

Brain injury occurring during or soon after birth: annual incidence and rates of brain injuries to monitor progress against the national maternity ambition

2020 national data

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1 Context

In November 2015, the Secretary of State for Health announced a national ambition to halve the annual rates of stillbirth, neonatal death, maternal death and brain injuries occurring during or soon after birth in England.

The Department of Health recognised that there was a lack of consensus in relation to the definition of *brain injury occurring during or soon after birth*, and limited data sources for measuring such brain injuries. Therefore, the Department of Health commissioned work to define *brain injury occurring during or soon after birth*, and using the National Neonatal Research Database (NNRD) established a baseline for 2010 and calculated annual rates up to 2019. These data have been previously published^{1 2 3 4}.

The Department of Health and Social Care want to build on this previous work, specifically to track progress towards the National Maternity Ambition to halve the rate of *brain injuries occurring during or soon after birth* by 2025, with a 20% reduction by 2020⁵.

In this follow-up report we provide the following rates for 2020 in England:

- (a) Annual rates of *brain injuries occurring during or soon after birth* for all gestational ages, and for term and preterm infants separately.**
- (b) Annual rates of individual conditions that contribute to *brain injuries occurring during or soon after birth*.**

¹ Brain injury occurring during or soon after birth: a report for the national maternity ambition commissioned by the Department of Health

https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/662974/Report_on_brain_injury_occuring_during_or_soon_after_birth.pdf

² Gale C, Statnikov Y, Jawad S On behalf of the Brain Injuries expert working group, et al., Neonatal brain injuries in England: population-based incidence derived from routinely recorded clinical data held in the National Neonatal Research Database. *Archives of Disease in Childhood - Fetal and Neonatal Edition* <https://fn.bmjjournals.org/content/early/2017/10/22/archdischild-2017-313707>

³ Gale C, Jeyakumaran D, Ougham K, Jawad S, Uthaya S, Modi N. Brain injury occurring during or soon after birth: annual incidence and rates of brain injuries to monitor progress against the national maternity ambition. 2016 and 2017 data <https://www.imperial.ac.uk/media/imperial-college/medicine/dept-medicine/infectious-diseases/neonatology/Brain-injury-occurring-during-or-soon-after-birth-120419-V3.3.pdf>

⁴ Gale C, Ougham K, Jawad S, Uthaya S, Modi N. Brain injury occurring during or soon after birth: annual incidence and rates of brain injuries to monitor progress against the national maternity ambition. 2018 and 2019 data <https://www.imperial.ac.uk/media/imperial-college/medicine/dept-medicine/infectious-diseases/neonatology/2018-2019-Brain-injury-occurring-during-or-soon-after-birth-NATIONAL-DATA-280121.pdf>

⁵ Safer maternity care: progress and next steps. Department of Health, November 2017 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/662969/Safer_maternity_care_-progress_and_next_steps.pdf

2 Methods

2.1 Defining brain injuries occurring during or soon after birth

The definition for *brain injuries occurring during or soon after birth* for the national maternity ambition was agreed by an expert group as previously described⁶. This definition is as follows:

- **Population:** *all babies admitted to a neonatal unit in England*
- **Time period after birth:** *all brain injuries that are detected during the neonatal unit stay*
- **Conditions to be included:**
 - a. *Infants with a diagnosis consistent with hypoxic ischaemic encephalopathy: term and near-term infants only*
 - b. *Infants with a diagnosis of intracranial haemorrhage, perinatal stroke, hypoxic ischaemic encephalopathy (HIE), central nervous system infection, and kernicterus (bilirubin encephalopathy): all infants*
 - c. *preterm white matter disease (periventricular leukomalacia): preterm infants only*
 - d. *Infants with a recorded seizure: all infants*
- **Denominator:** *all live births in England* to be used as the denominator for calculating the annual rate of “brain injuries occurring during or soon after birth”
- **Exclusions:** a consensus decision⁴ was made to present data before and after exclusion of infants with the following conditions leading to brain injury prior to birth: *congenital encephalopathies (including inborn errors of metabolism), congenital infections and congenital brain abnormalities*

For 2020 we present additional data reporting rates of brain injuries after exclusion of babies with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia (as described in 2.5).

Further descriptive information and the NNRD data fields used to determine *brain injuries occurring during or soon after birth* and exclusions are shown in Appendix 1.

⁶ Brain injury occurring during or soon after birth: a report for the national maternity ambition commissioned by the Department of Health
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/662974/Report_on_brain_injury_occuring_during_or_soon_after_birth.pdf

2.2 Numerator data source: National Neonatal Research Database

The Department of Health and Social Care commissioned the National Neonatal Research Database (NNRD) as the numerator source for the calculation of rates of *brain injuries occurring during or soon after birth* for the national maternity ambition.

The NNRD is formed from summary electronic patient data entered on all admissions to National Health Service (NHS) neonatal units in England, Scotland, and Wales. Data in the NNRD have undergone processing to identify duplicates, out of range values, internal inconsistencies, and other potentially erroneous entries. In addition to these internal processes, feedback and quality assurance checks are undertaken with clinicians for key items. Data in the NNRD are merged across multiple patient episodes, if necessary, for the purposes of an analysis.

All neonatal units (currently 100% of NHS neonatal units in England), that contribute data to the NNRD form the UK Neonatal Collaborative, UKNC. Approximately 450 predefined data items, the Neonatal Data Set⁷, are extracted quarterly from these electronic patient records to form the NNRD. The Neonatal Data Set is an approved NHS Information Standard (DAPB1595) and the NNRD is a national Information Asset.

National counts of *brain injuries occurring during or soon after birth* are calculated using a cohort of infants who receive at least one episode of care in an NHS neonatal unit in England. As part of the NNRD data cleaning process, babies with missing gestational age or missing birth year are excluded from the analysis data set. To extract counts for term and preterm babies, gestational ages of ≥ 37 weeks and < 37 weeks respectively were applied.

⁷https://www.datadictionary.nhs.uk/data_sets/clinical_data_sets/national_neonatal_data_set/national_neonatal_data_set_-_episodic_and_daily_care.html

2.3 Denominator data sources: National live births

To calculate national rates for 2020, denominator data from the Office for National Statistics (ONS) Birth Summary Tables for England⁸, describing total live births by gestational age (in weeks) for 2020 where mothers' usual residence is England, were used. These data were also used as the denominator when calculating rates of medical conditions leading to *brain injuries occurring during or soon after birth* where gestational age is specified. Births were extracted from a dataset containing birth registrations linked to their corresponding notification and infants missing gestational age and where birth weight was inconsistent with gestational age were excluded. As a result, lower numbers of live births are reported for these analyses than for analyses that include all infants.

⁸ Office for National Statistics, 2021. Live births occurring in 2020 by week of gestation, England. Available at: <https://www.ons.gov.uk/>

2.4 Statistical methods

We present rates of brain injuries per 1,000 live births unless otherwise stated. For years 2012-2019 rates of brain injuries were calculated as described previously^{9 10 11}.

Confidence intervals (CI) for rates have been calculated using the following method:

1) Calculate error factor (EF):

$$EF = e^{(1.96/\sqrt{D})}$$

where D = number of brain injuries

2) Calculate lower and upper CI:

$$\text{Lower CI} = \text{Rate} \div EF$$

$$\text{Upper CI} = \text{Rate} \times EF$$

⁹ Gale C, Statnikov Y, Jawad S et al on behalf of the Brain Injuries expert working group. Neonatal brain injuries in England: population-based incidence derived from routinely recorded clinical data held in the National Neonatal Research Database. *Archives of Disease in Childhood - Fetal and Neonatal Edition*

<https://fn.bmjjournals.org/content/early/2017/10/22/archdischild-2017-313707>

¹⁰ Gale C, Jeyakumaran D, Ougham K, Jawad S, Uthaya S, Modi N. Brain injury occurring during or soon after birth: annual incidence and rates of brain injuries to monitor progress against the national maternity ambition. 2016 and 2017 data. Last accessed 18th January 2021 <https://www.imperial.ac.uk/media/imperial-college/medicine/dept-medicine/infectious-diseases/neonatology/Brain-injury-occurring-during-or-soon-after-birth-120419-V3.3.pdf>

¹¹ Gale C, Ougham K, Jawad S, Uthaya S, Modi N. Brain injury occurring during or soon after birth: annual incidence and rates of brain injuries to monitor progress against the national maternity ambition. 2018 and 2019 data <https://www.imperial.ac.uk/media/imperial-college/medicine/dept-medicine/infectious-diseases/neonatology/2018-2019-Brain-injury-occurring-during-or-soon-after-birth-NATIONAL-DATA-280121.pdf>

2.5 Exclusion of babies with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia

Therapeutic hypothermia is a well-established treatment for moderate or severe hypoxic ischaemic encephalopathy where it has been demonstrated to reduce mortality without an increase in disability in high income settings such as the United Kingdom¹².

There is evidence from the United Kingdom and other countries that increasing numbers of babies with mild hypoxic ischaemic encephalopathy are being treated with therapeutic hypothermia, despite an absence of evidence that they will benefit from this treatment^{13 14}. The consensus definition for *brain injuries occurring during or soon after birth* was developed to include babies with moderate or severe hypoxic ischaemic encephalopathy, and to exclude babies with mild hypoxic ischaemic encephalopathy. However, the consensus definition for *brain injuries occurring during or soon after birth* includes all neonates treated with at least 48 hours of therapeutic hypothermia regardless of severity of hypoxic ischaemic encephalopathy. Evidence from the United Kingdom suggests that this definition may be including increasing numbers of babies with mild hypoxic ischaemic encephalopathy¹⁴.

To ensure that data presented in this report are not affected by inclusion of increasing numbers of babies with mild hypoxic ischaemic encephalopathy who receive at least 48 hours of therapeutic hypothermia, for 2020 data onwards we present additional data describing rates of brain injury after neonates with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia are excluded. Rates are presented per 1,000 live births, as previously. The denominator and numerator data are as previously described, but in addition we have excluded the following group:

Additional exclusion:

- **Conditions excluded:**
 - a. *Infants treated with 48 hours of therapeutic hypothermia without a diagnosis of moderate or severe hypoxic ischaemic encephalopathy*

¹² Jacobs SE, Berg M, Hunt R, Tarnow-Mordi WO, Inder TE, Davis PG. Cooling for newborns with hypoxic ischaemic encephalopathy. Cochrane Database of Systematic Reviews 2013, Issue 1. Art. No.: CD003311. DOI: 10.1002/14651858.CD003311.pub3

¹³ Yieh L, Lee H, Lu T, et al. Neonates with mild hypoxic-ischaemic encephalopathy receiving supportive care versus therapeutic hypothermia in California. Archives of Disease in Childhood - Fetal and Neonatal Edition 2022;107:324-328.

¹⁴ Hage L, Jeyakumaran D, Dorling J, Ojha S, Sharkey D, Longford N, Modi N, Battersby C, Gale C. Changing clinical characteristics of infants treated for hypoxic-ischaemic encephalopathy in England, Wales and Scotland: a population-based study using the National Neonatal Research Database. Arch Dis Child Fetal Neonatal Ed. 2021 Sep;106(5):501-508.

3 Results

3.1 National rates of brain injuries

3.1.1 Rates of brain injuries in England: all gestational ages

Numerator:	Annual number of infants who received at least one episode of care within a neonatal unit in England with a <i>brain injury occurring during or soon after birth</i> , with and without exclusions, obtained from the NNRD.
Denominator:	Annual number of live births in England obtained from ONS Birth Summary Tables ^{15 16} .

Table 1 presents the incidence and crude rates per 1,000 live births of brain injuries, with and without exclusions of infants with conditions leading to brain injury prior to birth, for years 2012 to 2020. Figure 1 displays the crude rates of brain injuries per 1,000 live births prior to exclusions.

¹⁵ Office for National Statistics, last accessed 14th December 2020, <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/12561livebirthsstillbirthsandneonataldeathsbygestationalageinengland2010to2018neonataldeathsand2010to2019livebirthsandstillbirths>

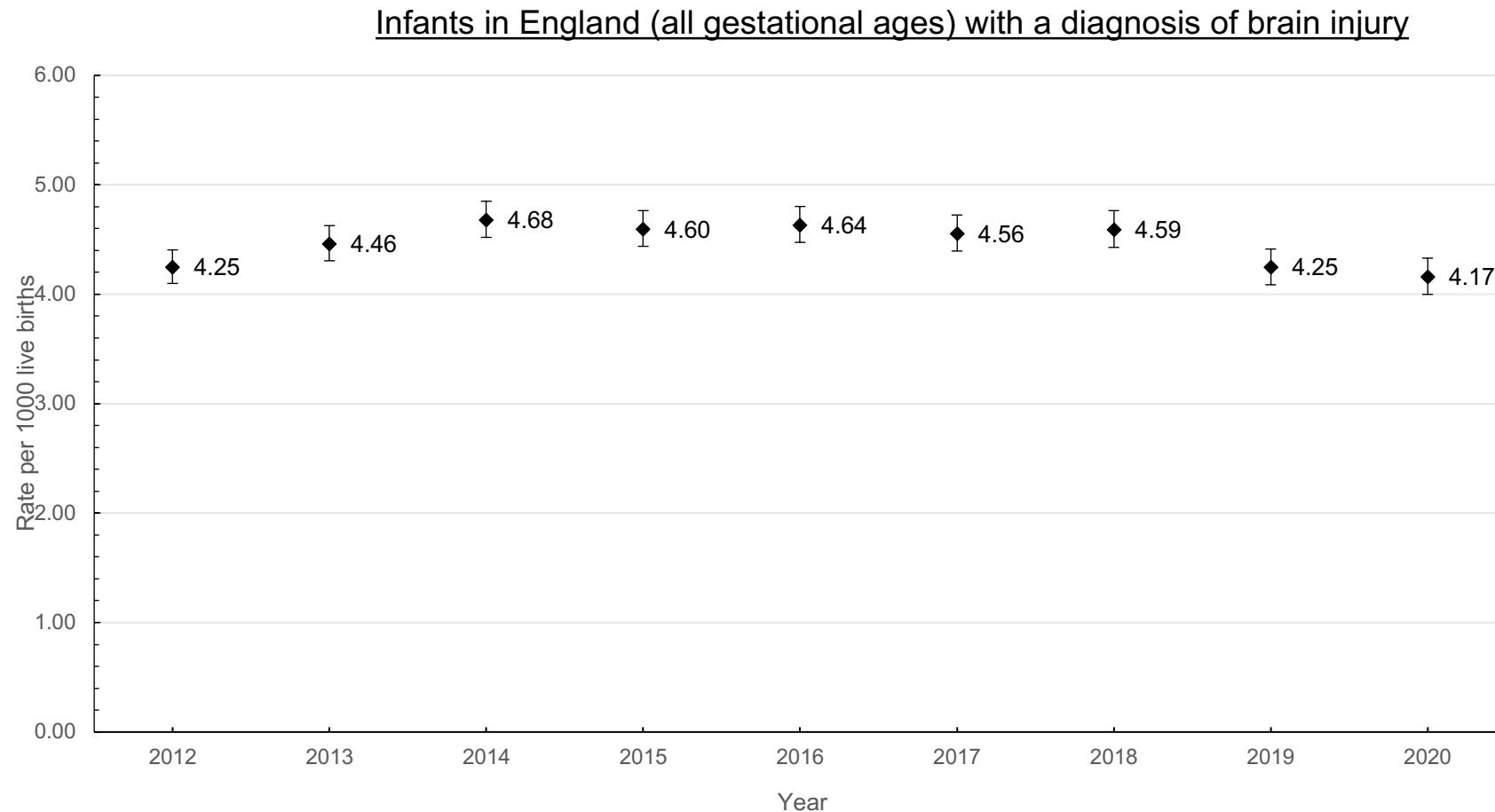
¹⁶ Office for National Statistics, 2021. Live births occurring in 2020 by week of gestation, England. Available at: <https://www.ons.gov.uk/>

Table 1: Infants in England (all gestational ages) with a diagnosis of brain injury, before and after exclusion of infants with conditions leading to brain injury prior to birth.

Year	Infants recorded in the NNRD	Infants recorded in the NNRD with GA available (%)	Live births in England	Before exclusion of infants with conditions leading to brain injury prior to birth		After exclusion of infants with conditions leading to brain injury prior to birth		
				Infants with brain injury	Rate of brain injuries per 1000 live births (95%CI)	Exclusions	Infants with brain injury	Rate of brain injuries per 1000 live births (95% CI)
2012	78,980	78,952 (99.96)	694,241	2,950	4.25 (4.10,4.41)	76	2,874	4.14 (3.99, 4.29)
2013	80,222	80,199 (99.97)	664,517	2,966	4.46 (4.31,4.63)	62	2,904	4.37 (4.21, 4.53)
2014	85,013	84,981 (99.96)	661,496	3,097	4.68 (4.52,4.85)	56	3,041	4.60 (4.44,4.76)
2015	88,931	88,785 (99.84)	664,399	3,055	4.60 (4.44,4.76)	54	3,001	4.52 (4.36, 4.68)
2016	92,582	92,487 (99.90)	663,157	3,074	4.64 (4.47,4.80)	65	3,009	4.54 (4.38, 4.70)
2017	97,405	97,341 (99.93)	646,794	2,947	4.56 (4.39,4.72)	57	2,890	4.47 (4.31, 4.63)
2018	96,641	96,629 (99.99)	625,310	2,872	4.59 (4.43,4.76)	69	2,803	4.48 (4.32, 4.65)
2019	94,734	94,717 (99.98)	610,140	2,591	4.25 (4.09, 4.41)	53	2,538	4.16 (4.00, 4.32)
2020	89,210	89,196 (99.98)	583,895	2,432	4.17 (4.00, 4.33)	58	2,374	4.07 (3.91, 4.23)

Abbreviations: CI: confidence interval, GA: gestational age

Figure 1: Annual rates of brain injury occurring during or soon after birth in England (all gestational ages) 2012-2020 without exclusions; error bars indicate 95% confidence intervals



3.1.2 Rates of brain injuries in England: term infants

Numerator:	Annual number of term infants (≥ 37 weeks gestational age) who received at least one episode of care within a neonatal unit in England with a <i>brain injury occurring during or soon after birth</i> in England, with and without exclusions, obtained from the NNRD.
Denominator:	Annual number of term live births in England obtained from ONS Live Births by Gestational Age ^{17 18} .

Table 2 presents the incidence and crude rates per 1,000 live term births of brain injuries in term infants, with and without exclusions of infants with conditions leading to brain injury prior to birth, for years 2012 to 2020. Figure 2 displays the crude rates of brain injuries in term infants per 1,000 live term births, prior to exclusions.

¹⁷ Office for National Statistics, last accessed 14th December 2020, <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/12561livebirthsstillbirthsandneonataldeathsbygestationalageinengland2010to2018neonataldeathsand2010to2019livebirthsandstillbirths>

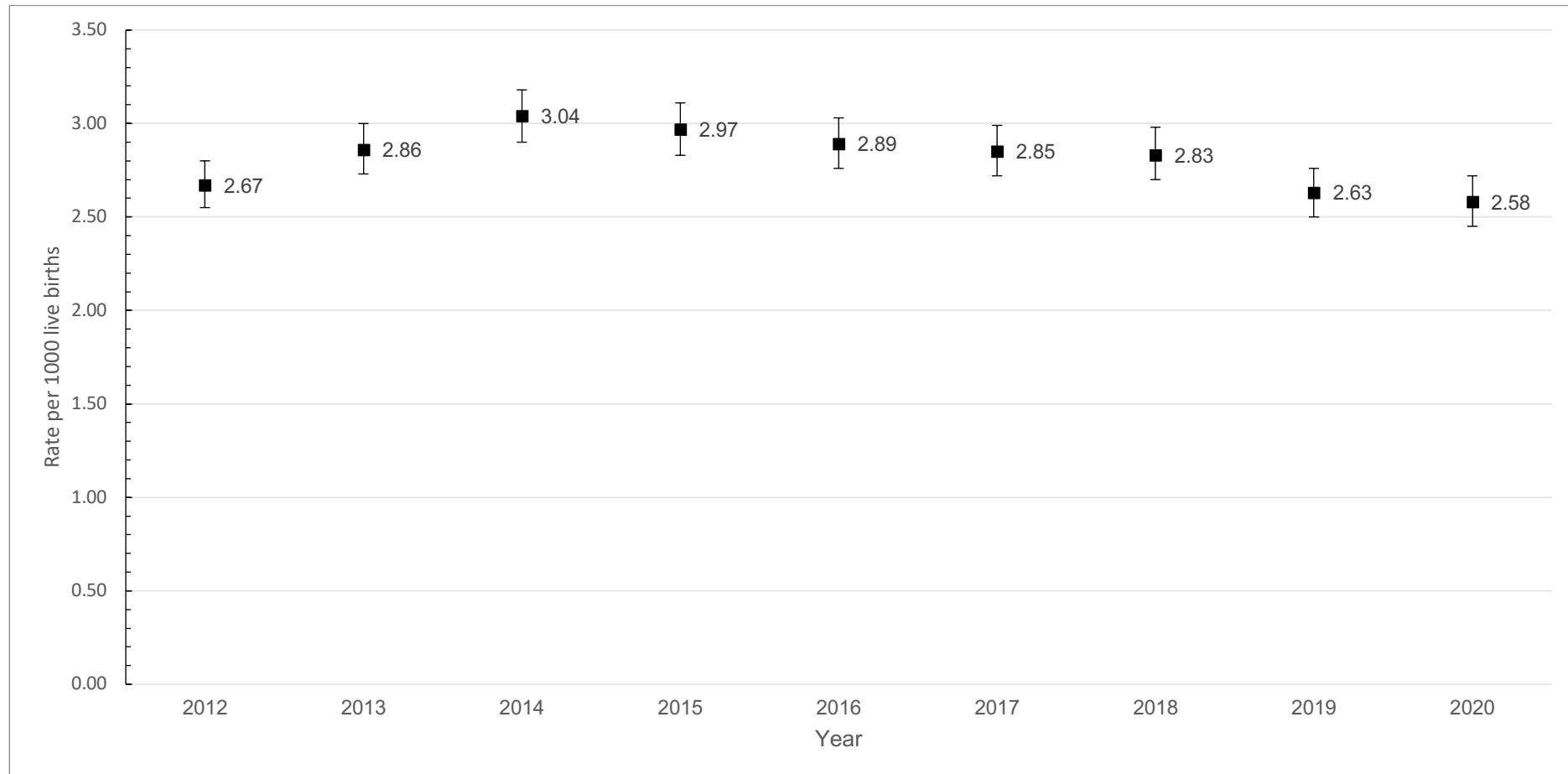
¹⁸ Office for National Statistics, 2021. Live births occurring in 2020 by week of gestation, England. Available at: <https://www.ons.gov.uk/>

Table 2: Term infants in England (≥ 37 weeks gestational age) with a diagnosis of brain injury, before and after exclusion of infants with conditions leading to brain injury prior to birth.

Year	Term infants recorded in the NNRD	Term live births in England	Before exclusion of infants with conditions leading to brain injury prior to birth		After exclusion of infants with conditions leading to brain injury prior to birth		
			Term infants with brain injury	Rate of brain injuries per 1000 term live births (95%CI)	Exclusions	Term Infants with brain injury	Rate of brain injuries per 1000 term live births (95% CI)
2012	46,200	640,787	1714	2.67 (2.55, 2.80)	53	1661	2.59 (2.47, 2.72)
2013	47,935	612,816	1754	2.86 (2.73, 3.00)	41	1713	2.80 (2.67, 2.93)
2014	51,945	607,972	1848	3.04 (2.90, 3.18)	44	1804	2.97 (2.83, 3.11)
2015	55,045	609,076	1808	2.97 (2.83, 3.11)	37	1771	2.91 (2.78, 3.05)
2016	58,069	609,118	1760	2.89 (2.76, 3.03)	38	1722	2.83 (2.70, 2.96)
2017	62,558	593,339	1692	2.85 (2.72, 2.99)	42	1650	2.78 (2.65, 2.92)
2018	62,930	574,063	1,627	2.83 (2.70, 2.98)	40	1587	2.76 (2.63, 2.90)
2019	61,989	560,765	1,473	2.63 (2.50, 2.76)	34	1439	2.57 (2.44, 2.70)
2020	58,573	538,715	1,392	2.58 (2.45, 2.72)	32	1,360	2.52 (2.39, 2.66)

Abbreviations: CI: confidence interval

Figure 2: Annual rates of brain injury occurring during or soon after birth in England in term infants (≥ 37 gestational weeks) 2012-2020 without exclusions; error bars indicate 95% confidence intervals



3.1.3 Rates of brain injuries in England: preterm infants

Numerator:	Annual number of preterm infants (<37 weeks gestational age) who received at least one episode of care within a neonatal unit in England with a <i>brain injury occurring during or soon after birth</i> in England, with and without exclusions, obtained from the NNRD.
Denominator:	Annual number of preterm live births in England obtained from ONS Live Births by Gestational Age ^{19 20} .

Table 3 presents the incidence and crude rates per 1,000 live preterm births of brain injuries in preterm infants, with and without exclusions of infants with conditions leading to brain injury prior to birth, for years 2012 to 2020. Figure 3 displays the crude rates of brain injuries in preterm infants per 1,000 live preterm births, prior to exclusions.

¹⁹ Office for National Statistics, last accessed 14th December 2020, <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/12561livebirthsstillbirthsandneonataldeathsbygestationalageinengland2010to2018neonataldeathsand2010to2019livebirthsandstillbirths>

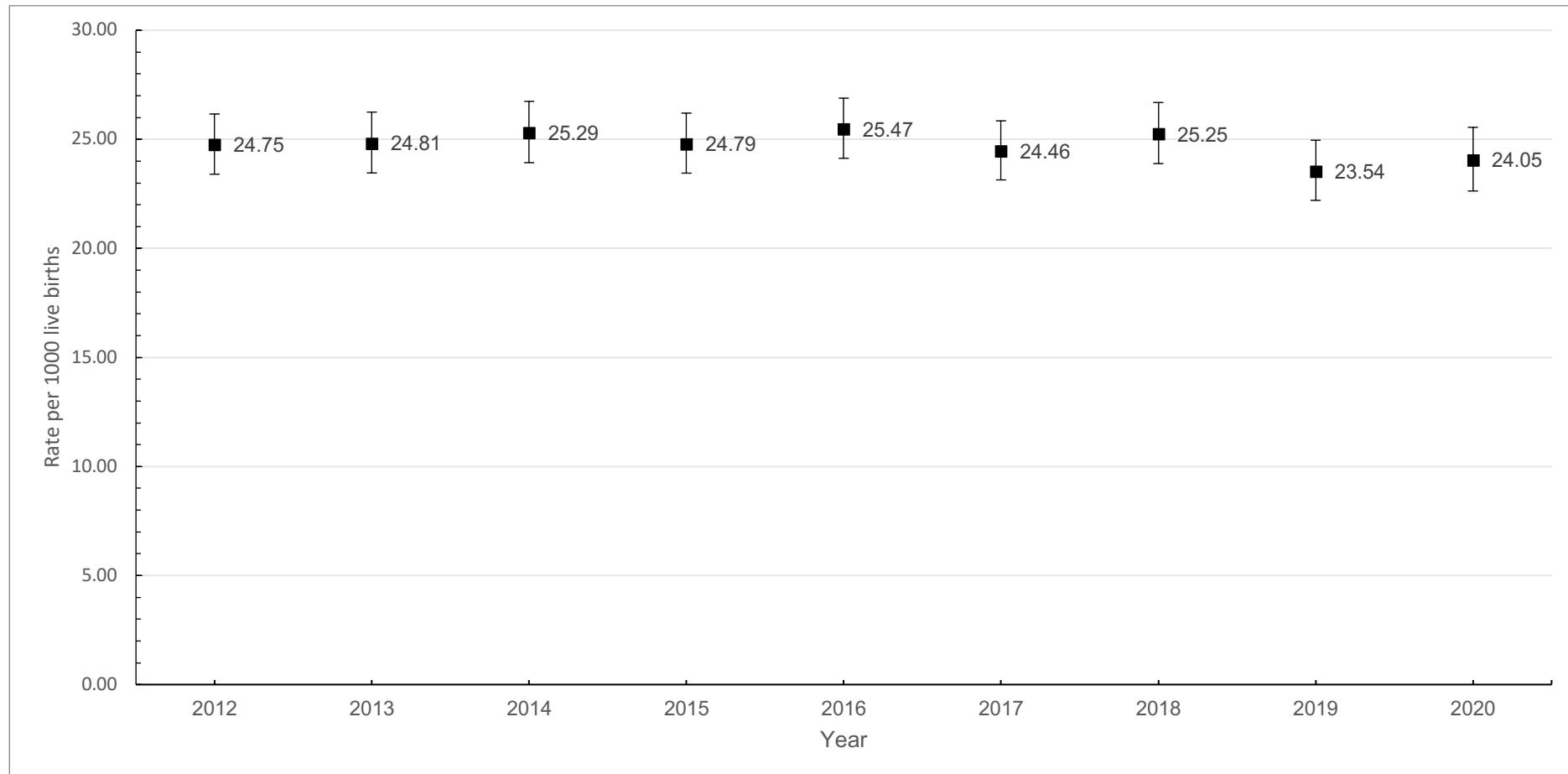
²⁰ Office for National Statistics, 2021. Live births occurring in 2020 by week of gestation, England. Available at: <https://www.ons.gov.uk/>

Table 3: Preterm infants in England (<37 weeks gestational age) with a diagnosis of brain injury, before and after exclusion of infants with conditions leading to brain injury prior to birth.

Year*	Preterm infants recorded in the NNRD	Preterm live births in England	Before exclusion of infants with conditions leading to brain injury prior to birth		After exclusion of infants with conditions leading to brain injury prior to birth		
			Preterm infants with brain injury	Rate of brain injuries per 1000 term live births (95%CI)	Exclusions	Preterm infants with brain injury	Rate of brain injuries per 1000 preterm live births (95% CI)
2012	32,752	49,949	1236	24.75 (23.40, 26.16)	23	1213	24.28 (22.96, 25.69)
2013	32,264	48,844	1212	24.81 (23.46, 26.25)	21	1191	24.38 (23.04, 25.81)
2014	33,036	49,379	1249	25.29 (23.93, 26.74)	12	1237	25.05 (23.69, 26.49)
2015	33,740	50,308	1247	24.79 (23.45, 26.20)	17	1230	24.45 (23.12, 25.85)
2016	34,418	51,581	1314	25.47 (24.13, 26.89)	27	1287	24.95 (23.62, 26.35)
2017	34,783	51,307	1255	24.46 (23.14, 25.85)	15	1240	24.17 (22.86, 25.55)
2018	33,699	49,302	1245	25.25 (23.89, 26.69)	29	1216	24.66 (23.32, 26.09)
2019	33,028	47,488	1118	23.54 (22.20, 24.96)	19	1099	23.14 (21.81, 24.55)
2020	30,623	43,252	1040	24.05 (22.63, 25.55)	26	1014	23.44 (22.04, 24.91)

Abbreviations: NNRD: National Neonatal Research Database; CI: confidence interval

Figure 3: Annual rates of brain injury occurring during or soon after birth in England in preterm infants (<37 gestational weeks) 2012-2020 without exclusions; error bars indicate 95% confidence intervals



3.1.4 Rates of brain injuries in England by condition

Numerators:	Number of infants who received at least one instance of care within a neonatal unit in England with individual conditions included in the definition of <i>brain injuries occurring during or soon after birth</i> obtained from the NNRD: <ol style="list-style-type: none"> 1. All gestational ages 2. Term births only (≥ 37 gestational weeks) 3. Preterm births only (< 37 gestational weeks)
Denominators:	<ol style="list-style-type: none"> 1. Annual number of live births in England obtained from ONS Birth Summary Tables^{21 22}. 2. Annual number of term live births in England obtained from ONS Live Births by Gestational Age^{17 18}. 3. Number of preterm live births in England obtained from ONS Live Births by Gestational Age^{17 18}.

Tables 4 - 10 present the national rates of different conditions leading to brain injury at or soon after birth. Further explanation of the way different conditions are defined, including the relevant NNRD data items, can be found in Appendix 1. It was possible for infants to be diagnosed with more than one condition leading to brain injury at or soon after birth, so the sum of total number of cases in tables 4 to 9 will not match totals in tables 1 to 3.

It is important to note that the definition of hypoxic ischaemic encephalopathy (HIE) included within the definition of *brain injuries occurring during or soon after birth* is different from the definition used in other national reports (e.g. the National Neonatal Audit Programme audit measure *encephalopathy*²³ and Each Baby Counts outcome *severe brain injury*²⁴).

Low numbers of annual cases of *bilirubin encephalopathy* were reported. To ensure confidentiality and prevent disclosure of protected information cases of *bilirubin encephalopathy* are presented in aggregate over the six-year period between 2012 and 2020.

²¹Office for National Statistics, last accessed 14th December 2020, <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/12561livebirthsstillbirthsandneonataldeathsbygestationalageinengland2010to2018neonataldeathsand2010to2019livebirthsandstillbirths>

²² Office for National Statistics, 2021. Live births occurring in 2020 by week of gestation, England. Available at: <https://www.ons.gov.uk/>

²³ National Neonatal Audit Programme A guide to the 2018 audit measures; v1.2 published November 2018, last accessed 21st March 2019; <https://www.rcpch.ac.uk/sites/default/files/2018-11/NNAP%202018%20Audit%20Measures%20Guide%20v1.2%20FINAL.pdf>

²⁴ Royal College of Obstetricians and Gynaecologists. Each Baby Counts: 2015 Full Report. London: RCOG, 2017, last accessed 21st March 2019; <https://www.rcog.org.uk/en/guidelines-research-services/audit-quality-improvement/each-baby-counts/ebc-2015-report/>



Table 4: Infants in England with hypoxic ischaemic encephalopathy (HIE)

HIE	Year								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cases	1,128	1,161	1,257	1,243	1,204	1,171	1,164	983	955
Rate per 1000 live births (95% CI)	1.62 (1.53,1.72)	1.75 (1.65,1.85)	1.90 (1.80,2.01)	1.87 (1.77,1.98)	1.82 (1.72,1.92)	1.81 (1.71,1.92)	1.86 (1.76,1.97)	1.61 (1.51,1.72)	1.64 (1.54,1.74)
Term cases	944	971	1,044	1,018	987	963	936	839	785
Preterm cases	184	190	213	225	217	208	228	144	170

Abbreviations: CI: confidence interval

Table 5: Infants in England with seizures

Seizures	Year								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cases	1,445	1,432	1,360	1,249	1,223	1,159	1,127	1,016	938
Rate per 1000 live births (95% CI)	2.08 (1.98,2.19)	2.15 (2.05,2.27)	2.06 (1.95,2.17)	1.88 (1.78,1.99)	1.84 (1.74,1.95)	1.79 (1.69,1.90)	1.80 (1.70,1.91)	1.67 (1.57,1.77)	1.61 (1.51,1.71)
Term cases	1,065	1,036	1,009	919	866	845	806	725	674
Preterm cases	380	396	351	330	357	314	321	291	264

Abbreviations: CI: confidence interval



Table 6: Infants in England with intracranial haemorrhage

Intracranial haemorrhage	Year								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cases	754	677	689	726	777	783	778	683	649
Rate per 1000 live births (95% CI)	1.09 (1.01,1.17)	1.02 (0.94,1.10)	1.04 (0.97,1.12)	1.09 (1.02,1.18)	1.17 (1.09,1.26)	1.21 (1.13,1.30)	1.24 (1.16,1.33)	1.12 (1.04,1.21)	1.11 (1.03,1.20)
Term cases	110	94	104	117	112	129	110	84	117
Rate per 10,000 term births (95% CI)	1.72 (1.42,2.07)	1.53 (1.25,1.88)	1.71 (1.41,2.07)	1.92 (1.60,2.30)	1.84 (1.53,2.21)	2.17 (1.83,2.58)	1.92 (1.59,2.31)	1.50 (1.21,1.86)	2.17 (1.81, 2.60)
Preterm cases	644	583	585	609	665	654	668	599	532
Severe P/IVH <32 weeks GA	483	445	468	452	519	482	523	481	430
Rate of severe P/IVH per 1000 live births <32 weeks GA (95% CI)	60.35 (55.20,65.98)	57.72 (52.60,63.35)	61.13 (55.83,66.93)	58.27 (53.14,63.90)	61.76 (56.67,67.31)	58.64 (53.64,64.12)	67.29 (61.77,73.31)	62.48 (57.13,68.32)	62.55 (56.90,68.75)

Abbreviations: CI: confidence interval; P/IVH: periventricular/intraventricular haemorrhage; GA: gestational age



Table 7: Infants in England with central nervous system (CNS) infection

CNS infection	Year								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cases	390	452	543	510	554	498	487	431	399
Rate per 1000 live births (95% CI)	0.56 (0.51,0.62)	0.68 (0.62,0.75)	0.82 (0.75,0.89)	0.77 (0.70,0.84)	0.84 (0.77,0.91)	0.77 (0.71,0.84)	0.78 (0.71,0.85)	0.71 (0.64,0.78)	0.68 (0.62,0.75)
Term cases	205	275	302	304	321	275	261	240	221
Preterm cases	185	177	241	206	233	223	226	191	178

Abbreviations: CI: confidence interval

Table 8: Infants in England with perinatal/neonatal stroke

Perinatal/ neonatal stroke	Year								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
Cases	77	100	88	90	82	91	92	99	92
Rate per 1000 live births (95% CI)	0.11 (0.09,0.14)	0.15 (0.12,0.18)	0.13 (0.11,0.16)	0.14 (0.11,0.17)	0.12 (0.10,0.15)	0.14 (0.11,0.17)	0.15 (0.12, 0.18)	0.16 (0.13, 0.20)	0.16 (0.13, 0.19)
Term cases	64	78	72	76	66	74	77	87	78
Preterm cases	13	22	16	14	16	17	15	12	14

Abbreviations: CI: confidence interval



Table 9: Infants in England with cystic periventricular leukomalacia (PVL)

Cystic PVL	Year								
	2012	2013	2014	2015	2016	2017	2018	2019	2020
No. preterm cases	199	175	171	184	210	175	167	172	161
Rate per 1000 live births (95% CI)	0.3 (0.3, 0.3)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)	0.3 (0.3, 0.4)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)	0.3 (0.2, 0.3)
No. cases at <34 weeks GA	186	175	157	176	201	171	161	165	154
Rate per 1000 live births <34 weeks GA (95% CI)	12.7 (11.0, 14.7)	12.5 (10.7, 14.4)	11.3 (9.7, 13.3)	12.4 (10.7, 14.4)	13.8 (12.0, 15.8)	11.8 (10.2, 13.7)	11.8 (10.1, 13.7)	12.3 (10.6, 14.4)	12.6 (10.8, 14.8)

Abbreviations: CI: confidence interval; GA: gestational age



Table 10: Infants in England with bilirubin encephalopathy

Bilirubin Encephalopathy	Year
	2012 – 2020
All Cases	39
Annual rate per 100,000 live births (95% CI)	0.67 (0.49, 0.92)

Abbreviations: CI: confidence interval. Note: Due to low numbers of cases, data from 2012 to 2020 were merged.



3.2 Exclusion of babies with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia

3.2.1 Exclusion of babies with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia: all gestational ages

Numerator:	Annual number of infants who received at least one episode of care within a neonatal unit in England with a <i>brain injury occurring during or soon after birth</i> after exclusion of infants with conditions leading to brain injury prior to birth, and exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia, obtained from the NNRD.
Denominator:	Annual number of live births in England obtained from ONS Birth Summary Tables ^{25 26} .

Table 11 presents the incidence and crude rates per 1,000 live births of brain injuries after exclusion of infants with conditions leading to brain injury prior to birth, and exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia, for the year 2020. Figure 4 displays the crude rates of brain injuries per 1,000 live births prior to exclusions.

²⁵ Office for National Statistics, last accessed 14th December 2020, <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/12561livebirthsstillbirthsandneonataldeathsbygestationalageinengland2010to2018neonataldeathsand2010to2019livebirthsandstillbirths>

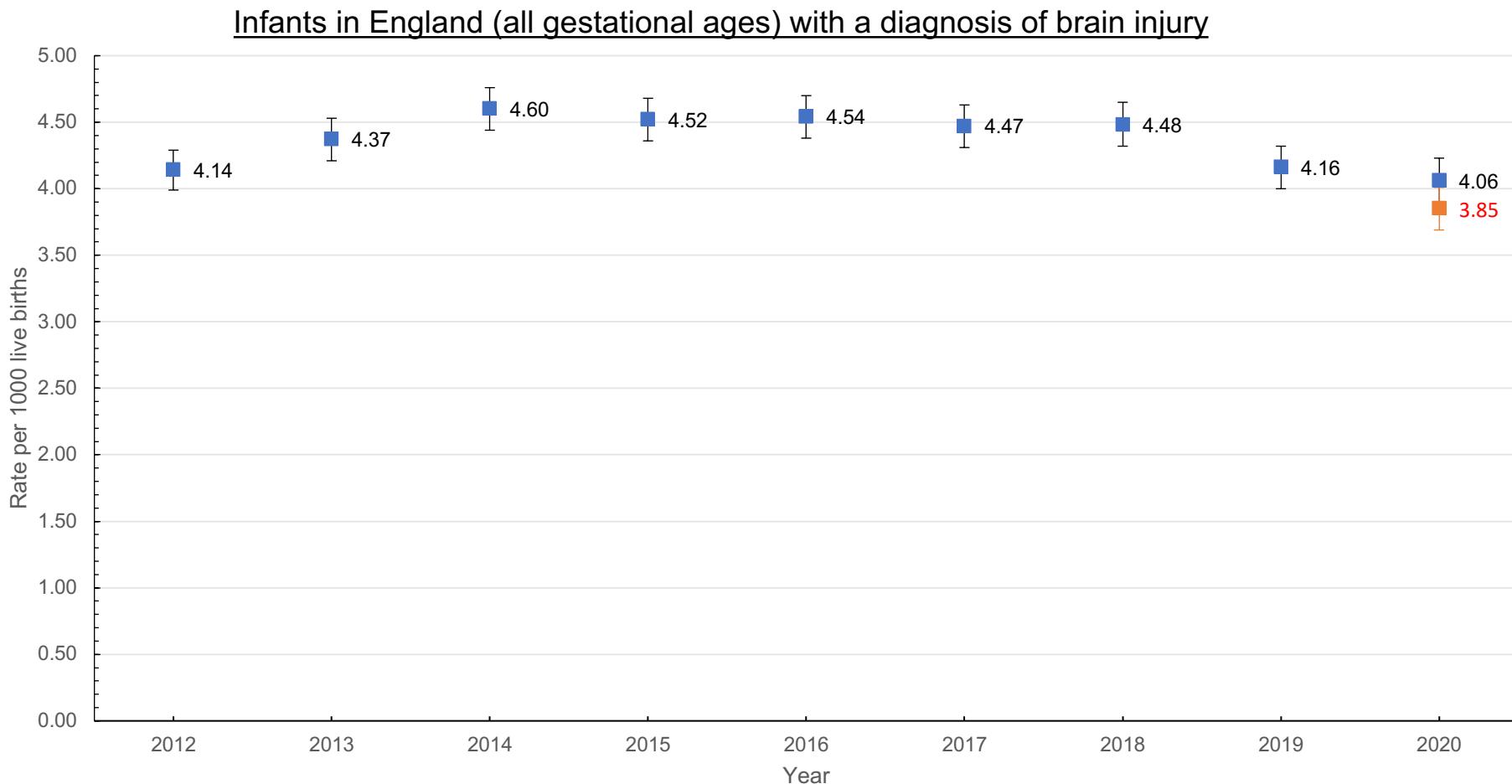
²⁶ Office for National Statistics, 2021. Live births occurring in 2020 by week of gestation, England. Available at: <https://www.ons.gov.uk/>

Table 11: Infants in England (all gestational ages) with a diagnosis of brain injury, after exclusion of infants with conditions leading to brain injury prior to birth, and infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia

Year	Infants recorded in the NNRD	Infants recorded in the NNRD with GA available (%)	Live births in England	After exclusion of infants with conditions leading to brain injury prior to birth		After exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia		
				Infants with brain injury	Rate of brain injuries per 1000 live births (95% CI)	Exclusions	Infants with brain injury	Rate of brain injuries per 1000 live births (95% CI)
2012	78,980	78,952 (99.96)	694,241	2,874	4.14 (3.99, 4.29)			
2013	80,222	80,199 (99.97)	664,517	2,904	4.37 (4.21, 4.53)			
2014	85,013	84,981 (99.96)	661,496	3,041	4.60 (4.44, 4.76)			
2015	88,931	88,785 (99.84)	664,399	3,001	4.52 (4.36, 4.68)			
2016	92,582	92,487 (99.90)	663,157	3,009	4.54 (4.38, 4.70)			
2017	97,405	97,341 (99.93)	646,794	2,890	4.47 (4.31, 4.63)			
2018	96,641	96,629 (99.99)	625,310	2,803	4.48 (4.32, 4.65)			
2019	94,734	94,717 (99.98)	610,140	2,538	4.16 (4.00, 4.32)			
2020	89,210	89,196 (99.98)	583,895	2,374	4.07 (3.91, 4.23)	124	2,250	3.85 (3.70, 4.02)

Abbreviations: CI: confidence interval, GA: gestational age

Figure 4: Annual rates of brain injury occurring during or soon after birth in England (all gestational ages) 2012-2020 with exclusion of infants with conditions leading to brain injury prior to birth (black squares), and exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia (red squares); error bars indicate 95% confidence intervals



3.2.2 Exclusion of babies with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia: term infants

Numerator:	Annual number of term infants (≥ 37 weeks gestational age) who received at least one episode of care within a neonatal unit in England with a <i>brain injury occurring during or soon after birth</i> in England, after exclusion of infants with conditions leading to brain injury prior to birth, and infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia, obtained from the NNRD.
Denominator:	Annual number of term live births in England obtained from ONS Live Births by Gestational Age ^{27 28} .

Table 12 presents the incidence and crude rates per 1,000 live births of brain injuries after exclusion of infants with conditions leading to brain injury prior to birth, and exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia, for the year 2020.

²⁷ Office for National Statistics, last accessed 14th December 2020, <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/12561livebirthsstillbirthsandneonataldeathsbygestationalageinengland2010to2018neonataldeathsand2010to2019livebirthsandstillbirths>

²⁸ Office for National Statistics, 2021. Live births occurring in 2020 by week of gestation, England. Available at: <https://www.ons.gov.uk/>

Table 12: Term infants in England (≥ 37 weeks gestational age) with a diagnosis of brain injury, after exclusion of infants with conditions leading to brain injury prior to birth, and infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia

Year	Term infants recorded in the NNRD	Term live births in England	After exclusion of infants with conditions leading to brain injury prior to birth		After exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia		
			Term Infants with brain injury	Rate of brain injuries per 1000 term live births (95% CI)	Exclusions	Term Infants with brain injury	Rate of brain injuries per 1000 term live births (95% CI)
2012	46,200	640,787	1661	2.59 (2.47, 2.72)			
2013	47,935	612,816	1713	2.80 (2.67, 2.93)			
2014	51,945	607,972	1804	2.97 (2.83, 3.11)			
2015	55,045	609,076	1771	2.91 (2.78, 3.05)			
2016	58,069	609,118	1722	2.83 (2.70, 2.96)			
2017	62,558	593,339	1650	2.78 (2.65, 2.92)			
2018	62,930	574,063	1587	2.76 (2.63, 2.90)			
2019	61,989	560,765	1439	2.57 (2.44, 2.70)			
2020	58,573	538,715	1,360	2.52 (2.39, 2.66)	115	1,245	2.31 (2.19, 2.44)

Abbreviations: CI: confidence interval

3.2.3 Exclusion of babies with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia: preterm infants

Numerator:	Annual number of preterm infants (<37 weeks gestational age) who received at least one episode of care within a neonatal unit in England with a <i>brain injury occurring during or soon after birth</i> in England, after exclusion of infants with conditions leading to brain injury prior to birth, and infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia, obtained from the NNRD.
Denominator:	Annual number of preterm live births in England obtained from ONS Live Births by Gestational Age ^{29 30} .

Table 13 presents the incidence and crude rates per 1,000 live births of brain injuries in preterm infants, after exclusion of infants with conditions leading to brain injury prior to birth, and exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia, for the year 2020.

²⁹ Office for National Statistics, last accessed 14th December 2020, <https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/deaths/adhocs/12561livebirthsstillbirthsandneonataldeathsbygestationalageinengland2010to2018neonataldeathsand2010to2019livebirthsandstillbirths>

³⁰ Office for National Statistics, 2021. Live births occurring in 2020 by week of gestation, England. Available at: <https://www.ons.gov.uk/>

Table 13: Preterm infants in England (<37 weeks gestational age) with a diagnosis of brain injury, after exclusion of infants with conditions leading to brain injury prior to birth, and infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia

Year*			After exclusion of infants with conditions leading to brain injury prior to birth		After exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia		
	Preterm infants recorded in the NNRD	Preterm live births in England	Preterm infants with brain injury	Rate of brain injuries per 1000 preterm live births (95% CI)	Exclusions	Preterm infants with brain injury	Rate of brain injuries per 1000 preterm live births (95% CI)
2012	32,752	49,949	1213	24.28 (22.96, 25.69)			
2013	32,264	48,844	1191	24.38 (23.04, 25.81)			
2014	33,036	49,379	1237	25.05 (23.69, 26.49)			
2015	33,740	50,308	1230	24.45 (23.12, 25.85)			
2016	34,418	51,581	1287	24.95 (23.62, 26.35)			
2017	34,783	51,307	1240	24.17 (22.86, 25.55)			
2018	33,699	49,302	1216	24.66 (23.32, 26.09)			
2019	33,028	47,488	1099	23.14 (21.81, 24.55)			
2020	30,623	43,252	1014	23.44 (22.04, 24.91)	9	1005	23.24 (21.84, 24.72)

Abbreviations: NNRD: National Neonatal Research Database; CI: confidence interval

Appendix 1

Brain injury definition: National Neonatal Research Database (NNRD) data fields

Scope

- All babies admitted to an NHS neonatal unit in England
- Injury detected during neonatal unit stay to discharge

Data source

- Data extracted from the National Neonatal Research Database (NNRD) at the Neonatal Data Analysis Unit at Imperial College London.
- The NNRD contains a predefined set of variables (the Neonatal Data Set, an authorised NHS Information Standard) extracted at regular intervals from the Electronic Patient Record of every admission to a NHS neonatal unit in England, Wales, and Scotland, cleaned and merged across multiple patient episodes, to create a single data file for each patient.

Condition	Data items
HIE	<p>Any of the following recorded in any <i>Diagnosis</i> field:</p> <ol style="list-style-type: none"> 1. Severe Hypoxic Ischaemic Encephalopathy (HIE) 2. Severe Neonatal Encephalopathy 3. Grade 3 Hypoxic Ischaemic Encephalopathy (HIE) 4. Moderate Hypoxic Ischaemic Encephalopathy (HIE) 5. Moderate Neonatal Encephalopathy 6. Grade 2 Hypoxic Ischaemic Encephalopathy (HIE) <p>OR</p> <p>The following recorded in <i>daily care neurology</i> field:</p> <ol style="list-style-type: none"> 1. Therapeutic hypothermia induced - for 2 or more consecutive days
Intracranial haemorrhage	<p>Any of the following recorded in any <i>Diagnosis</i> field:</p> <ol style="list-style-type: none"> 1. Subdural haemorrhage due to birth injury 2. Cerebral haemorrhage due to birth injury 3. Traumatic intraventricular haemorrhage 4. Subarachnoid haemorrhage due to birth injury 5. Subarachnoid haemorrhage 6. Tentorial tear due to birth injury 7. Intracranial laceration and haemorrhage due to birth injury 8. Large intraventricular haemorrhage (IVH Grade 3) 9. Intraventricular haemorrhage/parenchymal 10. Parenchymal haemorrhage 11. haemorrhage (IVH Grade 4) 12. Intracranial Haemorrhage (unknown or unspecified cause) 13. Intracerebral haemorrhage 14. Intracerebral haemorrhage (term infant) 15. Intraventricular haemorrhage (perinatal) 16. Post-haemorrhagic hydrocephalus <p>OR</p> <p>Any of the following recorded in any <i>cranial ultrasound findings</i> field:</p> <ol style="list-style-type: none"> 1. Large intraventricular haemorrhage (IVH Grade 3) 2. Intraventricular haemorrhage/parenchymal haemorrhage (IVH Grade 4) 3. Parenchymal haemorrhage <p>OR</p> <p>Any of the following recorded in any <i>procedure</i> field:</p> <ol style="list-style-type: none"> 1. Ventriculoperitoneal or other ventricular shunt 2. External ventricular drain 3. Ventricular drain with reservoir 4. Insertion of ventricular peritoneal shunt. 5. Insertion of Rickham reservoir 6. Insertion of ventriculo-atrial CSF shunt 7. Insertion of ventriculo-peritoneal CSF shunt 8. Creation of ventriculoperitoneal shunt

Preterm white matter injury	<p>Any of the following recorded in any <i>Diagnosis</i> field:</p> <ol style="list-style-type: none"> 1. Cystic periventricular leukomalacia
	OR
	<p>Any of the following recorded in any <i>cranial ultrasound findings</i> field:</p> <ol style="list-style-type: none"> 1. Cystic periventricular leucomalacia
Perinatal stroke	<p>Any of the following recorded in any <i>Diagnosis at discharge</i> field:</p> <ol style="list-style-type: none"> 1. Neonatal stroke 2. Infarction: Middle cerebral artery (stroke) 3. Cerebrovascular accident (stroke) 4. Cerebral venous thrombosis 5. Neonatal cerebral ischaemia
Central nervous system infection	<p>Any of the following diagnosis codes recorded in the <i>Diagnosis</i> field:</p> <ol style="list-style-type: none"> 1. Bacterial meningitis 2. Viral meningitis 3. Meningitis – streptococcal 4. Meningitis – bacterial (specific organism) 5. Meningitis – bacterial (unknown or unspecified organism) 6. Meningitis – Candida 7. Candida encephalitis 8. Congenital herpes infection
	<p>Any pathogen recorded in the <i>suspected infection data</i> field <i>Pathogen in CSF</i></p>
Kernicterus	<p>Any of the following diagnoses recorded in any <i>Diagnosis</i> field:</p> <ol style="list-style-type: none"> 1. Bilirubin encephalopathy (immune) 2. Kernicterus (unspecified or unknown cause) 3. Kernicterus
Seizures	<p>Any of the following recorded in any <i>daily care neurology</i> field:</p> <ol style="list-style-type: none"> 1. Seizure occurred

Exclusions

Data will be presented before and after exclusion of infants with **seizures** (condition defined as above) AND the following diagnosis codes recorded in the *Diagnosis* field during their neonatal unit admission.

Condition

Data items

Congenital encephalopathies	<p>Episodic variables: Any of the following diagnosis codes entered into any <i>Diagnosis</i> field:</p>
	<ol style="list-style-type: none"> 1. Congenital neuropathy (unknown or unspecified cause) 2. Congenital myopathy 3. Mitochondrial myopathy 4. Congenital Central Hypoventilation Syndrome (CCHS) 5. Congenital hypertonia 6. Congenital hypotonia - floppy 7. Benign familial neonatal seizures 8. Inborn error of metabolism (description required) 9. Myotonic dystrophy requiring endotracheal intubation and assisted ventilation 10. Disorder of branch chain amino acid metabolism 11. Disorders of fatty acid metabolism 12. Disorders of fatty acid metabolism: carnitine metabolism 13. Disorder of glycine metabolism 14. Disorder of glycine metabolism: Non ketotic hyperglycinaemia 15. Hyperammonaemia of the newborn 16. Disorders of lysine and hydroxylysine metabolism 17. Disorders of ornithine metabolism 18. Disorders of pyruvate metabolism and gluconeogenesis 19. Disorder of carbohydrate metabolism (unknown or unspecified cause) 20. Down Syndrome (Trisomy 21) 21. Trisomy 21 22. Edwards Syndrome (Trisomy 18) 23. Trisomy 18 24. Patau Syndrome (Trisomy 13) 25. Trisomy 13
Congenital infections	<p>Episodic variables: Any of the following diagnosis codes entered into any <i>Diagnosis</i> field:</p>
	<ol style="list-style-type: none"> 1. Congenital viral disease (specify) 2. Syphilis - latent congenital 3. Congenital rubella syndrome 4. Congenital cytomegalovirus infection 5. Congenital herpes [herpes simplex] infection 6. Other congenital viral diseases 7. Congenital viral disease (unknown or unspecified cause) 8. Congenital toxoplasmosis
Congenital brain abnormalities	<p>Episodic variables: Any of the following diagnosis codes entered into any <i>Diagnosis</i> field:</p>
	<ol style="list-style-type: none"> 1. Malformations of aqueduct of Sylvius 2. Atresia of foramina of Magendie and Luschka

3. Atresia of foramina of Magendie and Luschka
4. Other congenital hydrocephalus
5. X linked congenital hydrocephalus
6. Congenital hydrocephalus (unknown or unspecified cause)
7. Congenital hydrocephalus
8. Lissencephaly
9. Vermal agenesis
10. Septum pelucidum absence – congenital
11. Congenital malformations of corpus callosum
12. Arhinencephaly
13. Holoprosencephaly
14. Other reduction deformities of brain
15. Septo-optic dysplasia
16. Other specified congenital malformations of brain
17. Congenital malformation of brain (unknown or unspecified cause)
18. Other congenital malformations of brain
19. Cervical spina bifida with hydrocephalus
20. Thoracic spina bifida with hydrocephalus
21. Spina bifida (unknown or unspecified cause)
22. Spina bifida
23. Amyelia
24. Hypoplasia and dysplasia of spinal cord
25. Other specified congenital malformations of spinal cord
26. Congenital malformation of spinal cord (unknown or unspecified cause)
27. Nerve palsies – congenital
28. Arnold-Chiari syndrome
29. Other specified congenital malformations of nervous system
30. Congenital malformation of nervous system (unknown or unspecified cause)
31. Other congenital malformations of nervous system
32. Congenital Hydrocephalus

Data will be presented before and after exclusion of infants with mild hypoxic ischaemic encephalopathy who received at least 48 hours of therapeutic hypothermia; using the below definition for hypoxic ischaemic encephalopathy (no longer including 'Therapeutic hypothermia induced - for 2 or more consecutive days' recorded in *daily care neurology* field).

Condition	Data items
HIE	Any of the following recorded in any <i>Diagnosis</i> field: 1. Severe Hypoxic Ischaemic Encephalopathy (HIE) 2. Severe Neonatal Encephalopathy 3. Grade 3 Hypoxic Ischaemic Encephalopathy (HIE) 4. Moderate Hypoxic Ischaemic Encephalopathy (HIE) 5. Moderate Neonatal Encephalopathy 6. Grade 2 Hypoxic Ischaemic Encephalopathy (HIE)