Epidural analgesia in labour and neonatal and childhood outcomes: national population based cohort study

Rachel J Kearns,[1,2] Aizhan Kyzayeva,[3] Sarjit Singh,[2] Deborah A Lawlor,[4,5] Martin Shaw,[6] Scott Nelson[2]

[1]Department of Anaesthesia, Glasgow Royal Infirmary, Glasgow, UK
[2]School of Medicine, University of Glasgow, Glasgow Royal Infirmary, Glasgow, G31 2ER, UK
[3]School of Health and Wellbeing, University of Glasgow, Glasgow, UK
[4]MRC Integrative Epidemiology Unit at the University of Bristol, Bristol, UK
[5]Population Health Science, Bristol Medical School, University of Bristol, Bristol, UK
[6]Department of Clinical Physics and Bioengineering, NHS Greater Glasgow and Clyde, Glasgow, UK

Correspondence to: R J Kearns
rachel.kearns@glasgow.ac.uk
(or @rjharrison79 on X;
ORCID 0000-0001-6156-6858)

Additional material is published online only. To view please visit the journal online.

Cite this as: *BMJ* 2026;394:e343320
http://dx.doi.org/10.1136/bmj-2026-343320

Accepted: 11 June 2026

ABSTRACT

OBJECTIVES

To examine whether epidural analgesia in labour is associated with neonatal neurological morbidity, other neonatal morbidity, neonatal sepsis, low Apgar score, neonatal mortality, and childhood cerebral palsy.

DESIGN

National population based cohort study.

SETTING

All NHS hospitals in Scotland, using Scottish NHS administrative linked data.

PARTICIPANTS

495 695 women in labour with a singleton pregnancy between 24+0 and 42+6 weeks' gestation delivering vaginally or via unplanned caesarean birth between 1 January 2007 and 31 December 2019.

MAIN OUTCOME MEASURES

The primary outcome was neonatal neurological morbidity defined using ICD-10 codes as one or more of hypoxic ischaemic encephalopathy, neonatal seizures, intraventricular haemorrhage, intraventricular infarction, periventricular leukomalacia, meningitis, encephalitis, kernicterus, hypotonia, birth asphyxia, or other cerebral diagnosis occurring within 28 days of birth. Secondary outcomes were other neonatal morbidity (one or more of acidosis at birth (cord artery pH <7.10), traumatic birth injury, brachial plexus injury, necrotising enterocolitis, respiratory distress syndrome, respiratory failure, pneumothorax, hypoglycaemia, or hypothermia), neonatal sepsis, Apgar score <4 at five minutes following birth, neonatal mortality, and cerebral palsy diagnosed at any point during childhood.

RESULTS

Of the 495 695 women, 114 897 (23.2%) had epidural analgesia in labour. Neonatal neurological morbidity occurred in 434 babies (0.9 per 1000 births, 95% confidence interval (CI) 0.8 to 1.0). No association was found between epidural analgesia in labour and neonatal neurological morbidity (adjusted relative risk 0.87, 95% CI 0.68 to 1.12), other severe neonatal morbidity (1.17, 0.90 to 1.51), neonatal sepsis (1.11, 0.90 to 1.37), Apgar score <4 at five minutes (0.97, 0.87 to 1.09), neonatal mortality at 28 days (0.81, 0.62 to 1.06), or cerebral palsy in childhood (0.80, 0.60 to 1.06). Findings were consistent across subgroups including women considered to have high risk pregnancies, preterm births, and across different modes of birth.

CONCLUSION

Epidural analgesia during labour was not associated with clinically significant risks of harm to newborn babies or children, including risks of neonatal morbidity, death, or cerebral palsy. These findings have important policy implications, and support widening availability and equitable access to epidural analgesia as a safe component of intrapartum care.

WHAT IS ALREADY KNOWN ON THIS TOPIC

Neonatal morbidity can have lifelong consequences

Epidural analgesia in labour provides effective pain relief and may reduce severe maternal morbidity; however, evidence on neonatal and childhood outcomes is limited

Assessing the effect of epidural analgesia in labour on neonatal and childhood morbidity outcomes is a research priority for women and healthcare providers

WHAT THIS STUDY ADDS

Epidural analgesia in labour was not associated with clinically significant increased risks of neonatal morbidity, neonatal mortality, or childhood cerebral palsy

These findings were consistent across subgroups, including high risk pregnancies, preterm births, and different modes of birth

This study provides strong evidence that epidural analgesia in labour is safe for neonates

Introduction

Epidural analgesia is widely regarded as the most effective method of pain relief during labour, contributing to improved maternal satisfaction and facilitating conversion to anaesthesia for operative delivery when required.[1] Poorly controlled pain can lead to the development of physiological stress in mothers, resulting in cortisol and catecholamine release, hyperventilation, increased oxygen consumption, and impaired fetal oxygen transfer.[2] The provision of analgesia in labour may to mitigate these effects and hence benefit both mothers and fetuses.[3 4] In a previous Scottish population based cohort study by this group, we found that epidural analgesia in labour was associated with reduced risk of severe maternal morbidity, a key classifier of near-miss maternal mortality.[4] This was particularly evident in women with high risk pregnancies or giving birth preterm.[4] Maternal and neonatal wellbeing are inextricably linked, making it essential to establish the neonatal safety profile of epidural analgesia to support informed consent and shared decision making.[2 5-9] When consent for epidural analgesia is obtained, however, neonatal effects are less consistently discussed than maternal risks.

Although epidural analgesia in labour offers important maternal benefits, fetuses and subsequently neonates may be affected via placental transfer of drugs and indirect effects through changes to

maternal physiology. Epidural analgesia during labour is associated with physiological side effects such as maternal hypotension, altered uteroplacental perfusion, fetal heart rate abnormalities, and maternal fever, all of which may result in ongoing alterations to a neonate's physiology raising concerns about possible impacts on neonatal and later childhood outcomes.[10 11] Maternal fever secondary to sepsis during labour is strongly associated with adverse outcomes, including neonatal sepsis, hypoxic ischaemic encephalopathy, and cerebral palsy. Infectious fever cannot reliably be distinguished from non-infectious epidural associated fever in real time, and it remains unknown whether the latter results in similar harm to neonates.[12] Understanding these potential risks is important, as increasing evidence highlights the role of epidural analgesia during labour in lowering maternal morbidity.[3 4]

In a 2018 Cochrane review of 40 randomised controlled trials including more than 11 000 women, Apgar scores and neonatal unit admissions did not differ between babies born to mothers who did or did not receive epidural analgesia in labour, although serious neonatal morbidity and longer term outcomes were not assessed.[1] In a previous Scottish population based study (n=435 281), we found no association between epidural analgesia and immediate neonatal or developmental outcomes at age 2 to 3 years, but we did not assess serious neurological morbidity.[5] A US based cohort of more than 230 000 births found no association between epidural analgesia and neonatal hypoxic ischaemic encephalopathy but only included infants born after 35 weeks' gestational age and did not examine cerebral palsy,[13] and a further smaller study from a single geographical area in the US (n=20 929) found no association between epidural analgesia and cerebral palsy.[14] Neither US study accounted for the mother's underlying risk status, and both took place in a healthcare system where the epidural rate was around 75%, limiting applicability of findings to a UK setting where epidural uptake is around 25%, despite being free at the point of access.[13-15] Concerns about potential harm to neonates continue to influence women's decisions about use of epidural analgesia in labour, and women cite fears about effects on their baby as a reason for declining such analgesia.[16] These gaps highlight the need for population level evidence on serious neonatal and childhood neurological outcomes.

In this national population based cohort, we analysed all births in Scotland over a 13 year period to examine whether epidural analgesia during labour was associated with neonatal neurological morbidity. Secondary outcomes included other neonatal morbidity, neonatal sepsis, low Apgar score, neonatal mortality, and cerebral palsy in childhood. Our aim was to generate population level evidence on the safety of epidural analgesia in labour to support clinical counselling and informed decision making.

Methods

Our methods are reported in accordance with Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidance.[17]

Data sources and study population

We linked six Scotland-wide administrative databases: Scottish Morbidity Record-2 (SMR02), Scottish Morbidity Record-1 (SMR01), Scottish Birth Record, National Records of Scotland, Scottish Stillbirth Infant Death Survey, and Scottish Intensive Care Society Audit Group. The SMR01 records all non-obstetric inpatient and day case admissions according to ICD-10 (international classification of diseases, 10th revision) codes and UK NHS OPCS-4 (Office of Population Censuses and Surveys classification of interventions and procedures).[18 19] SMR02 documents all obstetric inpatient and day case admissions during pregnancy and the postnatal period and includes maternal and infant characteristics.[20] SMR01 and SMR02 are subject to regular quality assurance checks, with data around 90% complete.[21 22] All neonatal care is recorded in the Scottish Birth Record. The National Records of Scotland registers all births, stillbirths, and infant deaths, and the Scottish Stillbirth Infant Death Survey collects additional information from the relevant coordinator of the survey (obstetrician, paediatrician, or midwife) at each hospital.

Inclusion and exclusion criteria

We analysed all women in labour with a singleton pregnancy between 24+0 and 42+6 weeks' gestation in Scotland between 1 January 2007 and 31 December 2019. We excluded any births where mode of delivery, child identity, or data for analgesia during labour were not recorded, or where there was a known congenital anomaly (n=29 015, 4.2% of all pregnancies considered). We also excluded women with planned caesarean births as they did not experience labour and could not have chosen to have epidural analgesia (n=84 099, 12.1%; fig 1).

Epidural analgesia

Epidural analgesia was defined as a conventional lumbar epidural administered at any point during labour. Women recorded as not receiving epidural analgesia may have received no additional analgesia or may have undergone spinal or general anaesthesia for operative birth, reflecting the variability in labour progression and clinical decision making. Owing to hierarchical coding of anaesthetic interventions in the SMR02 dataset, it was not possible to determine whether women who received spinal or general anaesthesia had previously received epidural analgesia earlier in labour. Around 5% of women receiving epidural analgesia require conversion to spinal or general anaesthesia.[23] Combined spinal-epidural analgesia could not be separately identified, as it is coded within the dataset as spinal anaesthesia. The use of combined spinal-epidural analgesia in labour

doi: 10.1136/bmj-2026-343320 | *BMJ* 2026;394:e343320 | the bmj

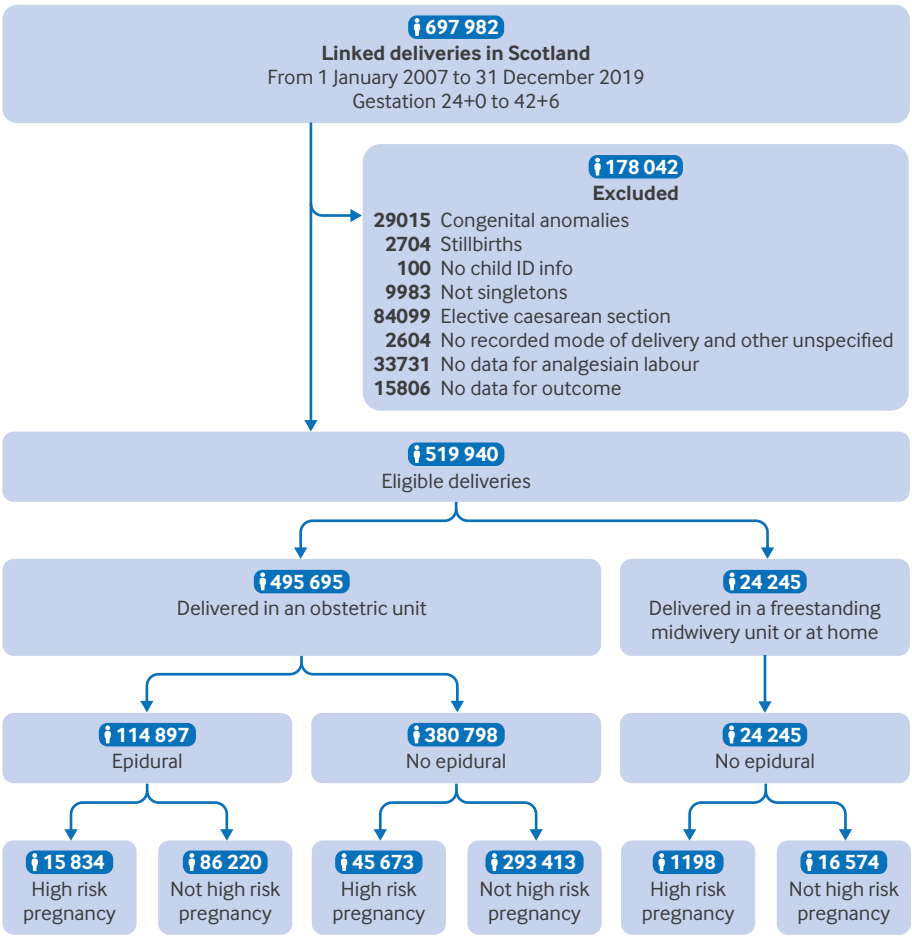


Fig 1 | Flow of participants through study: complete case data

in Scotland is uncommon, accounting for about 1% of epidural procedures.[24]

Outcomes

The primary outcome was a composite of neonatal neurological morbidity, defined as any one or more of hypoxic ischaemic encephalopathy, neonatal seizures, intraventricular haemorrhage, intraventricular infarction, periventricular leukomalacia, meningitis, encephalitis, kernicterus, hypotonia, birth asphyxia, or other cerebral diagnosis occurring from the date of delivery to 28 days post partum.[25-27] All conditions were identified using ICD-10 diagnostic codes from the SMR01 and SMR02 national administrative datasets (see supplementary eTable 1 for specific codes), with diagnoses assigned at discharge by clinical coding staff. Diagnostic codes were not individually validated for this study; however, SMR01 and SMR02 are subject to regular quality assurance checks, with data accuracy around 90%.[21 22] We constructed the composite outcome from clinically related conditions that share plausible mechanistic pathways through which epidural analgesia could affect neonates, all of which represent serious conditions with potential long term consequences. The same direction of effect would be expected for each component, and individual event rates were too low for reliable separate analysis.

Secondary outcomes were other neonatal morbidity (one or more of acidosis at birth (cord artery pH <7.10), traumatic birth injury, brachial plexus injury, necrotising enterocolitis, respiratory distress syndrome, respiratory failure, pneumothorax, hypoglycaemia, or hypothermia, diagnosed from the date of delivery to 28 days post partum[26 27]); neonatal sepsis from date of delivery to 28 days post partum; Apgar score <4 at five minutes following birth; neonatal mortality at 28 days; and cerebral palsy diagnosed at any point during childhood through linked ICD-10 codes from SMR01. ICD-10 codes are provided in supplementary eTable 1.

Confounders and other variables used in analyses

We identified potential measured and unmeasured confounders a priori as variables plausibly associated with both epidural use and neonatal outcomes. Directed acyclic graphs were constructed using DAGitty to visualise both measured and unmeasured confounding.[28] This approach allowed visualisation of unmeasured confounding and assessment of whether such confounding might be mitigated by other measured variables along the same causal pathway (see supplementary eFigures 1 and 2). We included

ethnicity and socioeconomic status because these factors are recognised as influencing both neonatal outcomes and epidural use during labour. Ethnicity was defined using NHS Scotland 2011 census categories.[29] As a proxy for individual socioeconomic status, we used residential area deprivation according to the Scottish Index of Multiple Deprivation - the first 10% of deprivation denoting the most deprived areas and the last 10% the least deprived.[30] We used ICD-10 codes from SMR02 to obtain information on maternal height, weight, comorbidities of pre-eclampsia and diabetes, smoking status, drug use, plus obstetric indices of previous caesarean birth, parity, and induction of labour. Gestational age at birth was based on ultrasound assessment in the first half of pregnancy. Smoking status at the booking visit was defined as current, former, or never. Birth location was categorised into obstetric unit, freestanding midwifery unit, or home. Obstetric units were defined as hospitals with on-site obstetric and anaesthetic services, inclusive of epidural analgesia provision, or midwifery led units co-located with an obstetric unit. Freestanding midwifery units were defined as midwifery led units without direct access to obstetric or anaesthetic care.[31]

In exploratory analyses we assessed whether associations differed by factors known to influence neonatal outcomes. These were preterm birth, the underlying risk status of the mother, and mode of birth. We classified births as preterm if they occurred before 37 weeks' gestation and as term or post-term if they occurred at ≥37+0 weeks.[32] We defined high risk pregnancies as patients with any one or more of serious cardiovascular or respiratory disease (congestive heart failure, congenital heart disease, pulmonary hypertension, ischaemic heart disease, asthma), pre-eclampsia, previous caesarean section, breech presentation, multiple pregnancy, and morbid obesity (body mass index ≥40) diagnosed before the date of delivery (see supplementary eTable 2).[4] These conditions were included if recorded up to the day before delivery to ensure they occurred before the decision to have epidural analgesia. Mode of birth was defined as spontaneous vaginal, instrumental vaginal, or unplanned caesarean.

Statistical analysis

As this was a whole population study, we did not perform sample size calculations. We report baseline characteristics by epidural status, with continuous variables expressed as medians and interquartile ranges (IQRs) and categorical variables as counts and percentages. Our primary analysis included women giving birth in an obstetric unit, as these women would have had access to epidural analgesia if required. We assessed temporal trends in the primary outcome by fitting adjusted Poisson regression models with calendar year as a continuous variable to estimate the adjusted relative risk per year for each outcome. To assess any associations of epidural use with temporal trends, we conducted an epidural×year of birth interaction analysis within the temporal trend models. To adjust for confounders, we used multivariable Poisson regression models with cluster robust sandwich estimators under the generalised estimation equation framework based on directed acyclic graphs (see supplementary eFigures 1 and 2). We chose these models in place of log-binomial models to avoid problems with convergence. The robust estimator was used to correct the inflated variance with the standard Poisson model and to account for more than one birth in some women.[33] As some women gave birth more than once during the study period, descriptive statistics are reported by pregnancy rather than by individual woman. In the modelling of outcome risk, neonates with multiple conditions within the composite outcome were counted once in the primary analysis to avoid double counting within the same outcome category. These models were used to determine absolute risks and adjusted relative risks.

Dealing with missing confounder data

All eligible pregnancies had complete data on epidural analgesia and outcomes. Missing data on confounders varied, with the least for maternal age (0 missing) and most for maternal ethnicity (n=186 112, 37.5%). In total, 253 479 (51.1%) of eligible participants had missing data on one or more confounders. We imputed missing data for confounders using multiple imputations through chained equations to form 10 imputed datasets, employing a predictive mean matching methodology.[34] Ten iterations assured stability of data output, and 10 imputations guaranteed the accuracy of pooled variable effect size estimates.

Additional subgroup analyses

We performed three sets of stratified subgroup analyses using the same adjusted Poisson regression modelling. Firstly, we stratified by gestational age at birth: preterm (<37 weeks) versus term or post-term (≥37 weeks).[32] For the preterm and term or post-term analysis, we excluded gestational age from the adjustment variables. Secondly, by maternal risk status: high risk versus low risk pregnancy (defined as the absence of any high risk criteria). Finally, by mode of birth (spontaneous vaginal, instrumental vaginal, or unplanned caesarean). For the high and low risk pregnancy analysis, we excluded pre-eclampsia, weight, height, and previous caesarean birth from the adjustment variables as they were components of the high risk classification (see supplementary eTable 2). Statistical evidence for a difference between the two related subgroups was assessed by comparing a model with an interaction term (eg, interaction term between epidural analgesia during labour and high risk: yes *v* no) using a likelihood ratio test to compare these two models. We considered a more stringent P<0.01 to provide statistical evidence of a difference in the analysis of subgroups.

Table 1 | Maternal and neonatal characteristics of births in obstetric units in Scotland according to epidural analgesia use in labour. Values are number (percentage) unless stated otherwise

Characteristics	Overall (n=495 695)	No epidural analgesia (n=380 798)	Epidural analgesia (n=114 897)	Standardised mean difference (95% CI)
Median (IQR) maternal age (years)	29.0 (25.0-33.0)	29.0 (25.0-33.0)	29.0 (24.0-33.0)	-0.07 (-0.08 to -0.06)
Median (IQR) maternal weight (kg)	67.0 (59.0-79.0)	67.0 (59.0-79.0)	68.0 (60.0-80.0)	0.06 (0.06 to 0.07)
Missing data	45 610 (9.2)	35 551 (9.3)	10 059 (8.8)	
Median (IQR) maternal height (cm)	164.0 (160.0-169.0)	165.0 (160.0-169.0)	164.0 (160.0-168.0)	-0.06 (-0.07 to -0.05)
Missing data	47 133 (9.5)	35 865 (9.4)	11 268 (9.8)	
Median (IQR) maternal BMI	24.8 (22.0-28.9)	24.7 (21.9-28.7)	25.1 (22.3-29.4)	0.09 (0.08 to 0.10)
Missing data	54 555 (11.0)	41 712 (11.0)	12 843 (11.2)	
Maternal ethnicity:				
White	286 217 (92.5)	217 605 (92.5)	68 612 (92.4)	-0.01 (-0.02 to -0.01)
Asian	14 018 (4.5)	10 611 (4.5)	3407 (4.6)	0.02 (0.01 to 0.02)
Black	4721 (1.5)	3690 (1.6)	1031 (1.4)	-0.01 (-0.01 to 0.00)
Other	3130 (1.0)	2361 (1.0)	769 (1.0)	0.01 (0.00 to 0.01)
Mixed	1497 (0.5)	1 094 (0.5)	403 (0.5)	0.01 (0.00 to 0.02)
Missing data	186 112 (37.5)	145 437 (38.2)	40 675 (35.4)	
SIMD 10th:				
1st (most deprived)	66 494 (13.5)	52 043 (13.7)	14 451 (12.6)	-0.03 (-0.04 to -0.03)
2nd	60 996 (12.3)	47 477 (12.5)	13 519 (11.8)	-0.02 (-0.02 to -0.01)
3rd	54 772 (11.1)	42 171 (11.1)	12 601 (11.0)	0.00 (-0.01 to 0.00)
4th	51 471 (10.4)	39 631 (10.4)	11 840 (10.3)	0.00 (0.00 to 0.00)
5th	48 044 (9.7)	37 500 (9.9)	10 544 (9.2)	-0.02 (-0.03 to -0.02)
6th	44 722 (9.0)	34 649 (9.1)	10 073 (8.8)	-0.01 (-0.01 to -0.01)
7th	44 073 (8.9)	33 645 (8.9)	10 428 (9.1)	0.01 (0.00 to 0.01)
8th	43 840 (8.9)	32 840 (8.6)	11 000 (9.6)	0.03 (0.03 to 0.03)
9th	41 101 (8.3)	30 967 (8.2)	10 134 (8.8)	0.02 (0.02 to 0.03)
10th (least deprived)	38 690 (7.8)	28 759 (7.6)	9931 (8.7)	0.04 (0.04 to 0.05)
Missing data	1492 (0.3)	1116 (0.3)	376 (0.3)	
Smoker status:				
Current	88 207 (18.6)	69 912 (19.2)	18 295 (16.7)	-0.06 (-0.07 to -0.06)
Former	61 904 (13.0)	44 708 (12.2)	17 196 (15.7)	0.11 (0.10 to 0.12)
Never, non-smoker	324 689 (68.4)	250 403 (68.6)	74 286 (67.7)	-0.02 (-0.03 to -0.02)
Missing data	20 895 (4.2)	15 775 (4.1)	5120 (4.5)	
Illicit drug use	7809 (2.2)	5999 (2.2)	1810 (2.2)	0.01 (0.00 to 0.01)
Missing data	137 193 (27.7)	104 832 (27.5)	32 361 (28.2)	
Induction of labour	157 262 (31.8)	104 878 (27.5)	52 384 (45.6)	0.39 (0.39 to 0.40)
Missing data	5458 (1.1)	3884 (1.0)	1574 (1.4)	
Parity	2.0 (1.0-2.0)	2.0 (1.0-2.0)	1.0 (1.0-2.0)	-0.48 (-0.49 to -0.47)
Missing data	2 357 (0.5)	1 829 (0.5)	528 (0.5)	
No of previous caesarean births:				
0	467 142 (94.5)	359 495 (94.6)	107 647 (93.9)	-0.03 (-0.04 to -0.02)
1	24 990 (5.1)	18 355 (4.8)	6635 (5.8)	0.04 (0.03 to 0.05)
≥2	2458 (0.5)	2065 (0.5)	393 (0.3)	-0.05 (-0.05 to -0.04)
Missing data	1105 (0.2)	883 (0.2)	222 (0.2)	
Diabetes	11 880 (2.5)	8641 (2.3)	3239 (2.9)	0.04 (0.03 to 0.04)
Missing data	16 434 (3.3)	13 010 (3.4)	3424 (3.0)	
Pre-eclampsia	6568 (1.3)	4299 (1.1)	2269 (2.0)	0.07 (0.07 to 0.08)
Median (IQR) estimated gestation (weeks)	40.0 (39.0-41.0)	40.0 (39.0-40.0)	40.0 (39.0-41.0)	0.23 (0.22 to 0.24)
Median (IQR) birthweight (g)	3450 (3100-3780)	3430 (3080-3760)	3500 (3180-3835)	0.17 (0.17 to 0.18)
Missing data	534 (0.1)	427 (0.1)	107 (<0.1)	
Mode of delivery:				
Spontaneous vaginal	330 430 (66.7)	288 000 (75.6)	42 430 (36.9)	-0.85 (-0.85 to -0.84)
Unplanned caesarean	91 421 (18.4)	56 453 (14.8)	34 968 (30.4)	0.38 (0.37 to 0.38)
Instrumental	73 844 (14.9)	36 345 (9.5)	37 499 (32.6)	0.59 (0.59 to 0.59)
Year of birth:				
2007	27 290 (5.5)	20 553 (5.4)	6737 (5.9)	0.02 (0.02 to 0.03)
2008	37 985 (7.7)	28 908 (7.6)	9077 (7.9)	0.01 (0.01 to 0.01)
2009	41 164 (8.3)	29 998 (7.9)	11 166 (9.7)	0.07 (0.06 to 0.07)
2010	42 297 (8.5)	31 617 (8.3)	10 680 (9.3)	0.04 (0.03 to 0.04)
2011	42 633 (8.6)	31 769 (8.3)	10 864 (9.5)	0.04 (0.03 to 0.04)
2012	43 649 (8.8)	34 327 (9.0)	9322 (8.1)	-0.03 (-0.04 to -0.03)
2013	41 913 (8.5)	33 029 (8.7)	8884 (7.7)	-0.03 (-0.04 to -0.03)
2014	42 234 (8.5)	32 986 (8.7)	9248 (8.0)	-0.02 (-0.03 to -0.02)
2015	40 519 (8.2)	31 611 (8.3)	8908 (7.8)	-0.02 (-0.03 to -0.01)
2016	39 810 (8.0)	31 267 (8.2)	8543 (7.4)	-0.03 (-0.03 to -0.02)
2017	35 391 (7.1)	27 626 (7.3)	7765 (6.8)	-0.02 (-0.02 to -0.02)
2018	30 999 (6.3)	24 123 (6.3)	6876 (6.0)	-0.01 (-0.02 to -0.01)
2019	29 811 (6.0)	22 984 (6.0)	6827 (5.9)	0.00 (-0.01 to 0.00)

Descriptive analyses are by pregnancy, not individual women. In total, 363 357 women experienced 495 695 pregnancies, with 111 460 contributing more than one pregnancy.
BMI=body mass index; CI=confidence interval; IQR=interquartile range; SIMD=Scottish Index of Multiple Deprivation.

Sensitivity analyses

We conducted several sensitivity analyses to assess the robustness of our findings. Firstly, we performed an analysis of all births regardless of birth setting (ie, obstetric units, midwifery led units, and home). Secondly, we addressed potential exposure misclassification due to crossover between groups. For example, a woman who receives an epidural in labour may subsequently require spinal or general anaesthesia for operative delivery and would thus be included in the control group. Furthermore, she may be recorded as having spinal anaesthesia when in fact she had received combined spinal-epidural analgesia. We therefore conducted a sensitivity analysis restricted to spontaneous vaginal births, comparing women who received epidural analgesia with those who did not, and excluding any woman who was coded as having received a spinal or general anaesthetic. Thirdly, to further model the effect of epidural analgesia on neonatal neurological morbidity, we analysed the association throughout the continuum of gestational ages using robust Poisson regression with non-linear splines. Finally, we compared results from multiple imputation with complete case analyses (n=242 216) to assess the impact of handling missing data.

Patient and public involvement

This study used anonymised national registry data, analysing existing information without direct contact with participants. Patient and public involvement was limited owing to the retrospective nature of the study and lack of dedicated funding for patient and public involvement activities. However, we incorporated public perspectives through several mechanisms: research priorities were informed by the James Lind Alliance priority setting exercise for anaesthesia and perioperative care, which identified maternal and neonatal outcomes as research priorities.[9] Additionally, a patient representative reviewed the final manuscript and provided feedback on the presentation and interpretation of findings, helping to ensure our results were communicated in a clinically meaningful way.

Results

Study population and baseline characteristics

After exclusions, the study included 495 695 women in labour in Scotland between 1 January 2007 and 31 December 2019 (table 1, fig 1), of whom 114 897 (23.2%) received epidural analgesia. Mothers who received epidural analgesia during labour were more likely to be younger, have a higher body mass index, live in an area of less socioeconomic disadvantage, be primiparous, undergo induction of labour, have a multiple birth, have diabetes, have pre-eclampsia, give birth to a higher birthweight baby, and have an operative delivery (table 1). Neonatal neurological morbidity occurred in 434 babies (0.9 per 1000 births) and was more commonly observed in women who did not have epidural analgesia in labour (350/380 798, 0.09% *v* 84/114 897, 0.07%; table 2).

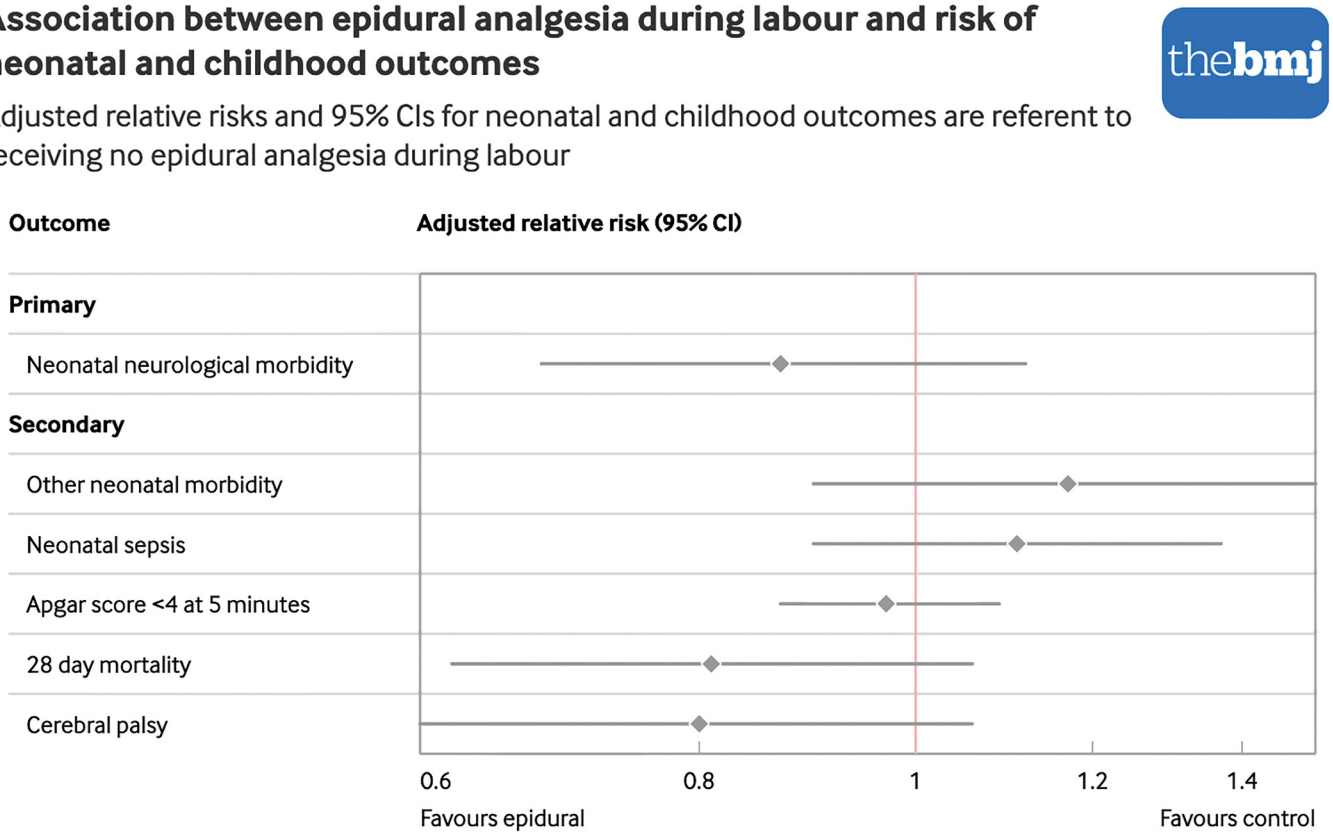
Temporal trends in neonatal neurological morbidity

There was an overall increase in incidence of neonatal neurological morbidity (adjusted relative risk per year 1.05, 95% confidence interval (CI) 1.01 to 1.09) and neonatal sepsis (1.06, 1.05 to 1.08) during the study period (see supplementary eTable 3), driven by an increase in babies with neonatal meningitis, which increased by 9% per year (see supplementary eTable 4 and eFigure 3). During this period the use of epidural analgesia in labour did not increase (see supplementary eFigure 3) and there was no effect modification by epidural status on interaction testing (P=0.64) (see supplementary eTable 4 and eFigures 4a and 4b). In contrast, the incidence of Apgar score <4 at five minutes (relative risk per year 0.93, 0.88 to 0.98), neonatal mortality (0.97, 0.95 to 0.99), and cerebral palsy (0.87, 0.84 to 0.90) all decreased (see supplementary eTable 3).

Table 2 | Observed outcomes for women giving birth in obstetric units in Scotland according to epidural analgesia in labour (reference group: no epidural analgesia (relative risk=1))

Outcomes	Crude event rate (No; % (95% CI))			Unadjusted relative risk (95% CI); P value	Adjusted relative risk* (95% CI); P value
	All pregnancies (n=495 695)	No epidural (n=380 798)	Epidural (n=114 897)		
Neonatal outcomes					
Neurological morbidity†	434; 0.09 (0.08 to 0.10)	350; 0.09 (0.08 to 0.10)	84; 0.07 (0.06 to 0.09)	0.80 (0.63 to 1.01); 0.06	0.87 (0.68 to 1.12); 0.27
Other severe morbidity‡	333; 0.07 (0.06 to 0.07)	243; 0.06 (0.06 to 0.07)	90; 0.08 (0.06 to 0.10)	1.23 (0.96 to 1.56); 0.10	1.17 (0.90 to 1.51); 0.24
Sepsis§	541; 0.11 (0.10 to 0.12)	411; 0.11 (0.10 to 0.12)	130; 0.11 (0.09 to 0.13)	1.05 (0.86 to 1.28); 0.64	1.11 (0.90 to 1.37); 0.32
Apgar score <4¶	1906; 0.38 (0.37 to 0.40)	1504; 0.39 (0.38 to 0.42)	402; 0.35 (0.32 to 0.39)	0.89 (0.79 to 0.99); 0.03	0.97 (0.87 to 1.09); 0.62
Mortality**	527; 0.11 (0.10 to 0.12)	464; 0.12 (0.11 to 0.13)	63; 0.05 (0.04 to 0.07)	0.45 (0.35 to 0.59); <0.001	0.81 (0.62 to 1.06); 0.13
Childhood outcome					
Cerebral palsy††	370; 0.07 (0.07 to 0.08)	311; 0.08 (0.07 to 0.09)	59; 0.05 (0.04 to 0.07)	0.63 (0.48 to 0.83); 0.001	0.80 (0.60 to 1.06); 0.12

CI=confidence interval.
*Adjusted for estimated gestation, maternal age, weight, height, ethnicity, Scottish Index of Multiple Deprivation, smoking history at booking visit, drug misuse, induction of labour, parity, previous caesarean birth, diabetes, pre-eclampsia, and year of birth.
†Defined as any one or more of hypoxic ischaemic encephalopathy, seizures, intraventricular haemorrhage, intraventricular infarction, periventricular leukomalacia, meningitis, encephalitis, kernicterus, hypotonia, birth asphyxia, or other cerebral diagnosis occurring at any point from the date of delivery to 28 days post partum.
‡Defined as any one or more of acidosis at birth (cord artery pH <7.10), traumatic birth injury, brachial plexus injury, necrotising enterocolitis, respiratory distress syndrome, respiratory failure, pneumothorax, hypoglycaemia, or hypothermia diagnosed from the date of delivery to 28 days post partum.
§Diagnosed from the date of delivery to 28 days post partum.
¶Scored at five minutes following birth.
**At 28 days.
††Diagnosed at any point during childhood.



Article DOI: 10.1136/bmj-2026-343320 • Download data

Fig 2 | Adjusted relative risks and 95% confidence intervals for neonatal and childhood outcomes according to use of epidural analgesia in labour. An interactive version of this graphic is available at https://public.flourish.studio/visualisation/29352604/

Association between epidural analgesia in labour and outcomes

There was no association between epidural analgesia and increased risk of neonatal neurological morbidity (adjusted relative risk 0.87, 95% CI 0.68 to 1.12). The upper confidence limit of 1.12 for this outcome excludes a relative increase of more than 12%, providing reassurance that any plausible harmful effect of epidural analgesia is small. Neither was epidural analgesia associated with other severe neonatal morbidity (adjusted relative risk 1.17, 0.90 to 1.51), neonatal sepsis (1.11, 0.90 to 1.37), Apgar score <4 at five minutes (0.97, 0.87 to 1.09), and neonatal mortality at 28 days (0.81, 0.62 to 1.06), nor cerebral palsy at any point during childhood (0.80, 0.60 to 1.06) (table 2, fig 2). The median time to diagnosis of cerebral palsy was 3 years (range 1.5 months to 12 years).

Subgroup analyses

In subgroup analyses, associations between epidural use and outcomes of neonatal neurological morbidity, other severe neonatal morbidity, neonatal sepsis, neonatal mortality, and childhood cerebral palsy did not differ between preterm and term/post-term births, nor between high risk and low risk pregnancies (table 3). A reduced risk of Apgar score <4 at five minutes was found in women who gave birth preterm and had an epidural compared with no epidural analgesia (adjusted relative risk 0.59, 0.44 to 0.79). This was not found in women who gave birth at term or post term (0.98, 0.87 to 1.11); P<0.01 for difference. There was no other statistical evidence of effect modification between groups of preterm versus term/post-term births nor between high risk and low risk pregnancies (table 3).

Epidural analgesia was not associated with increased risks of any outcome regardless of mode of delivery (spontaneous vaginal, instrumental, or unplanned caesarean birth) (table 4).

Robustness of results and sensitivity analyses

Results were similar when all births were included (ie, births in obstetric units plus midwifery led units,

Table 3 | Risk of outcomes in preterm and term or post-term babies of mothers who received epidural analgesia in labour. Values are adjusted relative risk* and 95% CI unless stated otherwise (reference group: no epidural analgesia (relative risk=1))

Outcomes	Preterm births*	Term or post-term births*	P value for difference	High risk mother†	Low risk mother†	P value for difference	Preterm plus high-risk mother‡	Term or post-term plus low risk mother‡	P value for difference
Neonatal outcomes									
Neurological morbidity§	1.06 (0.37 to 3.03); 0.92	0.86 (0.67 to 1.11); 0.25	0.37	1.09 (0.64 to 1.85); 0.75	0.82 (0.62 to 1.08); 0.15	0.24	0.53 (0.02 to 11.9); 0.69	0.80 (0.60 to 1.07); 0.13	0.93
Other severe morbidity¶	1.41 (0.72 to 2.77); 0.32	1.11 (0.84 to 1.47); 0.46	0.53	1.05 (0.53 to 2.06); 0.89	1.21 (0.91 to 1.60); 0.19	0.65	0.56 (0.12 to 2.66); 0.46	1.12 (0.83 to 1.51; 0.46	0.82
Sepsis**	0.45 (0.10 to 2.06); 0.30	1.15 (0.93 to 1.42); 0.20	0.16	1.14 (0.68 to 1.91); 0.63	1.09 (0.87 to 1.37); 0.44	0.80	0.79 (0.10 to 6.08); 0.77	1.13 (0.90 to 1.41); 0.31	0.86
Apgar score <4††	0.59 (0.44 to 0.79); <0.001	0.98 (0.87 to 1.11); 0.80	<0.01	0.76 (0.58 to 0.99); 0.04	1.06 (0.93 to 1.20); 0.39	0.02	0.54 (0.32 to 0.92); 0.02	1.06 (0.93 to 1.22); 0.38	0.02
Mortality‡‡	0.58 (0.38 to 0.86); 0.008	0.74 (0.51 to 1.06); 0.10	0.18	0.74 (0.44 to 1.27); 0.28	0.86 (0.62 to 1.17); 0.33	0.91	0.90 (0.47 to 1.75); 0.77	0.90 (0.60 to 1.36); 0.62	0.94
Childhood outcome									
Cerebral palsy§§	0.58 (0.31 to 1.03); 0.06	0.79 (0.56 to 1.09); 0.15	0.14	0.79 (0.40 to 1.54); 0.48	0.81 (0.59 to 1.11); 0.20	0.89	0.95 (0.37 to 2.48); 0.92	0.83 (0.58 to 1.19); 0.32	0.95

CI=confidence interval.
*Adjusted for maternal age, weight, height, ethnicity, Scottish Index of Multiple Deprivation, smoking history at booking visit, drug misuse, induction of labour, parity, previous caesarean birth, diabetes, pre-eclampsia, and year of birth.
†Adjusted for maternal age, ethnicity, Scottish Index of Multiple Deprivation, smoking history at booking visit, gestation at birth, induction of labour, parity, drug misuse, and year of birth.
‡Adjusted for maternal age, ethnicity, Scottish Index of Multiple Deprivation, smoking history at booking visit, induction of labour, parity, drug misuse, and year of birth.
§Defined as any one or more of hypoxic ischaemic encephalopathy, seizures, intraventricular infarction, periventricular leukomalacia, meningitis, encephalitis, kernicterus, hypotonia, birth asphyxia, or other cerebral diagnosis occurring at any point from the date of delivery to 28 days post partum.
¶Defined as any one or more of acidosis at birth (cord artery pH <7.10), traumatic birth injury, brachial plexus injury, necrotising enterocolitis, respiratory distress syndrome, respiratory failure, pneumothorax, hypoglycaemia, or hypothermia, diagnosed from the date of delivery to 28 days post partum.
**Diagnosed from the date of delivery to 28 days post partum.
††Scored at five minutes following birth.
‡‡At 28 days.
§§Diagnosed at any point during childhood.

plus home births; see supplementary eTable 5), in unadjusted analyses (table 2), and in complete case analyses without imputation (see supplementary eTable 6). Sensitivity analysis examining only spontaneous vaginal births, excluding any subsequent spinal or general anaesthetics, was consistent with our main findings (see supplementary eTable 7). Gestational age did not alter this relation (see supplementary eFigure 5).

Discussion

In this large, population based cohort study of 495 695 births in Scotland between 2007 and 2019, epidural analgesia in labour was not associated with serious neonatal morbidity, neonatal sepsis, low Apgar score, neonatal death, or cerebral palsy in childhood. In addition, there was no evidence that epidural analgesia increased risk in groups traditionally perceived to be more vulnerable, such as preterm infants, operative births, or babies of high risk mothers.

Based on the sample size, exposure prevalence, and baseline risk, the study had about 80% power to detect a relative risk of around 1.3 or greater. For a rare but serious outcome such as hypoxic ischaemic encephalopathy, an increase of around 0.3 per 1000 births (as detectable in this study) would be considered clinically meaningful. However, smaller increases, while still potentially important at a population level, may not have been reliably excluded. Interpreting the upper bounds of the 95% CIs, our results excluded clinically significant harmful effects of epidural analgesia on the outcomes studied and provide reassuring evidence to support the safety of epidural analgesia in labour.

Comparison with other studies

Our study addresses key gaps in a wider body of literature supporting that epidural analgesia in labour is safe for neonates. A 2018 Cochrane review of 40 randomised controlled trials reported no difference in Apgar scores or admission to neonatal units in women randomised to epidural analgesia compared with other analgesia in labour; however, serious neonatal morbidity and longer term childhood outcomes were not assessed.[1] In a 2021 Scottish population based cohort study of more than 400 000 births by our research group, we found no evidence of any association between epidural analgesia in labour and immediate adverse neonatal outcomes or childhood developmental outcomes at age 2-3 years, but we did not assess serious neonatal morbidity or childhood neurological outcomes.[5] Prospective studies focusing on behavioural and neurodevelopmental outcomes in early childhood provide some reassurance but do not specifically address concerns about serious neurological morbidity such as hypoxic ischaemic encephalopathy and cerebral palsy.[35 36] We found only two observational cohort studies examining the association between epidural analgesia and hypoxic ischaemic encephalopathy or cerebral palsy. The first, a US based cohort of more than 230 000 mother-infant pairs, found that epidural analgesia was associated

doi: 10.1136/bmj-2026-343320 | BMJ 2026;394:e343320 | the bmj

Table 4 | Risk of outcomes in babies of mothers who had epidural analgesia in labour according to mode of birth. Values are adjusted relative risk* (95% CI) unless stated otherwise (reference group: no epidural analgesia (relative risk=1))

Outcomes	Spontaneous vaginal birth (n=330 430); P value	Instrumental birth; P value (n=73 844)	P value for difference	Unplanned caesarean birth (n=91 421); P value	P value for difference
Neonatal outcomes					
Neurological morbidity†	1.03 (0.73 to 1.46); 0.85	0.83 (0.45 to 1.53); 0.55	0.61	0.73 (0.44 to 1.20); 0.22	0.38
Other severe morbidity‡	0.54 (0.30 to 0.96); 0.04	1.03 (0.69 to 1.54); 0.88	0.06	1.06 (0.63 to 1.78); 0.82	0.09
Sepsis§	1.25 (0.94 to 1.64); 0.12	1.13 (0.74 to 1.72); 0.58	0.57	1.10 (0.63 to 1.92); 0.74	0.40
Apgar score <4¶	0.92 (0.75 to 1.40); 0.50	0.97 (0.74 to 1.27); 0.82	0.55	0.68 (0.57 to 0.81); <0.001	0.11
Mortality**	1.16 (0.76 to 1.78); 0.50	0.74 (0.38 to 1.44); 0.37	0.24	0.45 (0.29 to 0.71); 0.001	0.03
Childhood outcome					
Cerebral palsy††	0.82 (0.49 to 1.39); 0.47	0.63 (0.34 to 1.16); 0.14	0.78	0.48 (0.30 to 0.75); 0.001	0.33

Interaction testing was performed referent to spontaneous vaginal births.
CI=confidence interval.
*Adjusted for: estimated gestation, age, weight, height, ethnicity, Scottish Index of Multiple Deprivation, smoking history at booking visit, drug misuse, induction of labour, parity, previous caesarean birth, diabetes, pre-eclampsia, year of birth.
†Neonatal neurological morbidity, defined as any one or more of; hypoxic ischaemic encephalopathy, neonatal seizures, intraventricular haemorrhage, intraventricular infarction, periventricular leukomalacia, meningitis, encephalitis, kernicterus, hypotonia, birth asphyxia, or other cerebral diagnosis occurring at any point from the date of delivery to 28-days post-partum.
‡Other severe neonatal morbidity defined as any one or more of; acidosis at birth (cord artery pH < 7.10), traumatic birth injury, brachial plexus injury, necrotising enterocolitis, respiratory distress syndrome, respiratory failure, pneumothorax, hypoglycaemia, or hypothermia), diagnosed from the date of delivery to 28-days post-partum.
§Neonatal sepsis diagnosed from the date of delivery to 28-days post-partum.
¶Apgar < 4 at 5 mins following birth.
**Neonatal mortality at 28-days.
††Cerebral palsy diagnosed at any point during childhood.

with a higher incidence of maternal fever in labour but was not associated with neonatal hypoxic ischaemic encephalopathy.[13] Longer term outcomes such as cerebral palsy were not examined, and only neonates born after 35 weeks' gestation were included, limiting its wider applicability. The second smaller study examined cerebral palsy, but its findings were limited by small sample size (n=20 929) and restricted geographical range.[14] That both studies took place in US healthcare systems where epidural uptake is around 75% and did not consider underlying maternal risk profiles further limits their interpretation. The Scottish epidural rate of 23.2% reflects a healthcare system with a strong tradition of midwifery led care and community midwifery units where epidural analgesia is not available on-site. This rate is broadly consistent with rates in other parts of the UK during the same period.[15 37 38] We recognise that rates are higher in other settings, including the US, where they can exceed 70%.[13] The relative effect of epidural analgesia on neonatal outcomes is a property of the intervention rather than of how often it is used, and therefore the absolute population burden will differ between settings but the relative effect should not. The consistency between our findings and those of an ethnically diverse US cohort supports the external validity of our results.[13]

Although epidural related maternal fever is a recognised concern, we were unable to assess maternal temperature directly and therefore could not examine this association in our cohort. The incidence of fever in all women undergoing labour is estimated at between 1.6% and 14.6% of women.[39] Data from meta-analyses report the incidence of epidural related maternal fever as being between 15% and 25% but do not show a causal link with serious neonatal morbidity.[12 40] Our population level findings are in keeping with this evidence and provide reassurance that epidural use does not increase serious neonatal complications, including neurological morbidity, despite the expected higher rate of fever and regardless of the underlying mechanism.

While epidural analgesia was associated with lower observed rates of some adverse outcomes among women having unplanned caesarean births, formal interaction testing provided no statistical evidence that mode of birth modified the effect of epidural use. The associations observed in this exploratory analysis are consistent with the known advantages of regional anaesthesia over general anaesthesia at the time of operative delivery, and they are hypothesis generating. A functioning epidural that can be topped up for caesarean birth avoids the need for rapid induction of general anaesthesia, which holds greater risk for both mother and baby. In a Scottish population based study of more than 140 000 caesarean births, reduced risks of adverse neonatal outcomes, including need for resuscitation at birth, Apgar score <7 at five minutes, and admission to a neonatal unit, were observed when spinal or epidural anaesthesia was used instead of general anaesthesia in both planned and unplanned caesarean births.[6] Similarly, in a meta-analysis of 46 randomised controlled trials (3689 women), general anaesthesia was associated with lower Apgar scores at five minutes compared with regional techniques,[41] and a large study of World Health Organization data showed an association between general anaesthesia and adverse neonatal outcomes in a low and middle income setting.[42] These data add to the evidence base showing that epidural analgesia does not increase the risk of harm to neonates, and the associations observed in unplanned caesarean births are in keeping with the known advantages of regional anaesthesia over general anaesthesia at the time of operative delivery.

The incidence of neonatal neurological morbidity and neonatal sepsis increased across the study period, driven by increased numbers of reported infants with meningitis. Notably, epidural rates did not change substantially during this period, and epidural

analgesia use did not influence this change after formal interaction testing. These findings may reflect improvements in detection, reporting, laboratory methods, or coding practices, or they may indicate a true increase in disease burden. Publications, including the Surviving Sepsis campaign in 2004 and guidelines on neonatal infection from the National Institute for Health and Care Excellence, are likely to have contributed towards increased awareness of sepsis and may have influenced rates of reported central nervous system infections.[43 44] That the incidence of low Apgar score, neonatal mortality, and cerebral palsy in childhood decreased over the same period indicates that this may be a factor of increased recognition and recording or improved treatment rather than a true increase in disease burden.

Policy implications

These findings are relevant for clinical practice and public health messaging. Epidural analgesia remains the most effective method of pain relief in labour, improving maternal satisfaction and reducing severe maternal morbidity in high risk women.[3 4] Concerns about potential harm to neonates continue to influence clinical decision making and women's choices. Women from ethnic minority groups and from areas of socioeconomic disadvantage are more likely to have high risk pregnancies and may have more benefit from epidural analgesia, yet are less likely to choose it.[3 4 45-47] Possible reasons for this include misinformation, distrust of healthcare professionals, cultural norms, peer pressure, and concerns for their own and their babies' health.[48-51] Differences in healthcare professionals' attitudes as well as institutional and structural biases may act as further barriers to epidural use.[50-52] Our study provides population level reassurance that epidural analgesia in labour does not increase the risk of serious neonatal or childhood morbidity. By addressing concerns about fetal harm as a basis for declining epidural analgesia, these findings remove a barrier to its uptake, particularly for women in groups currently less likely to receive epidural analgesia during birth. These results further support equitable access to epidural analgesia and highlight the importance of shared, evidence informed decision making between women and their care providers.

Strengths and limitations of this study

The primary strength of this study was its large sample size of 495 695 births spanning a 15 year period, reflecting contemporary obstetric and anaesthetic practice. Use of a national dataset with linkage across multiple routine health records enabled long term follow-up of neonatal and childhood outcomes, including cerebral palsy during childhood. We adjusted for confounders identified a priori using directed acyclic graphs, employed multiple imputation for missing confounder data, and showed consistency between imputed and complete case analyses. The additional sensitivity analyses in strata of women with increased risk of adverse neonatal outcomes and with different modes of birth, support the reliability of our findings.

This observational study had several main limitations. Women who receive epidural analgesia in labour differ systematically from those who do not, particularly in parity, birth setting, socioeconomic status, and risk profile, and unmeasured confounding may remain despite adjustment. SMR02 does not record total labour duration, specific indications for epidural analgesia (maternal request versus medical recommendation), timing and duration of analgesia, and severity of fetal distress preceding delivery, nor detailed indications for operative delivery. Adjustment for pre-eclampsia, diabetes, and the high risk classification partially accounts for medically indicated deliveries. Beyond this, prolonged or complicated labours independently increase the risk of adverse neonatal outcomes and strongly predict requests for epidural analgesia. Any residual confounding by indication would therefore be expected to bias our results towards harm in the epidural analgesia group, and the null findings we observed are robust against this concern.

We acknowledge that our study lacked data on physiological variables such as maternal temperature and hypotension and therefore we could not discern which women had developed fever in labour. As a result we were unable to examine the association between epidural analgesia associated maternal fever and neonatal outcomes directly within our cohort. Epidural analgesia is more commonly required and requested in women with more complex medical and obstetric histories, longer labours, malpositioned fetuses, longer interval between rupture of membranes and birth, greater use of oxytocic drugs, more vaginal examinations, and increased duration of epidural analgesia. That all these factors may increase the risk of maternal fever and adverse neonatal outcomes increases our confidence in our findings. We also acknowledge that other forms of anaesthesia may have been used in more urgent clinical scenarios, such as fetal hypoxia, and that this could bias towards more favourable results in the epidural analgesia group. However, our analysis aimed to reflect the different management pathways and possible outcomes depending on a woman's choices about epidural analgesia in labour - for example, a woman having epidural analgesia in labour may use the epidural for anaesthesia if required and is less likely to require general anaesthesia. While some women may have received spinal or general anaesthesia after epidural analgesia (and thus be counted in the control group), the findings of our sensitivity analysis examining only vaginal births where no spinal or general anaesthesia was used were consistent with our main findings. Our analysis is based on administrative diagnostic codes, and we acknowledge that the absence of more detailed data sources, such as individual clinical records or imaging reports, is a limitation and may have resulted in incomplete case ascertainment. This level of granularity is not generally available

within population level administrative datasets and represents a recognised limitation of such studies. We also recognise that the low absolute incidence of the neonatal outcomes limits statistical power; however, this large population based study highlights the value of using such datasets despite their limitations. The upper confidence interval of 1.12 for our primary outcome excludes a relative increase of greater than 12% making any clinically significant increase in risk unlikely. We used widely validated area deprivation indices to indicate socioeconomic status. However, this may not always reflect individual socioeconomic positions - for example, women with higher educational attainment or higher income living in an area with a high deprivation score. Data on ethnicity were missing for 37.5% of women. The consistency of results between imputed and complete case analyses suggests that missing ethnicity data did not materially alter our findings, although residual confounding from ethnicity related factors cannot be excluded.[29] As the population of Scotland is predominantly white, our results might not be generalisable to more diverse populations; however, the similarity of our results to those of a US study with an ethnically diverse population increases confidence in our findings.[13] Additionally, we did not have information on individual care providers and factors influencing maternal decision making about epidural analgesia in labour nor mode of birth. Qualitative studies of women's decision making around use of epidural analgesia in labour may complement these findings and support person centred care.

Conclusion

This analysis of 495 695 births in Scotland found no evidence of a clinically significant association between epidural analgesia in labour and serious neonatal morbidity or mortality or cerebral palsy in childhood. Findings were consistent across subgroups of high risk pregnancies, preterm births, and operative births. These results should reassure parents and clinicians that epidural analgesia use in labour is safe for babies and support informed, evidence based decision making about analgesic options in labour.

We acknowledge the support of the eDRIS team (Public Health Scotland) for their involvement in obtaining approvals, providing and linking data, and the use of the secure analytical platform within the National Safe Haven.

Contributors: RJK, MS, and SN conceived and designed the study. All authors contributed to the acquisition, analysis, or interpretation of the data. RJK, MS, and SN drafted the initial manuscript, and all authors critically revised the manuscript for important intellectual content. RJK, SS, AK, and MS conducted the statistical analyses. RJK, MS, DAL, and SN obtained funding. AK and SS provided administrative, technical, and material support. MS, DAL, and SN supervised the study. RJK, MS, DAL, and SN obtained regulatory approvals and provided analytical advice. RJK is the guarantor. The corresponding author attests that all listed authors meet the criteria for authorship and that no individuals meeting these criteria have been omitted.

Funding: This work was supported by an NHS Greater Glasgow and Clyde senior researcher fellowship (RJK), a research project grant from Wellbeing of Women-Chief Scientist Office (AK and RJK), and a Chief Scientist Office (Scotland) PhD fellowship (SS). DAL's contribution is supported by the UK Medical Research Council (MC_UU_00032/05) and British Heart Foundation (CH/F/20/90003 and AA/18/1/34219). None of the funders had any role in the design, data analyses, or interpretation of results. The views expressed in this publication are those of the author(s) and not necessarily those of the UK NHS or any funders or institutions acknowledged here.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: support form NHS Greater Glasgow and Clyde, Wellbeing of Women, Chief Scientist Office (Scotland), UK Medical Research Council, and British Heart Foundation; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work. Outside of the submitted work, RK is a board member of the Obstetric Anaesthetists' Association. RK has declared funding from Wellbeing of Women (for research unrelated to this work in the past 36 months). SMN has participated in advisory boards and received speakers or consultancy fees from Access Fertility, Beckman Coulter, Ferring, Finox, Merck, MSD, Roche Diagnostics, and The Fertility Partnership. SMN has declared funding from the Chief Scientist Office, Wellbeing of Women, and National Institute of Health and Care Research (NIHR), for research unrelated to this work in the past 36 months. All funds for these grants go to and are managed and audited by the University of Glasgow. DAL has declared funding from the NIHR, Diabetes UK, and US National Institute of Research, for research unrelated to this work in the past 36 months. All funds for these grants go to and are managed and audited by the University of Bristol. DAL is a member of the UK Biobank strategic oversight committee, chair of the scientific advisory board for the Bradford Health Research Institute public health "ActEarly" Programme, and chair of the NIHR and BHF (British Heart Foundation) partnership working group on maternal cardiovascular health. She does not receive any payment for these activities. MS, AK, and SS certify they have no affiliations with or involvement in any organisation or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors declare no other relationships or activities that could appear to have influenced the submitted work.

Ethical approval: The Public Benefit and Privacy Panel for Health and Social Care (HSC-PBPP) of NHS Scotland provided ethical approval for the linkage (ref 1920-0097) and the NHS Greater Glasgow and Clyde Research and Development department approved the study (ref GN20PH059).

Data sharing: De-personalised study data are not held by the authors and cannot be made available directly by the authors. Access to these data may be granted to accredited researchers who submit an application to NHS Scotland's electronic Data Research and Innovation Service (eDRIS), and whose application is approved in accordance with the relevant governance and regulatory requirements. The authors of this manuscript have no authority to grant access to, share, or approve the release of the data.

Transparency: The lead author (RJK) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported, that no important aspects of the study have been omitted, and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Dissemination to participants and related patient and public communities: To maximise the reach of our findings, we will use a multifaceted dissemination strategy aimed at both academic and public audiences. This includes sharing content via social media platforms such as X and Facebook, engaging healthcare professionals, the public, and policymakers. We will work with patient advocacy groups (eg, the Maternal Mental Health Alliance and FIVExMORE) and professional bodies like the Royal College of Obstetricians and Gynaecologists, Royal College of Anaesthetists, and Obstetric Anaesthetists' Association to ensure wide distribution, using accessible formats such as lay summaries and infographics. Press releases and conference presentations will support academic engagement, while social media will provide a valuable feedback loop to inform future research and policy.

Provenance and peer review: Not commissioned; externally peer reviewed.

1 Anim-Somuah M, Smyth RMD, Cyna AM, et al. Epidural versus non-epidural or no analgesia for pain management in labour. *Cochrane Database of Systematic Reviews* 2018;5:CD000331. doi:10.1002/14651858.CD000331.pub4.

2 Kearns RJ, Lucas DN. Neuraxial analgesia in labour and the foetus. *Best Pract Res Clin Anaesthesiol* 2023;37:73-86. doi:10.1016/j.bpa.2023.02.005
3 Guglielminotti J, Landau R, Daw J, et al. Use of Labor Neuraxial Analgesia for Vaginal Delivery and Severe Maternal Morbidity. *JAMA Netw Open* 2022;5:e220137. doi:10.1001/jamanetworkopen.2022.0137
4 Kearns RJ, Kyzayeva A, Halliday LOE, et al. Epidural analgesia during labour and severe maternal morbidity: population based study. *BMJ* 2024;385:e077190. doi:10.1136/bmj-2023-077190
5 Kearns RJ, Shaw M, Gromski PS, et al. Association of Epidural Analgesia in Women in Labor With Neonatal and Childhood Outcomes in a Population Cohort. *JAMA Netw Open* 2021;4:e2131683. doi:10.1001/jamanetworkopen.2021.31683
6 Kearns RJ, Shaw M, Gromski PS, et al. Neonatal and early childhood outcomes following maternal anesthesia for cesarean section: a population-based cohort study. *Reg Anesth Pain Med* 2021;46:482-9. doi:10.1136/rapm-2020-102441
7 Palmer E, Ciechanowicz S, Reeve A, et al. Operating room-to-incision interval and neonatal outcome in emergency caesarean section: a retrospective 5-year cohort study. *Anaesthesia* 2018;73:825-31. doi:10.1111/anae.14296
8 Reynolds F. Labour analgesia and the baby: good news is no news. *Int J Obstet Anesth* 2011;20:38-50. doi:10.1016/j.ijoa.2010.08.004
9 Boney O, Bell M, Bell N, et al. Identifying research priorities in anaesthesia and perioperative care: final report of the joint National Institute of Academic Anaesthesia/James Lind Alliance Research Priority Setting Partnership. *BMJ Open* 2015;5:e010006. doi:10.1136/bmjopen-2015-010006
10 Abrão KC, Francisco RPV, Miyadahira S, et al. Elevation of uterine basal tone and fetal heart rate abnormalities after labor analgesia: a randomized controlled trial. *Obstet Gynecol* 2009;113:41-7. doi:10.1097/AOG.0b013e31818f5eb6
11 Callahan EC, Lee W, Aleshi P, et al. Modern labor epidural analgesia: implications for labor outcomes and maternal-fetal health. *Am J Obstet Gynecol* 2023;228:S1260-9. doi:10.1016/j.ajog.2022.06.017
12 Morton S, Kua J, Mullington CJ. Epidural analgesia, intrapartum hyperthermia, and neonatal brain injury: a systematic review and meta-analysis. *Br J Anaesth* 2021;126:500-15. doi:10.1016/j.bja.2020.09.046
13 Cornet MC, Kuzniewicz MW, Scheffler AW, et al. Epidural Analgesia During Labor and Neonatal Hypoxic-Ischemic Encephalopathy. *JAMA Netw Open* 2024;7:e2433730. doi:10.1001/jamanetworkopen.2024.33730
14 Zhang L, Graham JH, Feng W, et al. No association of labor epidural analgesia with cerebral palsy in children. *J Anesth* 2016;30:1008-13. doi:10.1007/s00540-016-2244-8
15 NHS patient survey programme. 2019 survey of women's experiences of maternity care. https://www.cqc.org.uk/sites/default/files/20200128_mat19_statisticalrelease.pdf. 21 Aug 2025.
16 Weinstein ER, Aaronson J, Abramovitz SE, et al. Patients' perspectives on pain relief during childbirth and labor epidurals: a pilot qualitative study among women who chose to deliver without neuraxial labor analgesia. *Int J Obstet Anesth* 2025;61:104294. doi:10.1016/j.ijoa.2024.104294
17 von Elm E, Altman DG, Egger M, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *The Lancet* 2007;370:1453-7. doi:10.1016/S0140-6736(07)61602-X
18 World Health Organization. The ICD-10 classification of mental and behavioural disorders: clinical descriptions and diagnostic guidelines. Geneva: World Health Organization, 1992. https://www.who.int/publications/i/item/9241544228. 21 Aug 2025.
19 Office of Population Censuses and Surveys. Classification of Interventions and Procedures (OPCS-4.10). 2025. https://digital.nhs.uk/data-and-information/information-standards/governance/latest-activity/standards-and-collections/dapb0084-opcs-classification-of-interventions-and-procedures/#current-release. Accessed 18 Jul 2025.
20 SMR Datasets, SMR02 - Maternity Inpatient and Day Case. Information Services Division Scotland. Data Dictionary. https://publichealthscotland.scot/resources-and-tools/health-intelligence-and-data-management/national-data-catalogue/smr-data-manual/definitions-by-smr-record-section/smr02-maternity-inpatient-and-day-case/general-definitions/. 21 Aug 2025.
21 NSS Information and Intelligence. Data Quality Assurance Assessment of SMR02 (Maternity Inpatient and Day Case) Data; Scotland 2017-2018. Isdscotland.org. 2019. https://www.isdscotland.org/Products-and-Services/Data-Quality/docs/20191023-Assessment-of-SMR02-Data-Scotland-2017-2018.pdf. 12 Apr 2026.
22 NHS National Services Scotland. Data quality and assurance: assessment of SMR01 data Scotland 2014-2015. ISD Scotland, 2015. https://www.isdscotland.org/Products-and-Services/Data-Quality/docs/Assessment-of-SMR01-Data-2014-15-report-181019.pdf
23 Halpern SH, Soliman A, Yee J, et al. Conversion of epidural labour analgesia to anaesthesia for Caesarean section: a prospective study of the incidence and determinants of failure. *Br J Anaesth* 2009;102:240-3. doi:10.1093/bja/aen352
24 Vedagiri Sai R, Rappai G, Johnstone C. Survey of obstetric epidural anaesthetic practises in Scotland [Abstract]. Presented at the Obstetric Anaesthetists' Association Annual Meeting, Bournemouth 2013:43.
25 Gale C, Statnikov Y, Jawad S, et al. Neonatal brain injuries in England: population-based incidence derived from routinely recorded clinical data held in the National Neonatal Research Database. *Arch Dis Child Fetal Neonatal Ed* 2018;103:F301-6. doi:10.1136/archdischild-2017-313707
26 Razaz N, Bolk J, Graham H, et al. Severe Neonatal Morbidity Across Gestational Age: Monitoring Infants at High Risk of Mortality. *Acta Paediatr* 2025;114:1847-56. doi:10.1111/apa.70038
27 Triggs T, Crawford K, Hong J, et al. The influence of birthweight on mortality and severe neonatal morbidity in late preterm and term infants: an Australian cohort study. *Lancet Reg Health West Pac* 2024;45:101054. doi:10.1016/j.lanwpc.2024.101054
28 Textor J, van der Zander B, Gilthorpe MS, et al. Robust causal inference using directed acyclic graphs: the R package 'dagitty'. *Int J Epidemiol* 2016;45:1887-94. doi:10.1093/ije/dyw341
29 SMR Datasets. Patient Identification and Demographic Information. Ethnic Group. Information Services Division Scotland. Data Dictionary. https://publichealthscotland.scot/resources-and-tools/health-intelligence-and-data-management/national-data-catalogue/data-dictionary/search-the-data-dictionary/ethnic-group/. Accessed 13 Jun 2025.
30 Scottish Government. Scottish index of multiple deprivation 2020: introductory booklet. https://www.gov.scot/collections/scottish-index-of-multiple-deprivation-2020/. 15 Jun 2025.
31 Brocklehurst P, Hardy PBirthplace in England Collaborative Group, et al. Perinatal and maternal outcomes by planned place of birth for healthy women with low risk pregnancies: the Birthplace in England national prospective cohort study. *BMJ* 2011;343:d7400. doi:10.1136/bmj.d7400
32 World Health Organization. Preterm birth. https://www.who.int/news-room/fact-sheets/detail/preterm-birth. Accessed 15 Jun 2025.
33 Chen W, Qian L, Shi J, et al. Comparing performance between log-binomial and robust Poisson regression models for estimating risk ratios under model misspecification. *BMC Med Res Methodol* 2018;18:63. doi:10.1186/s12874-018-0519-5
34 Kontopantelis E, White IR, Sperrin M, et al. Outcome-sensitive multiple imputation: a simulation study. *BMC Med Res Methodol* 2017;17:2. doi:10.1186/s12874-016-0281-5
35 Isik OG, Junaid S, Guo L, et al. Behavioural and neuropsychological outcomes in children exposed in utero to maternal labour epidural analgesia. *Br J Anaesth* 2024;133:334-43. doi:10.1016/j.bja.2024.02.036
36 Asif S, Tu HF, White RA, et al. Labour epidural analgesia and early childhood behavioural outcomes: the moderating role of maternal mental health and pro-inflammatory cytokines. *Anaesthesia* 2026. doi:10.1111/anae.70203. Epub ahead of print.
37 Bhatia K, Columb M, Shelton C, et al. Epidural labour analgesia rates during the COVID-19 pandemic in the north-west of England. *Anaesthesia* 2022;77:1055-6. doi:10.1111/anae.15780
38 Bamber JH, Lucas DN, Plaat F, et al. Obstetric anaesthetic practice in the UK: a descriptive analysis of the National Obstetric Anaesthetic Database 2009-14. *Br J Anaesth* 2020;125:580-7. doi:10.1016/j.bja.2020.06.053
39 Burgess APH, Katz JE, Moretti M, et al. Risk Factors for Intrapartum Fever in Term Gestations and Associated Maternal and Neonatal Sequelae. *Gynecol Obstet Invest* 2017;82:508-16. doi:10.1159/000453611
40 Jansen S, Lopriore E, Naaktgeboren C, et al. Epidural-Related Fever and Maternal and Neonatal Morbidity: A Systematic Review and Meta-Analysis. *Neonatol* . 2020;117:259-70. doi:10.1159/000504805.
41 Kim WH, Hur M, Park SK, et al. Comparison between general, spinal, epidural, and combined spinal-epidural anesthesia for cesarean delivery: a network meta-analysis. *Int J Obstet Anesth* 2019;37:5-15. doi:10.1016/j.ijoa.2018.09.012
42 Lumbiganon P, Moe H, Kamsa-Ard S, et al. Outcomes associated with anaesthetic techniques for caesarean section in low- and middle-income countries: a secondary analysis of WHO surveys. *Sci Rep* 2020;10:10176. doi:10.1038/s41598-020-66897-8
43 Martin GS, Kane-Gill SL, Nadkarni V, et al. The Evolution of Toolkits and Bundles to Improve the Care of Sepsis Patients. *Crit Care Med* 2021;49:1849-50. doi:10.1097/CCM.0000000000005356

44 National Institute for Health and Care Excellence. Suspected sepsis in pregnant or recently pregnant people: recognition, diagnosis and early management, 2025. NICE Guideline NG255. https://www.nice.org.uk/guidance/ng255. Accessed 1 Dec 2025.
45 Knight M, Bunch K, Felker A, Patel R, Kotnis R, Kenyon S, Kurinczuk JJ, MBRRACE-UK. *Saving Lives, Improving Mothers' Care Core Report - Lessons learned to inform maternity care from the UK and Ireland Confidential Enquiries into Maternal Deaths and Morbidity 2019-21* . Oxford: National Perinatal Epidemiology Unit, University of Oxford, 2023.
46 Bamber JH, Goldacre R, Lucas DN, et al. A national cohort study to investigate the association between ethnicity and the provision of care in obstetric anaesthesia in England between 2011 and 2021. *Anaesthesia* 2023;78:820-9. doi:10.1111/anae.15987
47 Halliday L, Shaw M, Kyzayeva A, et al. Socio-economic disadvantage and utilisation of labour epidural analgesia in Scotland: a population-based study. *Anaesthesia* 2024;79:473-85. doi:10.1111/anae.16236
48 Toledo P, Sun J, Peralta F, et al. A qualitative analysis of parturients' perspectives on neuraxial labor analgesia. *Int J Obstet Anesth* 2013;22:119-23. doi:10.1016/j.ijoa.2012.11.003
49 D'Souza RS, D'Souza S, Sharpe EE. YouTube as a source of medical information about epidural analgesia for labor pain. *Int J Obstet Anesth* 2021;45:133-7. doi:10.1016/j.ijoa.2020.11.005
50 Starr A, Dasilva G, Soto P, et al. A scoping review of barriers experienced by underserved and rural maternal populations in accessing epidural analgesia in the United States. *J Anesth* 2026;40:123-44. doi:10.1007/s00540-025-03586-8
51 Foulon J, Mackay R, Bamber JH, et al. Experiences of obstetric anaesthesia care among minoritised ethnic groups in England: a qualitative study. *Int J Obstet Anesth* 2026;66:104921. doi:10.1016/j.ijoa.2026.104921
52 The All-Party Parliamentary Group on Birth Trauma. Listen to Mums: Ending the Postcode Lottery on Perinatal Care. 2024. https://www.theo-clarke.org.uk/sites/www.theo-clarke.org.uk/files/2024-05/Birth%20Trauma%20Inquiry%20Report%20for%20Publication_May13_2024.pdf. Accessed 1 Oct 2025.

Supplementary file: Additional information