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ORIGINAL ARTICLE

Temporal trends in the incidence of post-dural puncture headache following labor neuraxial analgesia in the United States, 2006 to 2015

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ABSTRACT
Background: Labor neuraxial analgesia utilization has increased in the United States (U.S.) but its impact on maternal safety is unknown. This study analyzed the temporal trends in the incidence of post-dural puncture headache (PDPH) in obstetrics.
Methods: Data for vaginal or intrapartum cesarean deliveries came from the National Inpatient Sample 2006–2015, a U.S. 20% representative sample of hospital discharge records. The outcome was PDPH (ICD-9-CM codes 349.0 and 03.95) categorized into (1) PDPH coded without epidural blood patch (EBP), and (2) PDPH coded with EBP. Temporal trends in incidence were described using the percent change between 2006 and 2015 and its 95% confidence interval (CI).
Results: Of the 29 011 472 deliveries studied, 86 558 (29.8 per 10 000; 95% CI: 29.3 to 30.2) recorded a diagnosis of PDPH, including 34 019 without EBP (11.7 per 10 000; 95% CI 11.4 to 12.0) and 52 539 with EBP (18.1 per 10 000; 95% CI 17.8 to 18.4). A significant decrease in the incidence of PDPH was observed from 31.5 per 10 000 in 2006 to 29.2 per 10 000 in 2015 (–7.5%; 95% CI −2.2 to −0.5; P=0.001). The decrease in the incidence of PDPH was significant irrespective of the presence of EBP. The decrease was observed in the three categories of hospitals examined (rural, urban non-teaching, and urban teaching).
Conclusions: During the study period, the reported incidence of PDPH in the U.S. has decreased modestly. Intervention programs are needed to address this persistent and preventable cause of maternal morbidity.

Keywords: Epidemiology; Epidural blood patch; Healthcare quality; Labor neuraxial analgesia; Post-dural puncture headache

Introduction

Neuraxial analgesia is the most effective technique to relieve labor pain and contributes to maternal safety.[1] It decreases the utilization and maternal risks associated with general anesthesia if an intrapartum cesarean delivery or any other urgent obstetrical intervention is required.[2,3] It is estimated that about 73% of laboring women in the United States (U.S.) receive labor neuraxial analgesia for vaginal or intrapartum cesarean delivery, corresponding to about two million annual procedures.[4]

Post-dural puncture headache (PDPH) remains the most frequent complication of labor neuraxial analgesia, with a reported incidence in the U.S. ranging from 0.1 to 0.8%.[5,6] Post-dural puncture headache hinders women's ability to perform daily activities, including caring for their baby. It also delays hospital discharge, and leads to hospital re-admission and to potentially legal liability.[7,8] More concerningly, PDPH is associated with an increased risk of persistent headache, persistent backache, depression, and major life-threatening neurologic complications such as cerebral venous thrombosis or subdural hematoma.[9–11] While research indicates an improvement in the safety of anesthetic care for cesarean delivery during the last two decades and a decrease in the incidence of anesthesia-related complications, no study has specifically examined the temporal trends in the incidence of PDPH associated with labor neuraxial analgesia.[12] To address this gap in our knowledge, this study analyzed the temporal trends in the incidence of PDPH in the obstetric population in the U.S. between January 2006 and September 2015.

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Materials and methods

The study protocol was approved by the Institutional Review Board (IRB) of Columbia University Irving Medical Center (IRB-AAAR2286). The Strengthening The Reporting of OBservational studies in Epidemiology (STROBE) and the Reporting of studies Conducted using Observational Routinely-collected health Data (RECORD) statements were followed.

Data systems

Data for this study came from the National Inpatient Sample (NIS) of the Healthcare Cost and Utilization Project (HCUP), sponsored by the Agency for Healthcare Research and Quality. The NIS is a stratified sample of approximately 20% of discharge records from community hospitals in the U.S. The HCUP defines community hospitals as non-federal short-term hospitals. They include both general and specialty hospitals (e.g. obstetrics and gynecology), and tertiary or academic centers. For each discharge, the NIS includes some patient characteristics (e.g. age or race/ethnicity), hospital characteristics (e.g. rural or urban location), and up to 15 procedural codes and 30 diagnostic codes defined in the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM). ICD-9-CM was used until September 2015. The NIS also provides individual discharge weight that permits inference for a nationally representative population. Discharge weights before 2011 were updated in 2012 to take into consideration the 2012 NIS sampling redesign. This update allows providing valid national estimates in multi-years analysis. Detailed information on NIS data, methodology, and variables is publicly available (https://www.hcup-us.ahrq.gov/db/nation/nis/nisdbdocumentation.jsp).

Study sample

The study sample included all vaginal and intrapartum cesarean deliveries between January 1, 2006 and September 30, 2015. We excluded the fourth quarter of 2015 because of the introduction of the ICD-10-CM in October 2015 and because of the potential impact of the transition from ICD-9-CM to ICD-10-CM on the incidence of PDPH.

Delivery hospitalizations were identified using a combination of ICD-9-CM diagnosis and procedure codes, as previously described.[13] Cesarean delivery cases were qualified intrapartum if associated with at least one ICD-9-CM code indicating labor, as previously described (Supplemental Table 1).[3]

Outcome

The primary outcome was PDPH, identified using two ICD-9-CM codes: the diagnosis code 349.0 (“Reaction to spinal or lumbar puncture: headache following lumbar puncture”) and the procedure code 03.95 (“Spinal blood patch”).

Post-dural puncture headache was further categorized into 1) PDPH coded as ‘without an epidural blood patch’ (EBP), and 2) PDPH coded as ‘with an EBP’. Post-dural puncture headache without an EBP corresponded to discharges recording only the diagnosis code 349.0 without the procedure code 03.95. Post-dural puncture headache with an EBP corresponded to discharges recording (1) both the diagnosis code 349.0 and the procedure code 03.95, or (2) only the procedure code 03.95 without the diagnosis code 349.0.

Patient and hospital characteristics

The following patient characteristics were recorded directly from the NIS: maternal age; race and ethnicity (categorized as White, Black, Hispanics Asian or Pacific Islander, and other); patient residence (categorized as rural or urban); insurance type (categorized as Medicaid or Medicare, private, self-pay, and other); and quartile of median household income for the patient zone improvement plan code of residence. Coding intensity was calculated as the number of ICD-9-CM diagnosis or procedure codes reported per discharge. The comorbidity index for obstetric patients was calculated using a previously described ICD-9-CM algorithm.[14,15] This index was designed specifically for use in obstetric patient populations; it includes maternal age and 20 maternal conditions (e.g. severe pre-eclampsia/eclampsia) that are predictive of maternal end-organ injury or death during the delivery hospitalization through until 30 days postpartum. Other characteristics were identified using ICD-9-CM codes (Supplemental Table 1).

The following hospital characteristics were recorded from the NIS: hospital bed size (categorized as small, medium, or large); location and teaching status (categorized as rural, urban non-teaching, and urban teaching); and census region. In the NIS, thresholds used to define bed size categories depend on the hospital census region, location (rural or urban), and teaching status (https://www.hcup-us.ahrq.gov/db/vars/hosp_bedsize/nisnote.jsp).

Statistical analysis

Statistical analysis was performed with R version 3.6.2 (R Foundation for Statistical Computing, Vienna, Austria) and specific packages (survey for analysis of survey data and mice for multiple imputations).

Results are expressed as count (% or per 10 000), mean, or median (interquartile range). All counts and proportions presented are weighted using individual discharge weights.

We performed a comparison between women with PPDH and women without PPDH, and a comparison

between women with PDPH who received an EBP and women with PDPH who did not receive an EBP. Comparisons used chi-square tests for survey data for categorical variables (function svychisq in the R package survey), Wilcoxon tests for continuous variables (function svyranktest), and the standardized mean difference (a value >10% is usually considered indicative of a relevant difference). Missing values were estimated using multiple imputations using the R package mice with five iterations and five imputed datasets created.

Temporal trends in the incidence of the three outcomes (PDPH, PDPH without EBP, and PDPH with EBP) were described using the percentage change and its 95% confidence interval (CI). The percentage change was calculated as 100 × [(incidence in 2015 − incidence in 2006)/incidence in 2006]. The number of PDPH cases for the full calendar year 2015 was estimated, using a rule of three, as (number of cases for the first 9 months of 2015/3) × 4.

The statistical significance of the temporal trends was tested using the regression coefficient and associated *P*-value for the year of delivery from a generalized linear model for complex survey data (function svyglm in the R package survey).[16] In this model, the unit of analysis was the delivery hospitalization, the dependent variable was the complication (yes/no), and the independent

Table 1 Univariate comparison of women with and without post-dural puncture headache in the National Inpatient Sample January 2006 to September 2015

	No PDPH (n=28 924 915)	PDPH (n=86 558)	*P*-value	SMD (a)
General characteristics				
Age (median, interquartile range) (missing=1779)	27 (22–32)	28 (23–32)	<0.001	9.4%
Race or ethnicity (missing=4 240 227)			<0.001	
White	12 959 660 (52.5%)	43 568 (59.0%)		13.2%
Black	3 377 452 (13.7%)	7340 (9.9%)		−12.6%
Hispanic	5 625 927 (22.8%)	14 544 (19.7%)		−7.7%
Asian or Pacific Islander	1 321 493 (5.4%)	3929 (5.3%)		−0.2%
Other	1 412 879 (5.7%)	4452 (6.0%)		1.0%
Rural residence (missing=3 558 123)	3 701 509 (14.6%)	13 250 (17.7%)	<0.001	8.0%
Insurance type (missing=48 927)			<0.001	
Medicaid or Medicare	12 745 037 (44.1%)	34 695 (40.2%)		−8.3%
Private	14 347 001 (49.7%)	46 916 (54.3%)		9.5%
Self-pay (uninsured)	914 831 (3.2%)	1999 (2.3%)		−5.7%
Other	869 270 (3.0%)	2795 (3.2%)		1.3%
Lowest quartile of median household income or poorest (missing=534 639)	7 811 680 (27.5%)	21 313 (25.1%)	<0.001	−5.7%
Obesity	1 072 898 (3.7%)	4607 (5.3%)	<0.001	7.2%
Comorbidity index for obstetric patients (median, interquartile range) (missing=1769)	0 (0–1)	0 (0–1)	<0.001	5.1%
Pregnancy and delivery				
Previous cesarean delivery	856 903 (3.0%)	3313 (3.8%)	<0.001	4.6%
Multiple gestation	233 280 (0.8%)	1113 (1.3%)	<0.001	4.2%
Abnormal presentation	1 167 637 (4.0%)	4586 (5.3%)	<0.001	5.6%
Fetal macrosomia	601 405 (2.1%)	2578 (3.0%)	<0.001	5.3%
Induction of labor	7 442 520 (25.7%)	25 923 (29.9%)	<0.001	9.2%
Intrapartum cesarean delivery	3 482 623 (12.0%)	14 151 (16.3%)	<0.001	11.7%
Hospital characteristics				
Location and teaching status (missing=168 755)			<0.001	
Rural	31 81 447 (11.1%)	11 976 (13.9%)		8.2%
Urban non-teaching	11 010 584 (38.3%)	32 249 (37.5%)		−1.6%
Urban teaching	14 564 692 (50.6%)	41 769 (48.6%)		−4.2%
Hospital bed size (missing=168 755)			<0.001	
Small	3 181 447 (11.1%)	11 976 (13.9%)		2.8%
Medium	11 010 584 (38.3%)	32 249 (37.5%)		1.4%
Large	14 564 692 (50.6%)	41 769 (48.6%)		−3.2%
Census region			<0.001	
Northeast	4 622 995 (16.0%)	16 233 (18.8%)		6.9%
Midwest	6 386 165 (22.1%)	21 577 (24.9%)		6.8%
South	10 665 007 (36.9%)	30 005 (34.7%)		−4.6%
West	7 250 748 (25.1%)	18 743 (21.7%)		−8.2%

PDPH: post-dural puncture headache. SMD: standardized mean difference. (a) A standardized mean difference >10% is considered to indicate a relevant difference.

variable the year of delivery, treated as a continuous variable. This model was further adjusted for the following characteristics: (1) maternal age, (2) race/ethnicity, (3) insurance category, (4) comorbidity index for obstetric patients, (5) delivery mode (vaginal delivery or intrapartum cesarean delivery), (6) hospital location and teaching status (rural, urban non-teaching, urban teaching), and (7) hospital census region.

The temporal trends in the incidence of PDPH were also estimated according to the three hospital categories provided by the NIS (rural, urban non-teaching, urban teaching). The temporal trends in the coding intensity were also analyzed.

Results

During the study period, 37 993 487 delivery hospitalizations were identified. Among them, 8 982 015 corresponding to non-intrapartum cesarean deliveries were excluded. The final study sample included 29 011 472 (76.3%) hospitalizations for vaginal deliveries or intrapartum cesarean deliveries.

Table 2 Univariate comparison of women with post-dural puncture headache who received, or did not receive, an epidural blood patch in the National Inpatient Sample January 2006 to September 2015

	PDPH without EBP (n=34 019)	PDPH with EBP (n=52 539)	*P*-value	SMD (a)
General characteristics				
Age (median, interquartile range)	27 (23–32)	28 (24–32)	<0.001	7.2%
Race or ethnicity (missing=12 724)			<0.001	
White	15 317 (52.5%)	28 251 (63.3%)		21.6%
Black	3664 (12.6%)	3675 (8.2%)		−15.8%
Hispanics	6630 (22.7%)	7915 (17.7%)		−13.3%
Asian or Pacific Islander	1639 (5.6%)	2290 (5.1%)		−2.1%
Other	1922 (6.6%)	2530 (5.7%)		−3.9%
Rural residence (missing=11 681)	4879 (16.6%)	8370 (18.4%)	0.012	5.5%
Insurance type (missing=151)			<0.001	
Medicaid or Medicare	15 135 (44.6%)	19 560 (37.3%)		−15.2%
Private	16 655 (49.1%)	30 261 (57.7%)		17.4%
Self-pay (uninsured)	965 (2.8%)	1035 (2.0%)		−5.9%
Other	1187 (3.5%)	1608 (3.1%)		−2.4%
Lowest quartile of median household income or poorest (missing=1616)	9 152 (27.5%)	12 161 (23.5%)	<0.001	−8.9%
Individual comorbidities and comorbidity index				
Obesity	2145 (6.3%)	2462 (4.7%)	<0.001	−7.7%
Comorbidity index for obstetric patients (median, interquartile range)	0 (0–1)	0 (0–1)	0.095	−1.7%
Pregnancy and delivery				
Previous cesarean delivery	1391 (4.1%)	1923 (3.7%)	0.145	−2.1%
Multiple gestation	372 (1.1%)	741 (1.4%)	0.065	2.7%
Abnormal presentation	1818 (5.3%)	2768 (5.3%)	0.833	−0.4%
Fetal macrosomia	1010 (3.0%)	1568 (3.0%)	0.952	0.1%
Induction of labor	9703 (28.5%)	16 220 (30.9%)	0.001	5.0%
Intrapartum cesarean delivery	6031 (17.7%)	8119 (15.5%)	<0.001	−6.3%
Hospital characteristics				
Location and teaching status (missing=564)			<0.001	
Rural	4496 (13.3%)	7479 (14.3%)		3.6%
Urban non-teaching	11 931 (35.3%)	20 318 (38.9%)		7.4%
Urban teaching	17 373 (51.4%)	24 396 (46.7%)		−9.8%
Hospital bed size (missing=564)			0.001	
Small	4360 (12.9%)	7169 (13.7%)		2.6%
Medium	9002 (26.6%)	15 227 (29.2%)		5.5%
Large	20 093 (60.5%)	29 797 (57.1%)	−6.9%	
Census region			<0.001	
Northeast	6620 (19.5%)	9614 (18.3%)		−3.1%
Midwest	7617 (22.4%)	13 960 (26.6%)		9.7%
South	11 950 (35.1%)	18 055 (34.4%)		−1.7%
West	7833 (23.0%)	10 910 (20.8%)		−5.6%

EBP: epidural blood patch. PDPH: post-dural puncture headache. SMD: standardized mean difference. (a) A standardized mean difference >10% is considered to indicate a relevant difference.

A diagnosis of PDPH was recorded in 86 558 deliveries (29.8 per 10 000; 95% CI 29.3 to 30.2), including 34 019 coded as PDPH without EBP (11.7 per 10 000; 95% CI 11.4 to 12.0) and 52 539 coded as PDPH with EBP (18.1 per 10 000; 95% CI 17.8 to 18.4). Of the 52 539 coded as PDPH with EBP, 5203 (9.9%) had the ICD-9-CM procedure code for EBP but no diagnostic code for PDPH. Because EBP is usually used to relieve PDPH, we included the 5203 cases in the group coded as PDPH with EBP.

Compared with women without PDPH, women with PDPH were older, more likely non-Hispanic White, rural residents, or had private healthcare insurance (Table 1). Women with PDPH were more likely than those without PDPH to have undergone induced labor or intrapartum cesarean delivery, and delivered in rural hospitals. Compared with women coded as PDPH with EBP, women coded as PDPH without EBP were more likely racial and ethnic minorities, Medicaid or Medicare beneficiaries, and to have a lower median household income (Table 2).

During the study period, a statistically significant decrease in the incidence of reported PDPH was observed, from 31.5 per 10 000 in 2006 to 29.2 per 10 000 in 2015, yielding a percentage change of −7.5% (95% CI −10.4 to −4.6) (Table 3 and Fig. 1A). This corresponded to 10 062 women (95% CI 8884 to 11 239) affected in 2006 and 8447 women during the full calendar year 2015 (95% CI 7826 to 9147). The decrease was statistically significant for cases coded as PDPH without EBP (PC −8.7%, 95% CI −13.3 to −4.0) and for cases coded as PDPH with EBP (–6.7%, 95% CI −10.4 to −3.0). The incidence of PDPH decreased in the three categories of hospitals examined (rural, urban non-teaching, and urban teaching) but was statistically significant only in urban non-teaching hospitals (Table 4 and Fig. 1B). During the study period, a statistically significant increase in coding intensity was observed from 6.4 codes per discharge in 2006 to 7.9 codes per discharge in 2015 (P <0.001).

Discussion

In this nationally representative study, we observed a statistically significant decrease in the incidence of reported PDPH, overall and across the three categories of hospitals examined, suggesting an improvement in the safety of obstetric anesthesia care during the study period. However, the decrease was of small amplitude (7.5%).

We observed a higher incidence of reported PDPH in older non-Hispanic White women, rural residents, or women with private healthcare insurance. We acknowledge that we do not know whether women actually received labor neuraxial analgesia, because this information is not contained in the National Inpatient Sample. In other words, a higher incidence of PDPH

Table 3 Temporal trends in the incidence of post-dural puncture headache, post-dural puncture headache without epidural blood patch, and post-dural puncture headache with epidural blood patch, in the National Inpatient Sample, January 2006 to September 2015

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015 (a)	PC (95% CI) (b)	*P*-value (c)
Discharges	3 192 617	3 345 299	3 100 283	2 987 987	2 825 257	2 789 394	2 856 881	2 836 558	2 894 955	2 182 240	–	–
PDPH												
Events	10 062	9579	9304	9299	9066	8578	8560	8160	7585	6365	–	–
Incidence	31.5	28.6	30.0	31.1	32.1	30.8	30.0	28.8	26.2	29.2	−7.5% (−10.4 to −4.6)	0.001
PDPH without EBP												
Events	3884	3860	3736	3656	3648	3350	3240	3110	3110	2425	–	–
Incidence	12.2	11.5	12.1	12.2	12.9	12.0	11.3	11.0	10.7	11.1	−8.7% (−13.3 to −4.0)	0.003
PDPH with EBP												
Events	6178	5720	5568	5643	5418	5227	5320	5050	4475	3940	–	–
Incidence	19.4	17.1	18.0	18.9	19.2	18.7	18.6	17.8	15.5	18.1	−6.7% (−10.4 to −3.0)	0.033

CI: confidence interval. EBP: epidural blood patch. PC: percent change. PDPH: post-dural puncture headache. Incidence is expressed per 10 000 discharges. (a) The fourth quarter of 2015 using the ICD-10 classification is excluded. The total number of PDPH in 2015 can be estimated using a rule of three as (6335/3) × 4 = 8447. (b) The percent change is calculated as 100 × [(incidence in 2015-incidence in 2006)/incidence in 2006]. (c) The *P*-value is for the regression coefficient of the year of delivery from a generalized linear model for complex survey data, with the discharge as the unit of analysis, the outcome as the dependent variable, and the year of delivery treated as a continuous variable as the independent variable. The model is further adjusted for: (1) maternal age, (2) race or ethnicity, (3) insurance category, (4) comorbidity index for obstetric patients, (5) delivery mode (vaginal delivery or intrapartum cesarean delivery), (6) hospital location and teaching status (rural, urban non-teaching, urban teaching), and (7) hospital census region.

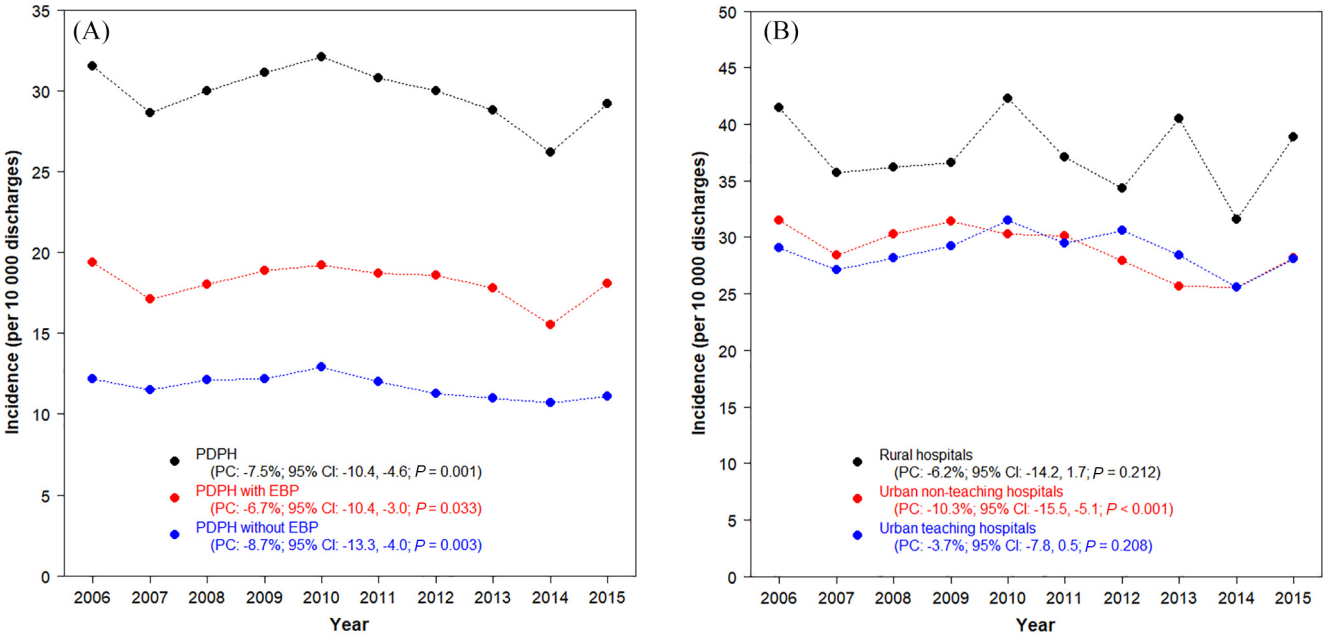

Fig. 1 Temporal trends in the incidence of post-dural puncture headache in the National Inpatient Sample, 2006–2015. A. Temporal trends in the incidence of post-dural puncture headache, post-dural puncture headache with epidural blood patch, and post-dural puncture headache without epidural blood patch. B. Temporal trends in the incidence of post-dural puncture headache in rural hospitals, urban non-teaching hospitals, and urban teaching hospitals. CI: confidence interval. EBP: epidural blood patch. PC: percent change calculated as 100 × [(incidence in 2015 − incidence in 2006)/incidence in 2006]. PDPH: post-dural puncture headache. P: *P*-value for the statistical significance of the temporal trends

associated with a particular characteristic (e.g. White race) may merely reflect a higher utilization of labor neuraxial analgesia in women with this characteristic. This limitation does not apply to the comparison of women with PDPH who benefited or did not benefit from an EBP. We observed a lower proportion of EBP when a PDPH occurred in racial and ethnic minority women or in women with a lower socio-economic status, such as Medicaid or Medicare beneficiaries or those with a lower median household income. This suggests socio-economic or racial and ethnic disparities in receipt of EBP in obstetric anesthesia care that could be targeted to improve management of PDPH in these vulnerable populations. We also acknowledge that we could not determine whether the lower proportion of EBP in these women was related to the availability of EBP in the hospital where they delivered or to patient choice. The 2019 UK Obstetric Anaesthetists' Association guidelines on PDPH treatment indicate that EBP should be offered to women with symptoms affecting daily living and care of the baby, with an interval of 48 h between the dural puncture and the EBP.[17,18]

The incidence of reported PDPH in this database was much lower than the widely cited incidence of 1–2%. This has several possible explanations.[19] First, the denominator used in our study to estimate the incidence was the number of women who gave birth rather than the number of women who actually received labor neuraxial analgesia, because this latter information is not available in NIS data. In other words, we probably underestimate the true incidence of PDPH. Second, we cannot exclude that changes in the incidence of reported PDPH or EBP may be related to changes in coding pattern such as a decrease in coding intensity. Nevertheless, we observed an increase in the coding intensity during the study period, indicating that the decreased incidence observed was not related to a decrease in coding intensity. Third, we limited the identification of PDPH to delivery hospitalizations because NIS data do not allow tracking of patients over time for hospital re-admission. About 5% of cases of PDPH are identified during re-admission after discharge from the delivery hospitalization.[11] Finally, we also cannot exclude that the 1–2% incidence is overestimated. Overestimation is suggested by the recent review by Delgado et al. that reports an incidence of PDPH in obstetrics ranging from a low of 0.1% to a high of 0.8%.[6] This indicates the need for further research using other data systems to obtain a more reliable estimate of the incidence of PDPH.

Although the incidence of PDPH may appear low and these data may be unprecise, this complication affected approximately 8500 women in the U.S. in 2015. It is a concern for both short-term and long-term maternal health outcomes, especially in view of the mounting evidence of the long-term consequences of PDPH such as persistent headache, persistent

Table 4 Temporal trends in the incidence of post-dural puncture headache according to hospital characteristics in the National Inpatient Sample, January 2006 to September 2015

	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015 (a)	PC (95% CI) (c)	*P*-value (c)
Rural hospitals												
Discharges	359 316	371 303	350 695	337 129	319 183	324 453	319 561	319 564	280 359	211 860	–	–
Events	1492	1327	1270	1234	1349	1204	1095	1295	885	825	–	–
Incidence	41.5	35.7	36.2	36.6	42.3	37.1	34.3	40.5	31.6	38.9	−6.2% (−14.2 to 1.7)	0.212
Urban non-teaching hospitals												
Discharges	1 326 988	1 407 758	1 269 271	1 236 773	1 192 582	1 121 136	1 098 709	1 079 671	742 899	567 045	–	–
Events	4174	4001	3852	3887	3613	3377	3060	2780	1905	1600	–	–
Incidence	31.5	28.4	30.3	31.4	30.3	30.1	27.9	25.7	25.6	28.2	−10.3% (−15.5 to –5.1)	<0.001
Urban teaching hospitals												
Discharges	1 499 767	1 561 929	1 475 086	1 61 615	1 259 370	1 297 728	1 438 611	1 437 324	1 871 697	1 403 335	–	–
Events	4371	4234	4163	3977	3968	3832	4405	4085	4795	3940	–	–
Incidence	29.1	27.1	28.2	29.2	31.5	29.5	30.6	28.4	25.6	28.1	−3.7% (−7.8 to 0.5)	0.208

CI: confidence interval. PC: percent change. Incidence is expressed per 10 000 discharges.(a) The fourth quarter of 2015 using the ICD-10 classification is excluded.(b) The percent change is calculated as$100 \times$ [(incidence in 2015-incidence in 2006)/incidence in 2006]. (c) The *P*-value is for the regression coefficient of the year of delivery from a generalized linear model for complex survey data, with the discharge as the unit of analysis, the outcome as the dependent variable, and the year of delivery treated as a continuous variable as the independent variable. The model is further adjusted for: (1) maternal age, 2) race or ethnicity, (3) insurance category, (4) comorbidity index for obstetric patients, (5) delivery mode (vaginal delivery or intrapartum cesarean delivery), (6) hospital location and teaching status (rural, urban non-teaching, urban teaching), and 7) hospital census region.

backache, depression, and cerebral venous thrombosis or subdural hematoma.[9–11] Some interventions have been suggested to address this persistent and preventable cause of anesthesia-related morbidity and its potential long-term sequelae. For example, the recent root-cause analysis by Haller et al. revealed that the absence of skilled assistance during epidural placement[21] (i.e. a nurse anesthetist) and multiple insertion attempts are associated with an increased risk of PDPH.[20] Although the current American Society of Anesthesiologists Task Force on Obstetric Anesthesia Practice Guidelines for Obstetric Anesthesia does not recommend any obstetric team composition for labor epidural placement, Haller et al. suggest that having a skilled assistant for the anesthesiologist during the procedure might reduce the incidence of PDPH.[20] Use of lumbar ultrasound imaging has been shown to decrease the number of epidural placement attempts and may reduce the risk of accidental dural puncture.[22] While further studies are required to assess the effectiveness of this non-invasive imaging technique in reducing the risk of PDPH in obstetrics, one may suggest its use in women with known risk factors for difficult epidural placement.[23] The role of simulation training in acquiring and maintaining technical skills and reducing the number of epidural placement attempts also warrants investigation.

The study has several limitations. First, our study findings may not be generalizable to other countries. Compared with other high-income countries, the U.S. is characterized by very marked socioeconomic and racial and ethnic disparities in healthcare utilization and maternal health outcomes during pregnancy and delivery hospitalizations that may not be observed in countries with universal health coverage.[24,25] Second, NIS data provide information on whether labor neuraxial analgesia complications occurred but not on whether labor neuraxial analgesia was used. We hypothesized that labor neuraxial analgesia utilization increased during the study period and that the parallel decrease in the incidence of PDPH suggested an improvement in the safety of obstetric anesthesia care. To examine whether labor neuraxial analgesia utilization increased during the study period, we conducted a post hoc analysis of birth certificate data that contain a check box to report whether or not the patient received "epidural or spinal anesthesia during labor" (Supplemental Table 3). Using these data, we observed a statistically significant increase in utilization, from 55.4% in 2006 to 72.7% in 2015. Third, we are not aware of a validation of the ICD-9-CM codes to identify PDPH used in this study against individual medical record analysis. Last, we chose to consider the 5203 discharges that recorded only the procedure code 03.95 (6% of all PDPH cases) as PDPH. Although EBP is usually used to relieve PDPH in obstetric patients, we cannot exclude that EBP was performed for another indication.

In conclusion, in this nationwide study we observed a modest decrease in the reported incidence of PDPH, suggesting an improvement in the safety of obstetric anesthesia care. The limitations of our database also reinforce the need to accurately and comprehensively code PDPH and EBP in our electronic health records, in order to monitor the time trends and the effect of interventions in addressing this persistent and preventable cause of anesthesia-related morbidity.

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Declaration of interests

The authors declare no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijoa.2020.10.003.