluid, mother's age at booking, mode of delivery, analgesia in delivery, Carstairs' score and Apgar score at 5 minutes.

\*\*Reference category.

since 2000, after the end of follow up in the study. The incidence of meconium-stained amniotic fluid has remained approximately constant, at about 15%, over the period of the study, so that it is unlikely (although by no means impossible) that this variable could affect alterations in prevalence of intubation over time. Moreover, the fact that there has been progressive reduction in the rate of both intubated and masked ventilation does not support the idea that a possible shift from intubated to masked ventilation accounts for the alterations in incidence of intubated IPPV seen in our cohort. There have been some changes in the way resuscitation is performed, for example introduction of T-piece-assisted ventilation instead of bag and mask in the late 1980s and early 1990s in many units; however, the decline in prevalence of neonatal resuscitation in a single hospital was not associated with the introduction of this technique.<sup>8</sup> Changes in resuscitation training should be considered as a factor influencing changes in IPPV rates. Of relevance to this is a study by Draycott *et al.*<sup>16</sup>, who analysed 19 460 births in a single hospital in Bristol over the periods 1998–99 and 2001–03, in particular comparing prevalence of low Apgar scores (Apgar score at 5 minutes of 6 or less) before and after obstetrics emergency training of anaesthetists and midwives. Draycott *et al.*<sup>16</sup> showed statistically significant fewer births with low Apgar scores at 5 minutes, and also fewer births with neonatal hypoxic-ischaemic encephalopathy, for births in the later period compared with those in the earlier.

The Apgar score was originally developed to determine the effects on neonates of the fetal presentation, the mode of delivery and the type of anaesthesia used and to compare the results of obstetric practice at different hospitals, although it was subsequently determined that Apgar score at 1 minute could be used to appraise the need for, or response to, resuscitation.<sup>17–19</sup> Our objective was to examine the need for initial resuscitation of the newborn. As such it would be inadvisable to adjust for Apgar score at 1 minute, as this might be regarded as another measure of this endpoint. However, 5-minute Apgar score is more closely linked to long-term outcome,<sup>20,21</sup> so that it is more appropriate to adjust for this variable to control for case mix. Parallel analyses of Apgar score in the same data set also show a reduction in the prevalence of low Apgar scores, whether measured at 1 or 5 minutes after birth; this reduction in prevalence of low Apgar scores, particularly at 5 minutes, was largely accounted for by reduction in use of general anaesthesia for delivery (M. P. Little, M.-R. Järvelin and D. E. Neasham, unpubl. obs.). Although reductions in the use of general anaesthesia for delivery largely account for the reduction in prevalence of low Apgar scores, the analysis given here suggests that changes in anaesthetic practice cannot account for the reduction in prevalence of intubation.

The limitations of our analysis, based as it is on variables that relate to the medical process and intervention rather than

to more fundamental physiological measures, should be noted. This reflects the limitations of the data available. The endpoint that we measure is therefore a function both of the physiological status of the fetus and the possibly changing criteria in use at the time; these jointly determine the type of intervention felt to be warranted, in particular the use of intubation. We cannot exclude the possibility that there have been such changes in clinical practice over the period of the study. However, there were no significant changes in resuscitation guidelines over the time period of the study, so that changes in clinical practice over the period are unlikely to be pronounced.

One potential source of the observed trend might be changes in the completeness and reliability of definitions and coding through time of IPPV. Much thought was given to how to code for resuscitation of the newborn when the SMMIS database was first set up. The categories were chosen specifically to make them self-evident and as impervious to misunderstanding as possible. In general, it was found that midwives are very good at differentiating between mask IPPV (that they can do themselves, although this is usually done by paediatricians) and intubation IPPV (which relatively few midwives can do). Midwives usually have to call a paediatrician or a neonatal nurse to intubate babies and therefore they are well aware of when this has been done. As the strength of the data collection has always been that it is done and overseen by the clinicians themselves, there is no evidence to suggest that the coding has changed significantly over time.

A potential problem with our analysis is the significant amount of missing data. Only about 68.9% (153 277/222 614) of our sample have a complete set of variables for the regression analysis. It is well known that restricting to records with complete data can potentially introduce bias.<sup>22</sup> The preliminary analysis we have conducted suggests that this should not matter too much in relation to inference on trends of intubation over time. However, this is no substitute for analysis that takes account of the pattern of missingness. Various methods have been proposed for dealing with this, including multiple imputation and more explicitly Bayesian treatments.<sup>22,23</sup>

Although the increase in the rate of delivery by caesarean section and the fall in the rate of general anaesthesia were not a sufficient explanation for the changes we observed, the avoidance of difficult vaginal deliveries may have contributed to the reduction in the number of babies in poor condition at birth, as has been shown in the various studies that have looked at the effect of mode of delivery on the condition of breech babies at birth. The distribution of risk within an obstetric population is unlikely to be symmetrical; thus, a 10% shift from vaginal delivery to caesarean section could theoretically result in a much larger fall in the incidence of poor condition at birth, if the pregnancies in which the mode of delivery was changed contained a high proportion of the

babies at risk. This lack of symmetry in the risk distribution could also explain why despite the substantial falls in the number of babies born in poor condition during the time period of our study, there was no significant change in the overall perinatal mortality rate.

Postterm pregnancy (one with gestation longer than 42 weeks) has been associated with elevated levels of infant and maternal mortality<sup>24</sup> and also with elevated rates of caesarean delivery.<sup>25</sup> Both these might have led to increased induction of pregnancies at 41 weeks or before; indeed, there is evidence of a reduction in the prevalence of postterm pregnancies over time in these data. However, adjusting for duration of gestation hardly affects the evidence for trends in intubation over time (Figure 2).

In conclusion, we suggest that changes in assisted ventilation rates are only minimally associated with increased rates of caesarean section and a reduction in the use of general anaesthesia, but there is a major component that currently remains unexplained.

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