**SUPPLEMENTARY INFORMATION**

**Table S1: Potential explanatory variables and categorisation**

| Type of characteristic | Categorisation |
|------------------------|----------------|
| **Maternal social demographic** | |
| Maternal age (years) | Under 20; 20-24; 25-29; 30-34; 35-39; ≥40 |
| Ethnic group | White (UK & Ireland); White (other); Asian; Black; Other |
| Socioeconomic status (derived from woman’s occupation, or partner’s if woman not in work or with unrecorded/uncodable occupation, using three class NS-SEC) | Higher managerial, admin, prof; Intermediate; Routine and manual; Unemployed/student; Employed, job unrecorded or uncodable; Employment status not recorded |
| Area deprivation quintile (derived from women’s postcode entered by midwives in to postcode look-up website which returned score from Children in Low-income Families Measure, converted into quintiles) | 1st (least deprived); 2nd; 3rd; 4th; 5th (most deprived) |
| Smoking status | Non-smoker during pregnancy; Smoker during pregnancy; Not recorded |
| **Pre-existing clinical factors** | |
| Previous pregnancies ≥24 weeks’ gestation | 0; 1; 2; ≥3 |
| Body mass index (BMI) at booking (kg/m²) | <18.5; 18.5-24.9; 25-29.9; 30-35.0; >35.0; Not recorded |
| Pre-existing medical risk factors (see Table S3) | None; One or more |
| Problems in a previous pregnancy (see Table S3) | None; One or more |
| **Clinical factors arising during pregnancy** | |
| Maternal current pregnancy problem (see Table S4) | None; One or more |
| Fetal current pregnancy problem (see Table S4) | None; One or more |
| Sex of baby | Male; Female |
| Gestation at birth (weeks) | 36-37; 38; 39; 40; 41-42 |
| **Intrapartum-related** | |
| Maternal complications identified at start of labour care (see Table S5) | None; One or more |
| Fetal complications identified at start of labour care (see Table S5) | None; One or more |
| Stage of labour at admission | Latent; Active 1st stage; Passive 2nd stage; Active 2nd stage |
| Duration of 1st stage of labour | Within guidance; Possibly prolonged; Not recorded |
| Duration of 2nd stage of labour | Within guidance; Possibly prolonged; Not recorded |
| Immersion in water during labour | No; Yes |
| Pethidine/diamorphine during labour | No; Yes |
| Duration between pethidine/diamorphine and birth (hours) | Mean (SD); Median (IQR) |
| Fetal heart rate concerns identified | No; Yes |
| Type of characteristic                                                                 | Categorisation                      |
|----------------------------------------------------------------------------------------|-------------------------------------|
| Maternal complications identified during labour, before birth (see Table S6)           | None; One or more                   |
| Fetal complications identified during labour, before birth (see Table S6)              | None; One or more                   |
| Obstetrician consulted for compromise during labour (see Table S6)                    | No; Yes                             |

**Birth-related**

| Variable (unit or how derived) | Categorisation                                      |
|--------------------------------|------------------------------------------------------|
| Shoulder dystocia              | No; Yes                                              |
| Birthweight (g)                | <2500; 2500-2999; 3000-3499; 3500-3999; ≥4500        |
| Birth in water                 | No; Yes                                              |
| Mode of birth                  | Spontaneous vertex; Vaginal breech; Instrumental    |

1 From start of active 1\textsuperscript{st} stage to start of active 2\textsuperscript{nd} stage: Categorised using NICE CG190 as: Within guidance ≤12 hours (nulliparous and multiparous); Possibly prolonged >12 hours (nulliparous and multiparous)

2 From start of active 2\textsuperscript{nd} stage to birth: Categorised using NICE CG190 as: Within guidance ≤2 hours (nulliparous), ≤1 hour (multiparous); Possibly prolonged >2 hours (nulliparous), >1 hour (multiparous)
### Table S2: Neonatal outcomes and categorisation

| Neonatal outcome (unit or how derived) | Categorisation |
|---------------------------------------|----------------|
| Apgar score at 5 minutes              | ≥7; <7         |
| Neonatal resuscitation               | No; Yes        |
| Type of resuscitation                | Stimulation; Positioning/managing airway; Five inflation breaths; Oxygen; Ventilation breaths; Intubation; Chest compression; Neonatal resuscitation drug |
| Neonatal team consulted while baby in midwifery unit | No; Yes |
| Primary reason for neonatal consultation | Respiratory problems; Suspected infection; Suspected perinatal asphyxia; Meconium aspiration; Congenital anomaly; Feeding problems; Physical trauma/birth injury; Other |
| Age of baby when neonatal team first consulted (hours) | Mean (SD); Median (IQR) |
| Skin to skin care                    | No; Yes        |
| Initiation of breastfeeding           | No; Yes        |
| Age of baby at neonatal admission (hours) | Mean (SD); Median (IQR) |
| Where was baby admitted from         | Birth room; Postnatal ward |
| Highest level of care baby received  | Intensive care; High dependency care; Special care |
| Reasons for admission                | Respiratory problems; Suspected infection; Suspected perinatal asphyxia; Meconium aspiration; Hypoglycaemia; Congenital anomaly; Feeding problems; Jaundice; Cardiac problems; Pulse oximetry; Abnormal movements; Hypothermia; Physical trauma/birth injury; Maternal substance abuse; Other |
| Diagnoses on discharge               | Sepsis; Respiratory Distress Syndrome; Congenital Pneumonia; Transient Tachypnoea of the Newborn; Pneumothorax; Hypoxic Ischaemic Encephalopathy; Meconium Aspiration Syndrome; PPHN; Hypoglycaemia; Jaundice; Feeding problems; Birth injury; Congenital anomaly; Cardiac problems; Neonatal Abstinence Syndrome/Social; Normal; Insufficient information/not specified; Other |
Approach for handling missing data

We anticipated that some of the data required to generate body mass index would be unrecorded in women’s notes, and that this ‘missing’ data would not be randomly distributed, so we provided the option at data entry of indicating that height or weight were ‘not recorded’ and used this category in our analysis.

The only other variable with a substantial proportion of missing data was socioeconomic status. This occurred because women’s or their partner’s occupation is often not recorded in women’s notes, and we know from previous work (e.g. Lindquist A, Knight M, Kurinczuk JJ. Variation in severe maternal morbidity according to socioeconomic position: a UK national case-control study. BMJ Open 2013;3:e002742 doi: 10.1136/bmjopen-2013-002742) that these data are not missing at random. Approaches such as multiple imputation would not therefore be appropriate. We therefore included a separate ‘missing/not recorded’ category in our analyses for these variables.

Sample size and power

We anticipated identifying approximately 900 cases over one year, based on an estimated incidence of 1.5% in a population of around 60,000 women (Hollowell J, Puddicombe D, Rowe R, et al. The Birthplace national prospective cohort study: perinatal and maternal outcomes by planned place of birth. Birthplace in England research programme. Final report part 4. London: NIHR Service Delivery and Organisation programme; 2011). The actual number of cases and controls generated 80% power at the 5% level to detect ORs of 1.6 or greater for an exposure variable with a frequency of 5%, and 1.3 or greater for an exposure variable with a frequency of 30%.

Box S1: Additional methodological detail

Table S3: Pre-existing medical and previous pregnancy risk factors

| Medical risk factors                        | Cases (n=1041) | Controls (n=1981) |
|--------------------------------------------|----------------|-------------------|
| Essential hypertension                     | 3 (0.3)        | 2 (0.1)           |
| Confirmed cardiac disease                  | 2 (0.2)        | 1 (0.1)           |
| Thromboembolic disorder                    | 0              | 5 (0.3)           |
| Atypical antibodies                        | 5 (0.5)        | 4 (0.2)           |
| Hyperthyroidism                            | 3 (0.3)        | 5 (0.3)           |
| Diabetes                                   | 2 (0.2)        | 3 (0.2)           |
| Renal disease                              | 0              | 3 (0.2)           |
| Epilepsy                                   | 0              | 2 (0.1)           |

| Problems in previous pregnancy             | Multiparous women only |
|--------------------------------------------|------------------------|
|                                             | n=518                  | n=1280               |
| Previous unexplained/intrapartum-related stillbirth/death | 0                      | 3 (0.2)              |
| Previous baby with Neonatal Encephalopathy | 1                      | 0 (0.0)              |
| Previous primary postpartum haemorrhage requiring treatment | 11 (2.1)              | 19 (1.5)             |
| Previous shoulder dystocia                 | 5 (1.0)                | 3 (0.2)              |
| Previous Caesarean section                 | 5 (1.0)                | 5 (0.4)              |
| “Other” previous pregnancy problem         | 2 (0.4)                | 3 (0.2)              |
### Table S4: Current pregnancy problems

|                      | Cases (n=1037) | Controls (n=1978) |
|----------------------|---------------|------------------|
|                      | n  | %    | n  | %    |
| **Maternal**         |    |      |    |      |
| Group B Streptococcus| 47 | 4.5  | 79 | 4.0  |
| BMI>35kg/m²          | 26 | 2.5  | 34 | 1.7  |
| Post-term (>42 weeks)| 4  | 0.4  | 6  | 0.3  |
| Pre-eclampsia/pregnancy induced hypertension | 3 | 0.3 | 1 | 0.1 |
| Preterm prelabour membrane rupture | 0 | 0 | 1 | 0.1 |
| Substance misuse/alcohol dependency | 4 | 0.4 | 7 | 0.4 |
| Gestational diabetes | 4  | 0.4  | 8  | 0.4  |
| Other                | 1  | 0.1  | 1  | 0.1  |
| **Fetal**            |    |      |    |      |
| Multiple birth       | 0  |      | 0  |      |
| Malpresentation      | 2  | 0.2  | 1  | 0.1  |
| Small for gestational age | 7 | 0.7 | 9 | 0.5 |
| Reduced fetal movements | 4 | 0.4 | 9 | 0.5 |
| Fetal abnormality    | 6  | 0.6  |     |      |

### Table S5: Complications identified at start of labour care

| Complications identified at start of labour care | Cases (n=1035) | Controls (n=1977) |
|-------------------------------------------------|---------------|------------------|
|                                                  | n  | %    | n  | %    |
| **Maternal**                                    |    |      |    |      |
| Maternal tachycardia                            | 9  | 0.9  | 7  | 0.4  |
| Essential hypertension                          | 2  | 0.2  | 4  | 0.2  |
| Proteinuria                                     | 2  | 0.2  | 4  | 0.2  |
| Maternal pyrexia                                | 0  |      | 1  | 0.1  |
| Vaginal blood loss                              | 3  | 0.3  | 1  | 0.1  |
| Prolonged membrane rupture                      | 11 | 1.1  | 19 | 1.0  |
| Pain differing from contractions                | 1  | 0.1  | 1  | 0.1  |
| **Fetal**                                       |    |      |    |      |
| Significant meconium                            | 14 | 1.4  | 10 | 0.5  |
| Non-significant meconium                        | 22 | 2.1  | 27 | 1.4  |
| Abnormal presentation                           | 3  | 0.3  | 0  |      |
| High /free floating head                        | 1  | 0.1  | 0  |      |
| Suspected fetal growth restriction / macrosomia | 5  | 0.5  | 4  | 0.2  |
| Suspected anhydramnios / polyhydramnios         | 2  | 0.2  | 0  |      |
| Fetal heart rate abnormality                    | 6  | 0.6  | 5  | 0.3  |
| Fetal heart rate decelerations                  | 9  | 0.9  | 6  | 0.3  |
| Reduced fetal movements in last 24 hours        | 18 | 1.7  | 18 | 0.9  |

1 Those with non-missing data for complications identified at start of labour care
### Table S6: Complications identified during labour (before birth)

| Complications identified during labour (before birth) | Cases (n=1035) | Controls (n=1981) |
|-------------------------------------------------------|----------------|-------------------|
|                                                       | n  | %   | n  | %   |
| **Maternal**                                          |    |     |    |     |
| Maternal tachycardia                                  | 6  | 0.6 | 9  | 0.5 |
| Hypertension                                          | 4  | 0.4 | 4  | 0.2 |
| Maternal pyrexia                                      | 5  | 0.5 | 3  | 0.2 |
| Vaginal blood loss                                     | 7  | 0.7 | 10 | 0.5 |
| Prolonged membrane rupture                            | 7  | 0.7 | 11 | 0.6 |
| Pain differing from contractions                      | 1  | 0.1 |     |     |
| **Fetal**                                             |    |     |    |     |
| Significant meconium                                  | 120| 11.6| 49 | 2.5 |
| Confirmed/suspected 1\textsuperscript{st} stage delay | 14 | 1.4 | 11 | 0.6 |
| Confirmed/suspected 2\textsuperscript{nd} stage delay | 12 | 1.2 | 10 | 0.5 |
| Obstetric emergency                                   | 15 | 1.5 | 2  | 0.1 |
| Abnormal presentation                                 | 7  | 0.7 | 2  | 0.1 |
| High /free floating head                              | 2  | 0.2 |     |     |
| Fetal heart rate abnormality                          | 22 | 2.1 | 14 | 0.7 |
| Fetal heart rate decelerations                        | 74 | 7.2 | 48 | 2.4 |

Note: more than one complication could be identified in each woman.

### Table S7: Reasons for consultation with obstetrician during labour (before birth)

| Primary reason for consulting obstetrician during labour | Cases (n=821) | Controls (n=801) |
|---------------------------------------------------------|--------------|-----------------|
|                                                         | n  | %   | n  | %   |
| **Maternal**                                            |    |     |    |     |
| Maternal tachycardia                                    | 1  | 1.2 | 1  | 1.3 |
| Hypertension                                            | 0  | 0.0 | 2  | 2.5 |
| Maternal pyrexia                                        | 0  | 0.0 | 2  | 2.5 |
| Vaginal blood loss                                      | 1  | 1.2 |     |     |
| Prolonged membrane rupture                              | 1  | 1.2 | 4  | 5.0 |
| Pain differing from contractions                        | 0  | 0.0 | 1  | 1.3 |
| Other maternal\textsuperscript{2}                       | 11 | 13.4| 15 | 18.8|
| **Fetal**                                               |    |     |    |     |
| Significant meconium                                    | 5  | 6.1 | 5  | 6.3 |
| Confirmed/suspected 1\textsuperscript{st} stage delay   | 6  | 7.3 | 9  | 11.3|
| Confirmed/suspected 2\textsuperscript{nd} stage delay   | 4  | 4.9 | 11 | 13.8|
| Obstetric emergency                                     | 14 | 17.1| 1  | 1.3 |
| Abnormal presentation                                   | 7  | 8.5 | 1  | 1.3 |
| Fetal heart rate abnormality                            | 13 | 15.9| 8  | 10.0|
| Fetal heart rate decelerations                          | 18 | 22.0| 23 | 28.8|
| Reduced fetal movements                                | 4  | 4.9 | 2  | 2.5 |
| Other fetal\textsuperscript{2}                          | 4  | 4.9 | 3  | 3.8 |

\textsuperscript{1} Those for whom an obstetrician was consulted during labour and a reason was given.

\textsuperscript{2} Other, including advising on suitability for AMU, categorised as maternal or fetal on individual basis.

Note: More than one reason could be given for each woman.
Table S8: Level of care and reasons for admission in centres with high and lower number of cases

|                          | Centres with fewer cases (n=810) | Centres with more cases (n=228) | p value |
|--------------------------|----------------------------------|---------------------------------|---------|
| **Highest level of neonatal care** |                                  |                                 |         |
| Intensive care           | 146                              | 36                              | <0.0001 |
| High dependency care     | 272                              | 47                              |         |
| Special care             | 382                              | 145                             |         |
| Missing                  | 10                               | 0                               |         |
| **Reasons for admission**|                                  |                                 |         |
| Respiratory problems     | 594                              | 137                             | <0.0001 |
| Suspected perinatal asphyxia | 81                            | 21                              | 0.72    |
| Hypoglycaemia            | 40                               | 17                              | 0.14    |
| Physical trauma/birth injury | 9                            | 2                               | 0.76    |
| Feeding problems         | 30                               | 14                              | 0.11    |
| Suspected infection      | 320                              | 118                             | 0.001   |
| Meconium aspiration      | 61                               | 25                              | 0.10    |
| Jaundice                 | 21                               | 11                              | 0.09    |
| Congenital anomaly       | 34                               | 12                              | 0.49    |
| Maternal substance abuse | 6                                | 0                               | 0.19    |
| Cardiac problems         | 18                               | 5                               | 1.0     |
| Pulse oximetry           | 11                               | 4                               | 0.66    |
| Abnormal movements       | 11                               | 3                               | 0.96    |
| Hypothermia              | 11                               | 2                               | 0.56    |
| Other                    | 26                               | 6                               | 0.65    |