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Temporal trends in severe maternal and neonatal trauma during childbirth: a population-based observational study

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ABSTRACT

Objective Instrumental vaginal delivery is associated with birth trauma to infant and obstetric trauma to mother. As caesarean delivery rates increased during the past decades, the rate of instrumental vaginal delivery declined. We examined concomitant temporal changes in the rates of severe birth trauma and maternal obstetric trauma.

Design A retrospective observational study.

Settings and participants All hospital singleton live births in Washington State, USA, 2004–2013, excluding breech delivery. Severe birth trauma (brain, nerve injury, fractures and other severe birth trauma) and obstetric trauma (third/fourth degree perineal lacerations, cervical/high vaginal lacerations) were identified from hospitalisation data. Pregnancy and delivery characteristics were obtained from birth certificates. Temporal trends were assessed by the Cochran-Armitage test. Logistic regression was used to obtain adjusted ORs (AORs) and 95% CI.

Results Overall, 732 818 live births were included. The rate of severe birth trauma declined from 5.3 in 2004 to 4.5 per 1000 live births in 2013 (P<0.001). The decline was observed only in spontaneous vaginal delivery, the rates of fractures and other severe birth trauma declined by 5% and 4% per year, respectively (AOR: 0.95, 95% CI 0.94 to 0.97 and AOR: 0.96, 95% CI 0.93 to 0.99; respectively). The rate of third/fourth degree lacerations declined in spontaneous vaginal delivery from 3.5% to 2.3% (AOR: 0.95; 95% CI 0.94 to 0.95) and in vacuum delivery from 17.3% to 14.5% (AOR: 0.97, 95% CI 0.96 to 0.98). Among women with forceps delivery, these rates declined from 29.8% to 23.4% (AOR: 0.98, 95% CI 0.96 to 1.00).

Conclusion While the rates of fractures and other birth trauma declined among infants delivered by spontaneous vaginal delivery, the rate of birth trauma remained unchanged in instrumental vaginal delivery and caesarean delivery. Among mothers, the rates of severe perineal lacerations declined, except for women with forceps delivery.

Strengths and limitations of this study

- Large, population-based data with detailed information on maternal and pregnancy risk factors.
- Consistent use of International Classification of Diseases, 9th revision, Clinical Modification codes to identify birth trauma during the study period.
- Lack of statistical power to detect temporal trends for very rare specific types of trauma.
- Lack of detailed clinical information on severity of some types of birth trauma.
- Non-differential errors in coding that may result in underestimation of temporal trends.

INTRODUCTION

Birth trauma refers to an injury sustained by the fetus during the process of labour and delivery, usually due to difficult vaginal birth with a need for obstetric manipulation of the fetus by forceps or vacuum (instrumental vaginal delivery).[1 2] While some degree of trauma to the fetus during delivery is relatively common, severe birth trauma is rare.[2–5] Such birth trauma, for example, intracranial haemorrhage, however, can result in intrapartum stillbirth, neonatal death or functional impairment.[1] The reported incidence of severe birth trauma in industrialised countries varies from 1.5 to 2.9 per 1000 live births,[2–6] depending on the definition and study population. Mode of delivery is strongly associated with trauma to the fetus. Infants born by forceps and vacuum delivery have an approximately fourfold and threefold higher rates of birth trauma, respectively, as compared with those born by spontaneous vaginal delivery.[4] Birth trauma can occur during caesarean delivery; however, the incidence rates are approximately 60% lower as compared with vaginal delivery.[4]

Mode of delivery is also associated with obstetric trauma to the mother, including third and fourth degree perineal lacerations, and cervical and high vaginal lacerations. Similarly to birth trauma, the rates of obstetric trauma vary, depending on definition and study population from 2% to 19%.[7–9] While some studies in the USA show a significant decline in perineal lacerations over time,[10] others from Denmark and Sweden report a temporal increase.[11 12] Short-term sequelae of obstetric trauma include perineal pain,[13] painful sexual intercourse,[14] defaecatory dysfunction and urinary and faecal incontinence.[15 16] The long-term consequences of obstetric trauma, which manifest 10–20 years after childbirth, include pelvic floor disorders such as pelvic organ prolapse, urinary and faecal incontinence.[17–21]

Rates of caesarean delivery increased substantially in the industrialised countries during the past decades,[22–25] while rates of instrumental vaginal delivery declined. In the USA, for example, caesarean delivery rate increased from 22.9% in 2000 to 32.9% in 2009, and then declined slightly to 32.2% in 2014. Over the same period, rate of forceps declined from 2.1% in 2000 to 0.6% in 2014 and rate of vacuum delivery declined from 4.8% to 2.6%.[23] In Canada, rate of caesarean delivery increased from 25.8% in 2003/2004 to 28.0% in 2010/2011,[24] while instrumental vaginal delivery declined from 12.0% of singleton births in 2004 to 10.7% in 2012.[25] Since instrumental vaginal delivery is a strong risk factor for severe birth trauma and obstetric trauma, we hypothesised that the rates of severe birth trauma and obstetric trauma also declined over time.

Our objective was to characterise temporal trends in rate of severe birth trauma, including brain injury, fractures, nerve injury and other injury to tissue and organs, and to examine these trends by mode of delivery. The second objective was to examine temporal trends in the rates of obstetric trauma among women with spontaneous vaginal delivery, forceps and vacuum delivery.

METHODS

Study population

We included all singleton live births to mothers from 15 years to 60 years of age in Washington State, USA from 2004 to 2013. Excluded were women who were not residents of Washington State, births at <20 weeks' and >44 weeks' gestation, births occurring outside hospital and breech deliveries. We used data from the Birth Events Record Database (BERD), which included information abstracted from live birth certificates. These data were linked to the Comprehensive Discharge Abstract Database (CHARS), which included all hospitalisations in Washington State with up to nine diagnostic and procedure codes related to each hospitalisation episode. The BERD database provided information on maternal characteristics (maternal age, race, education, marital status, body mass index (BMI), chronic hypertension, diabetes mellitus, obstetric history and so on), and pregnancy, labour and delivery characteristics (gestational diabetes, hypertension in pregnancy, gestational age at delivery, mode of delivery, prolonged labour and so on).

Outcomes definition

Severe birth trauma was identified from the CHARS using diagnoses coded by the International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) (online supplementary appendix table 1). Severe birth trauma was classified as follows: (1) brain injury (subdural and cerebral haemorrhage and injuries to scalp); (2) fractures (fracture of clavicle and other injuries to skeleton); (3) nerve injury (injury to spine and spinal cord, facial nerve injury, injury to brachial plexus, other cranial and peripheral nerve injuries); and (4) other severe birth trauma (other specified birth trauma, eg, injury to the internal organs). A composite outcome 'any severe birth trauma' was defined as one or more injuries described above. Severe maternal obstetric injury was identified from hospital delivery records using ICD-9-CM codes and categorised as follows: (1) severe perineal lacerations (third and fourth degree perineal tears and anal sphincter injury) and (2) cervical or high vaginal lacerations (online supplementary appendix table 1).

Mode of delivery

Mode of delivery was categorised as spontaneous vaginal delivery, forceps delivery, vacuum delivery, primary caesarean delivery with labour, repeat caesarean delivery with labour, primary caesarean delivery without labour and repeat caesarean delivery without labour. Delivery where both instruments were used were included in forceps delivery category, while failed forceps and failed vacuum delivery were included in caesarean delivery group. Due to low numbers in caesarean delivery categories and congruent trends between primary and repeat caesarean delivery with labour, we combined the latter two categories into one. Neonatal death was defined as death within the first 28 days after birth, and neonatal mortality was compared between infants with and without birth trauma.

Data analysis

The Cochran-Armitage test was used to assess statistical significance of temporal trends. We assessed the temporal trend in the rates of each mode of delivery and the rates of severe birth trauma (per 1000 live births). We examined the composite outcomes 'any severe birth trauma' and 'obstetric trauma', as well as each individual types of trauma. The Cochran-Armitage test for trend was used to assess temporal trends in risk factors (confounders) potentially associated with birth and obstetric trauma. These trends were also quantified by rate ratio (RR) and 95% CIs comparing the most recent years to the earliest years (2011–2013 vs 2004–2006).

Logistic regression was used to estimate the unadjusted ORs, adjusted ORs (AOR) and 95% CI for severe birth trauma to infant and for obstetric trauma to mother. Temporal trend was expressed as the change in the odds of trauma with each successive calendar year (continuous variable). Adjustment was made for mode of delivery, maternal and infant characteristics and pregnancy risk factors including: race (African-American, Hispanic, Native American and other vs non-Hispanic white), maternal age (<25, ≥35 years vs 25–34 years), marital status (single/widowed/separated vs married/common law), BMI (underweight <18.5 kg/m^2, overweight 20–29.9 kg/m^2 and obese ≥30 kg/m^2 vs normal 18.5–24.9 kg/m^2), smoking during pregnancy, parity (nullipara, grand multipara with ≥4 births vs para 1–3), assisted conception, maternal education (less than high school vs high school or more), maternal morbidity (chronic hypertension and gestational hypertension, chronic diabetes mellitus and gestational diabetes), premature rupture of membranes (PROMs; >12 hours), prolonged labour, precipitous labour (<3 hours), obstructed labour or cephalopelvic disproportion, labour induction, previous caesarean delivery, infant birth weight (≥4000 g vs <4000 g), preterm birth (<37 weeks' gestation) and infant's sex (male vs female). Information on diagnosis of obstructed labour and cephalopelvic disproportion (including diagnosis of shoulder dystocia) was obtained from maternal hospitalisation files. The ICD-9-CM codes for cephalo-pelvic disproportion and obstructed labour were '653.^^' and '660.^^', respectively. The same set of covariates (except for the mode of delivery) was used in logistic regression analyses stratified by mode of delivery. Covariates such as prolonged labour, precipitous labour (<3 hours) and obstructed labour/cephalopelvic disproportion were not used in regression analyses restricted to women with caesarean delivery without labour. All covariates were selected a priori as known risk factors for adverse birth outcomes and birth trauma. Backward stepwise selection process was used to derive final regression models. Maternal obstetric trauma was examined in the regression analysis stratified by mode of delivery only for spontaneous vaginal delivery, forceps and vacuum delivery.

Sensitivity analyses

Two sensitivity analyses were performed. First, we examined temporal trend in sequential instrumental delivery (using both, vacuum and forceps) and temporal trend in failed instrumental vaginal delivery (ie, delivery by caesarean after a failed attempt to deliver vaginally by vacuum or forceps). Rates of birth trauma were examined in both of these groups and also in women with caesarean delivery with labour after exclusion of failed instrumental vaginal delivery. The second sensitivity analysis was performed to examine trends in deliveries by mid/low-cavity forceps, which has a higher risk of trauma as compared with outlet forceps.[26 27] Adjustment for such forceps thus provided additional insight into temporal changes in birth trauma and obstetric trauma in forceps delivery.

All analyses were performed on publicly accessible deidentified data. Analyses were carried out using SAS V.9.3. Missing values for BMI (9.27%) were addressed with multiple imputation (proc MI) using Markov Chain Monte Carlo methods. Other missing values (<3% for other covariates) were excluded from multivariable analyses.

RESULTS

Overall, 871 649 mothers gave birth in Washington State between January 2004 and December 2013. After exclusions, the study population consisted of 732 818 mothers (online supplementary appendix figure 1). Most infants were born by spontaneous vaginal delivery (68.29%) in 2004; this proportion increased slightly to 68.98% in 2013. The rate of caesarean delivery increased during the study period from 24.76% to 26.24%, and caesarean with labour decreased from 9.96% to 8.70%, while caesarean without labour increased from 14.80% to 17.55%. The rates of forceps delivery declined from 0.90% to 0.65%, and the rates of vacuum delivery declined from 6.06% to 4.12%, respectively (figure 1).

The rate of neonatal birth trauma declined by 14.12%, from 5.27 per 1000 live births in 2004 to 4.52 in 2013 (P

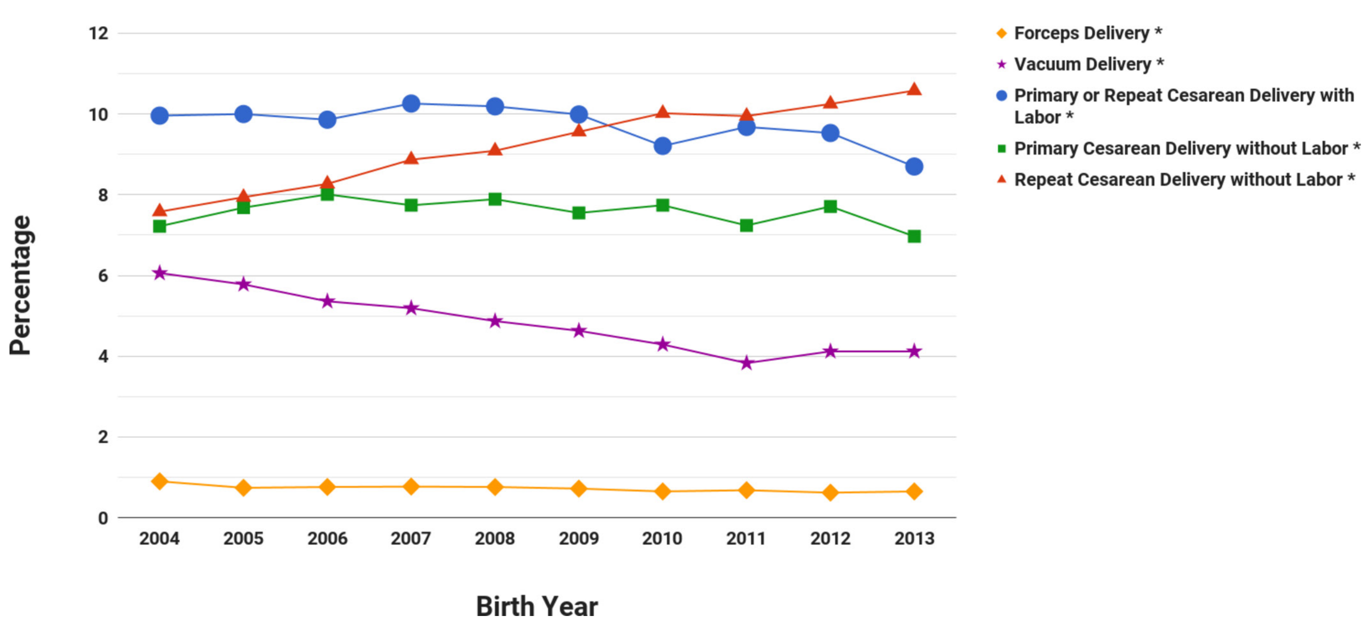

Figure 1 Temporal trends in mode of delivery in singleton infants, Washington State, USA, 2004–2013.

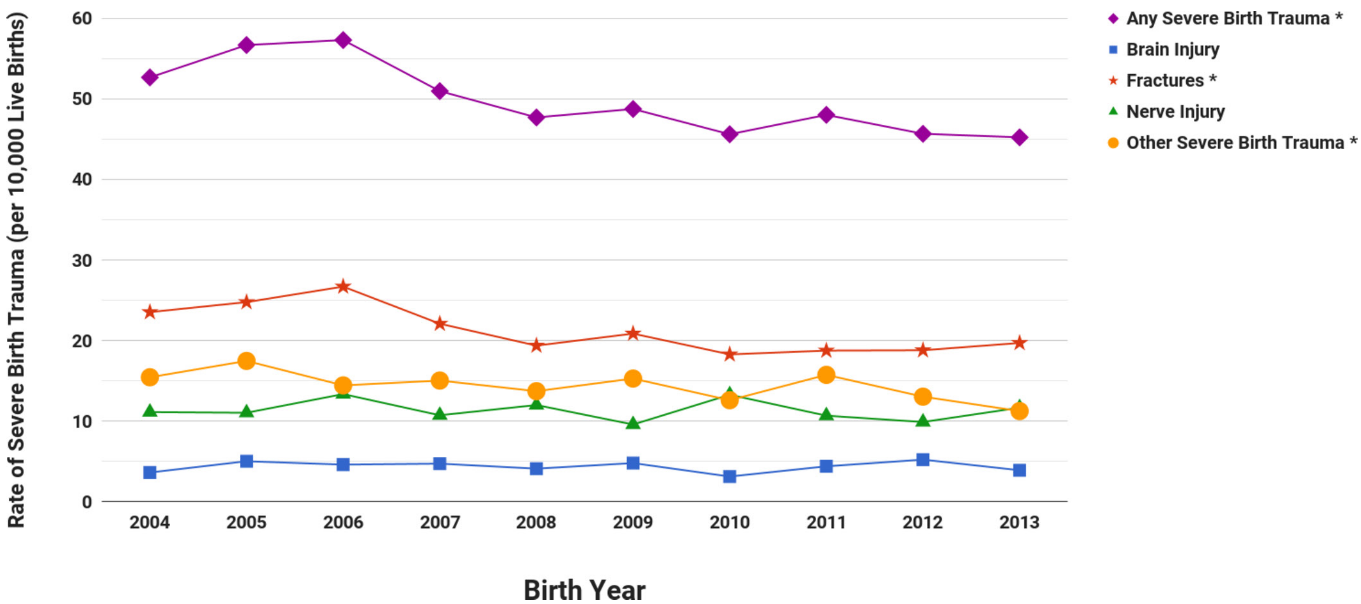

Figure 2 Temporal trends in severe birth trauma among singleton infants, Washington State, USA, 2004–2013.

for trend <0.001, figure 2), the overall risk of any severe birth trauma declined on average by 2% per year (OR 0.98, 95% CI 0.96 to 0.99). The incidence of birth trauma varied largely by mode of delivery; the average rate of birth trauma was 4.74 per 1000 live births among infants born by spontaneous vaginal delivery, which was lower than the rates among infants born by forceps (25.48 per 1000) and vacuum delivery (14.22 per 1000). Birth trauma rates were substantially lower for all caesarean delivery categories: primary (3.26 per 1000) and repeat (1.85 per 1000) caesarean deliveries without labour as well as primary (4.99 per 1000) and repeat caesarean (3.71 per 1000) with labour. The latter two rates were combined into one category for further analysis (4.89 per 1000 caesarean deliveries with labour), as both had similar rates of birth trauma (P=0.284). This rate was significantly higher compared with the overall rate of birth trauma following caesarean delivery without labour (2.48 per 1000; P<0.001). The majority of infants with birth trauma had only one type of trauma (97.18%). Neonatal mortality among infants with birth trauma was two times higher as compared with other infants (4.11 vs 1.97 per 1000 infants; RR 2.08, 95% CI 1.25 to 3.46). Most neonatal deaths (75%) occurred among infants with brain injury.

Unadjusted analysis showed a significant temporal decline in the rates of fractures (from 2.35 to per 1000 live births in 2004 to 1.97 per 1000 live births in 2013, P<0.001), and other birth trauma (from 1.54 to 1.12 per 1000 live births, P=0.009; figure 2). This decline was seen only in infants delivered by spontaneous vaginal delivery (online supplementary appendix figure 2) for the trauma subcategories of fractures (from 2.83 to 2.19 per 1000 births; P<0.001) and other severe birth trauma (from 1.10 to 0.56 per 1000 births; P=0.007). In contrast, a statistically significant upward trends was observed in the rate of nerve injury among infants delivered by forceps: from 3.53 per 1000 live births in 2004–2006 to 7.77 per 1000 live births in 2011–2013 (P=0.044).

Overall, the rate of maternal obstetric trauma declined from 7.52 in 2004 to 4.09 per 100 live births in 2013 (P<0.001). Among women with vaginal delivery, the decline was from 9.67% to 5.22% (P<0.001). While the rate of severe perineal lacerations declined from 4.91 to 3.16 per 100 vaginal deliveries (P<0.001), cervical/high vaginal lacerations remained stable between 1.63% in 2004 and 1.58% in 2013 (P=0.458; online supplementary appendix figure 3). These trends were observed among women with spontaneous vaginal delivery, with forceps and with vacuum delivery (online supplementary appendix figure 3).

Significant temporal trends were observed for the majority of maternal and infant risk factors for birth trauma (table 1), except for infant's sex, preterm birth (<34 weeks) and precipitous labour. A noticeable decline was seen in the proportion of births to mothers aged less than 30 years, Hispanic and Native American mothers, mothers with low education (less than high school), mothers who smoked during pregnancy and grand multipara. Temporal declines also occurred in the rates of labour induction, preterm birth (<37 weeks), obstructed labour and cephalopelvic disproportion and birth weight ≥4000 g. In contrast, a sizeable increase was observed in the proportion of African-American mothers, mothers with assisted conception, previous caesarean delivery, PROM and prolonged labour. Rates of maternal morbidity, including diabetes mellitus, gestational diabetes, chronic hypertension and hypertension during pregnancy increased between 2004 and 2013.

Regression analyses examining neonatal birth trauma for all deliveries showed that only the trend in the risk of fracture was statically significant before and after adjustment for other covariates (AOR 0.97; 95% CI 0.95 to 0.99; table 2). When stratified by mode of delivery, adjustment

Table 1 Temporal trends in maternal demographic characteristics and risk factors for birth trauma among singleton infants, Washington State, USA, 2004–2013

	Birth year				
	2004–2006 (n=213 270)	2007–2010 (n=301 508)	2011–2013 (n=218 040)	P value*	Rate ratio (95% CI)†
Maternal and infant characteristics	n (%)	n (%)	n (%)		
Maternal age (years)					
15–19	17 844 (8.4)	24 380 (8.1)	13 313 (6.1)	<0.001	0.73 (0.71 to 0.75)
20–29	111 509 (52.3)	157 445 (52.2)	109 527 (50.2)	<0.001	0.96 (0.96 to 0.97)
30–39	77 941 (36.6)	111 085 (36.8)	88 445 (40.6)	<0.001	1.11 (1.10 to 1.12)
≥40	5976 (2.8)	8598 (2.9)	6755 (3.1)	<0.001	1.11 (1.07 to 1.14)
Race					
Non-Hispanic white	153 872 (72.4)	213 846 (71.1)	155 618 (71.6)	<0.001	0.99 (0.99 to 0.99)
African-American	7775 (3.7)	12 201 (4.1)	9699 (4.5)	<0.001	1.22 (1.19 to 1.26)
Native American	4445 (2.1)	6123 (2.0)	4320 (2.0)	0.006	0.95 (0.91 to 0.99)
Hispanic	25 871 (12.2)	37 531 (12.5)	23 387 (10.8)	<0.001	0.88 (0.87 to 0.90)
Other	20 649 (9.7)	31 131 (10.3)	24 324 (11.2)	<0.001	1.15 (1.13 to 1.17)
Maternal education (<high school)	9800 (4.6)	11 318 (3.7)	6032 (2.8)	<0.001	0.60 (0.58 to 0.62)
Smoking during pregnancy	20 834 (9.9)	29 206 (9.8)	19 635 (9.0)	<0.001	0.91 (0.89 to 0.93)
Not married	67 109 (31.6)	104 035 (34.6)	75 055 (34.5)	<0.001	1.09 (1.08 to 1.10)
Parity					
Nullipara	85 407 (40.0)	124 799 (41.4)	88 428 (40.6)	0.010	1.01 (1.01 to 1.02)
Para 1–3	110 757 (51.9)	159 444 (52.9)	117 743 (54.0)	<0.001	1.04 (1.03 to 1.05)
Grand multipara (≥4 births)	17 106 (8.0)	17 265 (5.7)	11 869 (5.4)	<0.001	0.68 (0.66 to 0.69)
Body mass index (kg/m^2)					
Underweight (<18.5)	6240 (2.9)	8332 (2.8)	6230 (2.9)	0.045	0.98 (0.94 to 1.00)
Normal (18.5 to 24.9)	89 369 (41.9)	131 590 (43.6)	94 093 (43.1)	<0.001	1.03 (1.02 to 1.04)
Overweight (25 to 29.9)	46 074 (21.6)	72 295 (24.0)	53 849 (24.7)	<0.001	1.14 (1.13 to 1.16)
Obese (≥30)	39 752 (18.6)	65 239 (21.6)	51 806 (23.8)	<0.001	1.27 (1.26 to 1.29)
Missing	31 842 (14.9)	24 052 (8.0)	12 062 (5.5)	<0.001	
Assisted conception	1470 (0.7)	2702 (0.90)	2249 (1.0)	<0.001	1.47 (1.38 to 1.57)
Diabetes mellitus (types 1 and 2)	1578 (0.7)	2591 (0.9)	2151 (1.0)	<0.001	1.33 (1.25 to 1.42)
Gestational diabetes	12 255 (5.75)	19 160 (6.3)	16 382 (7.5)	<0.001	1.31 (1.28 to 1.34)
Chronic hypertension	2489 (1.2)	3783 (1.3)	2815 (1.3)	<0.001	1.09 (1.03 to 1.15)
Hypertension in pregnancy	10 857 (5.1)	15 304 (5.1)	12 010 (5.5)	<0.001	1.08 (1.06 to 1.11)
Infant sex (male)	109 744 (51.5)	154 777 (51.3)	112 326 (51.5)	0.846	1.00 (1.00 to 1.01)
Preterm birth					
<34 weeks	3042 (1.4)	4372 (1.4)	3255 (1.5)	0.104	1.05 (1.00 to 1.10)
<37 weeks	15 006 (7.0)	20 067 (6.7)	14 265 (6.5)	<0.001	0.93 (0.91 to 0.95)
Birth weight (g)					
<2500	9414 (4.4)	13 448 (4.5)	10 186 (4.7)	<0.001	1.06 (1.03 to 1.09)
2500–2999	29 718 (14.0)	43 033 (14.3)	31 990 (14.7)	<0.001	1.05 (1.04 to 1.07)
3000–3999	149 045 (70.1)	211 901 (70.3)	151 953 (69.7)	0.002	1.00 (0.99 to 1.00)
4000–4499	20 754 (9.8)	28 051 (9.3)	20 094 (9.2)	<0.001	0.95 (0.93 to 0.96)
≥4500	3731 (1.75)	4819 (1.6)	3640 (1.7)	0.005	0.95 (0.91 to 1.00)

Continued

Table 1 Continued

	Birth year				
	2004–2006 (n=213 270)	**2007–2010 (n=301 508)**	**2011–2013 (n=218 040)**	**P value***	**Rate ratio (95% CI)†**
Maternal and infant characteristics	**n (%)**	**n (%)**	**n (%)**		
Caesarean delivery					
Primary with labour	19 965 (9.4)	27 960 (9.3)	18 323 (8.4)	<0.001	0.90 (0.88 to 0.92)
Primary no labour	16 310 (7.6)	23 314 (7.7)	15 930 (7.3)	<0.001	0.96 (0.94 to 0.98)
Repeat with labour	1227 (0.6)	1939 (0.6)	1961 (0.9)	<0.001	1.56 (1.46 to 1.68)
Repeat no labour	16 931 (7.9)	28 281 (9.4)	22 366 (10.3)	<0.001	1.29 (1.27 to 1.32)
Vaginal delivery					
Spontaneous	144 931 (68.0)	203 513 (67.5)	149 270 (68.5)	<0.001	1.01 (1.00 to 1.01)
Forceps	1698 (0.8)	2185 (0.7)	1416 (0.6)	<0.001	0.82 (0.76 to 0.88)
Vacuum	12 208 (5.7)	14 316 (4.7)	8774 (4.0)	<0.001	0.70 (0.68 to 0.72)
Previous caesarean delivery					
One prior delivery	16 198 (7.6)	25 871 (8.6)	21 049 (9.6)	<0.001	1.27 (1.25 to 1.30)
Two or more	4518 (2.1)	8821 (2.9)	8069 (3.7)	<0.001	1.75 (1.68 to 1.81)
Labour induction	50 584 (24.2)	69 022 (23.1)	48 530 (22.3)	<0.001	0.92 (0.91 to 0.93)
PROM (>12 hours)	8435 (4.1)	16 232 (5.5)	13 246 (6.1)	<0.001	1.50 (1.46 to 1.54)
Precipitous labour (<3 hours)	6323 (3.1)	9595 (3.2)	6486 (3.0)	0.475	0.98 (0.95 to 1.01)
Prolonged labour	3206 (1.5)	7759 (2.6)	5691 (2.6)	<0.001	1.69 (1.62 to 1.77)
Cephalopelvic disproportion	6669 (3.1)	7873 (2.6)	4374 (2.0)	<0.001	0.64 (0.62 to 0.67)
Obstructed labour	16 256 (7.6)	21 224 (7.0)	13 524 (6.2)	<0.001	0.81 (0.80 to 0.83)

Breech delivery excluded.
*Cochran-Armitage test for trend.
†Rate ratio comparing periods 2011–2013 versus 2004–2006.
PROM, premature rupture of membranes.

for potential confounders did not change the downward temporal trend in fractures and other birth trauma among infants delivered by spontaneous vaginal delivery (table 3); the rate of fractures declined on average by 5% per year (AOR 0.95, 95% CI 0.94 to 0.97), while the risk of other birth trauma declined on average by 4% per year (AOR 0.96, 95% CI 0.93 to 0.99). The unadjusted increase in the risk of nerve injury among infants born by forceps

Table 2 Unadjusted and adjusted ORs expressing the change per year in the risk of birth trauma among singleton infants, Washington State, USA, 2004–2013

Severe birth trauma	**OR (95% CI)**	**AOR* (95% CI)**	**AOR** (95% CI)**
Brain injury	1.00 (0.96 to 1.04)	1.01 (0.98 to 1.05)	1.02 (0.98 to 1.06)
Fractures	0.96 (0.95 to 0.98)	0.97 (0.95 to 0.99)	0.97 (0.95 to 0.99)
Nerve injury	0.99 (0.97 to 1.02)	1.00 (0.98 to 1.03)	1.00 (0.98 to 1.03)
Other severe birth trauma	0.97 (0.95 to 0.99)	0.98 (0.96 to 1.00)	0.98 (0.960 to 1.002)
Any severe birth trauma	0.98 (0.96 to 0.99)	0.98 (0.97 to 0.99)	0.98 (0.972 to 0.995)

Breech delivery was excluded.
*Adjusted for temporal changes in mode of delivery.
†Adjusted for temporal changes in mode of delivery and other risk factors (parity, body mass index, maternal age, maternal education, race, marital status, assisted conception, hypertension, diabetes mellitus, gestational diabetes, smoking during pregnancy, birth weight, preterm birth, PROM (>12 hours), precipitous labour, prolonged labour, cephalopelvic disproportion, obstructed labour and fetal sex).
AOR, adjusted OR; PROM, premature rupture of membranes.

Table 3 Unadjusted and adjusted ORs expressing the change per year in the risk of birth trauma by mode of delivery among singleton infants, Washington State, USA, 2004–2013

	Mode of delivery							
	Spontaneous vaginal delivery		Forceps delivery		Vacuum delivery		Caesarean delivery with labour	
Severe birth trauma	OR (95% CI)	AOR* (95% CI)	OR (95% CI)	AOR* (95% CI)	OR (95% CI)	AOR* (95% CI)	OR (95% CI)	AOR* (95% CI)
Brain injury	0.99 (0.93 to 1.05)	0.99 (0.93 to 1.05)	1.09 (0.90 to 1.31)	1.08 (0.90 to 1.30)	1.04 (0.96 to 1.11)	1.04 (0.97 to 1.13)	1.04 (0.95 to 1.14)	1.06 (0.96 to 1.16)
Fractures	0.96 (0.94 to 0.98)	0.95 (0.94 to 0.97)	0.94 (0.82 to 1.07)	0.95 (0.83 to 1.08)	1.02 (0.97 to 1.07)	1.02 (0.97 to 1.07)	1.14 (0.97 to 1.32)	1.14 (0.97 to 1.32)
Nerve injury	0.99 (0.96 to 1.02)	0.98 (0.96 to 1.01)	1.12 (1.00 to 1.24)	1.11 (0.99 to 1.24)	1.01 (0.95 to 1.07)	1.01 (0.95 to 1.07)	1.10 (0.98 to 1.24)	1.12 (0.99 to 1.26)
Other severe birth trauma	0.96 (0.93 to 0.99)	0.96 (0.93 to 0.99)	1.04 (0.95 to 1.14)	1.05 (0.96 to 1.15)	0.95 (0.88 to 1.03)	0.95 (0.88 to 1.03)	1.00 (0.95 to 1.04)	1.00 (0.95 to 1.04)
Any severe birth trauma	0.97 (0.95 to 0.98)	0.96 (0.95 to 0.98)	1.05 (0.99 to 1.11)	1.05 (0.99 to 1.11)	1.00 (0.97 to 1.04)	1.00 (0.97 to 1.04)	1.02 (0.98 to 1.06)	1.03 (0.99 to 1.07)

*Adjusted for parity, body mass index, maternal age, maternal education, race, marital status, assisted conception, hypertension, diabetes mellitus, gestational diabetes, smoking during pregnancy, birth weight, preterm birth, PROM (>12 hours), precipitous labour, prolonged labour, cephalopelvic disproportion, obstructed labour and fetal sex.
aOR, adjusted OR; PROM, premature rupture of membranes.

delivery (OR 1.12, 95% CI 1.00 to 1.24) attenuated and was no longer significant after adjustment for temporal changes in other risk factors (AOR 1.11, 95% CI 0.99 to 1.24).

Regression analyses of maternal obstetric trauma showed that the risk of severe perineal lacerations declined over time, even after adjustment for mode of delivery and other risk factors (table 4). The risk of cervical/high vaginal lacerations remained unchanged. The temporal decline in severe perineal laceration in forceps delivery was not significant after adjustment for other covariates (online supplementary appendix table 2).

Sensitivity analyses

Sensitivity analyses showed a temporal decline in the rates of sequential instrumental vaginal delivery (from 0.11% in 2004–2006 to 0.04% in 2011–2013; RR 0.39; 95% CI 0.30 to 0.49); and a small temporal decline in the rates of failed instrumental vaginal delivery resulting in caesarean section (from 0.35% in 2004–2006 to 0.30% in 2011–2013). The rate of birth trauma remained unchanged in both groups (the average rates were 40.23 and 17.38 per 1000 live births, respectively). The rate of birth trauma did not change significantly among women with caesarean delivery with labour without failed instrumental delivery; the average rate was 4.47 per 1000 live births. Additional analyses showed that the proportion of mid/low-cavity forceps among women with forceps delivery increased from 4.83% in 2004 to 6.17% in 2013; this trend was not statistically significant (P=0.086). The overall rate of mid/low-cavity forceps remained relatively unchanged among women with vaginal delivery (0.52 in 2004–2006 and 0.55 per 1000 vaginal deliveries in 2011–2013). Adjustment for mid/low-cavity forceps did not change the results for infants and women with forceps delivery.

DISCUSSION

Monitoring temporal trends in major adverse health outcomes in childbearing women and their infants is important for identification of potential problems and areas for improvement in quality of maternal and infant care. Our results show a significant decline in the rate of severe birth trauma in Washington State, USA, between 2004 and 2013. This trend remained unchanged after adjustment for a temporal increase in caesarean delivery and concurrent decrease in instrumental vaginal delivery as well as after adjustment for other temporal changes in risk factors for birth trauma. Detailed analyses showed that the significant declines occurred only in the rates of fractures and other severe birth trauma among infants delivered by spontaneous vaginal delivery, whereas the rates of brain injury and nerve injury remained unchanged. The rates of severe perineal lacerations declined among women with spontaneous vaginal delivery and vacuum delivery.

Most studies have focused on the association of birth trauma with mode of delivery showing an increased risk

Table 4 Unadjusted and adjusted ORs expressing the change per year in the risk of maternal obstetric trauma among singleton infants, Washington State, USA, 2004–2013

Obstetric trauma	OR (95% CI)	AOR* (95% CI)	AOR† (95% CI)
Severe perineal lacerations	0.95 (0.95 to 0.96)	0.96 (0.96 to 0.97)	0.96 (0.95 to 0.96)
Cervical/high vaginal lacerations	0.99 (0.99 to 1.00)	1.00 (0.99 to 1.01)	1.00 (0.99 to 1.00)
Any severe lacerations	0.91 (0.91 to 0.92)	0.92 (0.92 to 0.92)	0.91 (0.91 to 0.92)

Breech delivery was excluded.
*Adjusted for temporal changes in mode of delivery.
†Adjusted for temporal changes in mode of delivery and other risk factors (parity, body mass index, maternal age, maternal education, race, marital status, assisted conception, hypertension, diabetes mellitus, gestational diabetes, smoking during pregnancy, birth weight, preterm birth, PROM (>12 hours), precipitous labour, prolonged labour, cephalopelvic disproportion, obstructed labour and fetal sex).
aOR, adjusted OR; PROM, premature rupture of membranes.

of birth trauma among infants delivered by instrumental vaginal delivery as compared with vaginal or caesarean delivery.[3–5 26–30] For example, Towner *et al*[3] reported the incidence rate of intracranial haemorrhage of 0.43 per 1000 infants born by spontaneous vaginal delivery in contrast with 1.16 and 1.57 per 1000 infants delivered by vacuum and forceps, respectively. Our study confirmed that the rate of instrumental vaginal delivery declined over the last 10 years while the rate of caesarean delivery increased, mainly due to increases in the rate of repeat caesarean delivery without labour. In agreement with our hypothesis, the magnitude of decline in the overall rate of birth trauma was slightly attenuated after adjustment for mode of delivery; however, the decline in the rate of birth trauma remained significant after adjustment for temporal changes in other risk factors.

The reasons for the decline in fractures and other birth trauma among spontaneous vaginal deliveries are unclear. The majority of fractures were fractures of the clavicle, which some obstetricians regard as an unavoidable event.[31] We did not find any evidence of the effect of temporal changes in major risk factors for fractures, including large birth weight, prolonged labour, precipitous labour, high BMI and obstructed labour or cephalopelvic disproportion (including shoulder dystocia),[32–35] as adjustment for these factors did not change the trends substantially. Clinical recognition of fractured clavicle may not be obvious, and some fractures may be identified only after discharge.[36 37] Thus, changes in clinical vigilance with respect to clavicular fractures that were unsuspected during spontaneous vaginal delivery may have influenced the temporal trends. Another possible explanation is improved selection of low-risk childbearing women for vaginal delivery, resulting in a lower proportion of complicated vaginal delivery and less need for vacuum and forceps. This explanation is only indirectly supported in our study by a concomitant increase in repeat caesarean delivery without labour and therefore remains speculative, as our study was not designed to examine such phenomena beyond the changes in risk factors that we adjusted for in multivariable analyses. The decline in the rate of birth trauma could also be attributed to improved quality of care. Rate of birth trauma has been recommended as one of the indicators for quality of prenatal care.[38–41] However, this notion has recently been contended due to several limitations, including the lack of a consistent definition, uncertainty about preventability of some injuries and variations in clinical recognition at birth.[38 42] Nevertheless, the decline in the rate of severe perineal lacerations in our study, which was not explained by temporal changes in underlying population risk factors, also point to improved quality of care (if we assume that the quality of obstetric trauma reporting did not decline over time).

In contrast to our findings, some previous studies showed increased rates of obstetric trauma in Sweden from 1.7% in 1990 to 4.2% in 2004,[11] and in England from 1.8% in 2000 to 5.9% in 2012,[43] that were not explained by temporal changes in risk factors. These studies concluded that the most likely reason for an increase in obstetric trauma was an improvement in recognition of lacerations.[11 12 43]

Our study has several strengths. We used large population databases with detailed information on maternal and pregnancy risk factors, labour and delivery characteristics and infant outcomes. The information on birth trauma was collected consistently over the study period using ICD-9-CM codes. The linkage between hospitalisation data and birth certificates has been shown to improve overall data accuracy.[44 45] Previous validation studies of the linked dataset[44 45] showed that the positive and negative predictive value was above 80% and 98%, respectively, for majority of labour and delivery information in birth certificates and in CHARS as compared with a gold standard of manually abstracted and reabstracted data from medical charts.[44] We had detailed information on mode of delivery and were able to adjust for the majority of other known risk factors for birth trauma, including BMI (with approximately 9% of values imputed).

Our study has several limitations. First, statistical power to detect temporal trends for some specific injuries may have been limited when examined by mode of delivery and adjusted for potential confounders. Second, the exact degree of severity of ‘other birth trauma’ was not possible to ascertain from the ICD-9-CM code. This condition includes severe injury (eye damage, traumatic glaucoma, haematoma/rupture of liver and spleen and injury to adrenal gland) and potentially less severe injury (such as scalpel wound laceration), haematoma of vulva and testes and haematoma of sternomastoid. We therefore reported on specific categories of birth trauma that are more homogenous in terms of severity. Third, the proportion of missing values for BMI declined during the study period. We used multiple imputation to adjust for BMI in the multivariable analysis. Fourth, some errors and omissions in diagnostic coding are inevitable in all large administrative databases. However, these errors would have resulted in non-differential misclassification, potentially resulting in underestimation of temporal trends. Fifth, the linked dataset did not include information on antepartum versus intrapartum stillbirths, thus the analysis did not account for birth trauma resulting in intrapartum stillbirth. Lastly, hypoxic–ischaemic encephalophathy (HIE), which can result from birth trauma, was not included in the analysis of temporal trends. This was due to inconsistencies in the ICD-9-CM coding (ICD-9-CM code for HIE was introduced in 2007)[46] and clinical definition of HIE over the study period (HIE vs birth asphyxia or other encephalopathy, which can result from other causes including placental abruption, uterine rupture and cord prolapse).[47]

CONCLUSION

Our study showed a temporal decline in fractures and other birth trauma among infants with spontaneous vaginal delivery in the past 10 years. Although rates of forceps and vacuum delivery declined over time, the rates of birth trauma following such delivery remained unchanged and higher as compared with all other types of delivery. Rate of severe perineal lacerations declined over time in all types of vaginal delivery, suggesting improved obstetric care.

Contributors SL and GMM designed the study, SL and QW performed data analysis and QW and SL wrote the first draft of the manuscript. GMM, JT, SC and KIL helped with the interpretation of the results and critically revised this first draft. All authors approved the final version of the manuscript.

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