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Maternal Body Mass Index and Use of Labor Neuraxial Analgesia: A Population-Based Retrospective Cohort Study

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Abstract

Background—Neuraxial labor analgesia may benefit obese women by optimizing cardiorespiratory function and mitigating complications related to emergency general anesthesia. We hypothesized that obese women have a higher rate of neuraxial analgesia compared with nonobese parturients.

Methods—Using United States natality data, our cohort comprised 17,220,680 deliveries, which accounts for 61.5% of 28 million births in the United States between 2009 and 2015. We examined the relationships between body mass index (BMI) class and neuraxial labor analgesia, adjusting for sociodemographic, antenatal, pregnancy, and peripartum factors.

Results—The study cohort comprised 17,220,680 women; 0.1% were underweight, 12.7% were normal BMI, 37% were overweight, 28.3%, 13.5%, and 8.4% were obesity class I, II, and III, respectively. Rates of neuraxial analgesia by BMI class were: underweight 59.7% (9,030/15,128); normal BMI 68.1% (1,487,117/2,182,797); overweight 70.3% (4,476,685/6,368,656); obesity class I 71.8% (3,503,321/4,881,938); obesity class II 73.4% (1,710,099/2,330,028); and obesity class III 75.6% (1,089,668/1,442,133). Compared to women with normal BMI, the likelihood of receiving neuraxial analgesia was slightly increased for overweight women (adjusted relative risk (aRR) 1.02; 95% confidence intervals (CI) 1.02 to 1.02), obese class I (aRR 1.04; 95% CI 1.04 to 1.04), obese class II (aRR 1.05; 95% CI 1.05 to 1.05), and obese class III (aRR 1.06; 95% CI 1.06 to 1.06).

Conclusion—Our findings suggest that the likelihood of receiving neuraxial analgesia is only marginally increased for morbidly obese women compared to women with normal BMI.

Introduction

The prevalence of maternal obesity in the United States (US) is high, with 1 in 4 deliveries occurring to women who are obese (classified as a body mass index (BMI) ≥ 30 kg/m²).¹

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Compared to nonobese women, obese women are at increased risk for pregnancy and peripartum complications, including preeclampsia, gestational diabetes mellitus, fetal macrosomia, stillbirth, post-term pregnancy, prolonged or dysfunctional labor, and cesarean delivery.²

The anesthetic management of obese women in labor often requires careful multidisciplinary planning and preparation. Performing neuraxial blockade in obese women can be technically challenging because bony landmarks are more difficult to palpate,^{3,4} back flexion is more limited, and the depth from skin to lumbar epidural space is increased⁵. Analgesia may also be suboptimal because of failure to achieve bilateral dermatomal spread or epidural catheter dislodgement, both of which increase the need for catheter replacement.⁶⁻⁸ Despite these technical concerns, neuraxial labor analgesia offers several important clinical benefits to obese women. From a physiological standpoint, neuraxial analgesia may optimize maternal respiratory function and attenuate sympathetically mediated cardiovascular responses in obese women.^{9,10} Obese parturients are at increased risk for cesarean delivery² and difficult or failed tracheal intubation (if general anesthesia is performed for emergency cesarean delivery);^{11,12} a pre-existing epidural catheter can mitigate this risk because an epidural top-up dose can extend epidural analgesia to surgical anesthesia. Given these potential benefits, we would expect the rate of neuraxial labor analgesia to be greater in obese women. However, there are limited epidemiological data examining whether rates of neuraxial labor analgesia differ between obese and nonobese women. In a retrospective cohort study of births in California between 2007 and 2010, Biel et al. found that overweight and obese women were more likely to receive regional labor analgesia.¹³ Data from a contemporary national cohort of women would be important for refining national guidelines for obstetric anesthetic management practices for obese women.

The aim of this study was to test the hypothesis that maternal obesity is associated with a higher rate of neuraxial labor analgesia use compared with nonobese parturients, and to estimate the difference in rate, if it exists.

Methods

As US vital statistics data are both publicly available and de-identified, our analysis was exempt from Stanford University Institutional Review Board review.

Study population

This population-based retrospective cohort study used US vital statistics data from 2009 to 2015 to evaluate the association between maternal obesity and neuraxial labor analgesia. This study period allows us to examine national obstetric anesthetic practices in a contemporary obstetric cohort. Data are based on a 100% sample of birth certificates from states that used the 2003 revision of the birth certificate. The 2003 revised birth certificate contains more detailed demographic, medical, and obstetric data compared to the 1989 version, including information on intrapartum methods of pain relief.¹⁴ The Centers for Disease Control and Prevention provide details of variables available in the revised birth certificate.¹⁵ Specifically, a checkbox exists on the revised birth certificate indicating whether or not “epidural or spinal anesthesia was used during labor.” The exact type of

neuraxial block is not described and no other information is captured for other types or modalities of labor analgesia.

For our analysis, we sourced data from all birth certificates that used the 2003 revision between 2009 and 2015. States using the revised format numbered 28 in 2009 (66% of all births), 33 in 2010 (76% of all births), 36 in 2011 (83% of all births), 38 in 2012 (86% of all births), 41 in 2013 (90% of all births), 47 in 2014 (96% of all births) and 48 states in 2015 (96% of all births). Our study cohort consisted of women who underwent labor prior to vaginal or intrapartum cesarean delivery. Because the birth certificate contains data on whether labor occurred or not prior to delivery, we were able to identify women who labored. We excluded women with cesarean deliveries without prior labor, women who had a non-US primary residence, out-of-hospital deliveries, and women with missing data for mode of delivery or neuraxial analgesia use.

Exposure, outcome and covariates

Maternal BMI at delivery was calculated based on the recorded weight and height at delivery, and was categorized using the World Health Organization BMI categories¹⁶: underweight (BMI < 18.5 kg/m²), normal BMI (BMI between 18.5 and 24.9 kg/m²), overweight (BMI between 25 and 29.9 kg/m²), obese class I (BMI between 30 and 34.9 kg/m²), obese class II (BMI between 35 and 39.9 kg/m²), and obese class III (BMI ≥ 40 kg/m²). Women at the extremes of height (height < 52 inches [1.32 m] or height > 76 inches [1.93 m]) (data judged likely to be in error) or who had missing height or weight data were excluded.

The outcome variable was use of neuraxial labor analgesia; this outcome was established *a priori* (prior to data analysis). Based on literature review^{17–21} and our combined clinical experience, we considered the following covariates as potential confounders in our analysis: maternal age, race/ethnicity, highest level of education, insurance type, marital status, pre-pregnancy hypertension, pre-pregnancy diabetes, prior cesarean delivery, prior live birth, prenatal care, multiple gestation, gestational diabetes, gestational hypertension, induction of labor, labor augmentation, gestational age at delivery, fetal presentation (classified as cephalic, breech, and other), attendant at birth (classified as doctor of medicine or osteopathy, midwife, and other), state where delivery occurred, and year of delivery. Data were only available for the state in which each delivery occurred between 2009 and 2013.

Because the anesthetic management becomes increasingly technically complex for morbidly obese women,^{6,7} we performed a subgroup analysis of women with a BMI ≥ 50 kg/m² to examine the unadjusted rates of neuraxial labor analgesia in the following BMI subgroups: 50–60 kg/m², 60–70 kg/m², 70–80 kg/m², and >80 kg/m².

Statistical analysis

Prior to data analyses, the main study aims and analytic plan were reviewed by all study investigators in May 2017. We performed descriptive analyses to characterize patient characteristics across BMI groups. An uncorrected chi-squared test was used to compare the frequencies of categorical variables across BMI classes. The margin command in STATA was used to determine the adjusted outcome values for each BMI class and for comparing

adjusted rates between BMI classes. A two-sided P -value <0.05 was considered to indicate statistical significance.

The associations between maternal BMI and neuraxial labor analgesia were assessed using relative risk (RR) with 95% confidence intervals (CI) and were estimated by multivariable log-linear regression analyses (with a Poisson distribution, a log-link function and a robust variance estimator). The basic model on our analytic sample examined the unadjusted association between BMI class and neuraxial labor analgesia. We then performed a series of sequential logistic models which grouped covariates into the following categories: sociodemographic factors, antenatal factors, pregnancy/peripartum factors, and attendant at birth. State and year of delivery were included as additional covariates in a final logistic model. Goodness of fit for each model was determined by likelihood ratio test statistics: log-likelihood, Akaike information criterion (AIC), and Bayesian information criterion (BIC). Additionally, because some women who underwent intrapartum cesarean delivery may have received de-novo epidural or spinal blockade for surgical anesthesia instead of labor analgesia, we performed a sensitivity analysis (planned *a priori*), including only women who underwent vaginal delivery. Post-hoc, we examined whether interaction exists between BMI and a history of live births (categorized as no livebirths and 1 or more live births). Lastly, we examined unadjusted and adjusted risk differences (ARDs) with 95% CIs to present the magnitude of the absolute risk differences. The adjusted risk difference indicates the additional proportion of mothers who would receive neuraxial labor analgesia above a baseline proportion if the same maternal and obstetric characteristics were present in the reference group (women with normal BMI).

We did not perform an *a priori* sample size estimation. However, before performing formal data analysis, we performed a power analysis using baseline data from our analytic sample. With 2,182,797 women with normal BMI and 1,442,133 women of obesity class III in our sample, an alpha of 0.05, power of 80%, and an assumed proportion of nonobese women who received neuraxial labor analgesia of 61%,²² the minimum detectable relative risk of neuraxial labor analgesia for obese class III compared to nonobese women was 1.002. Therefore, our study was adequately powered to detect a clinically relevant relative risk of 2.0 for use of neuraxial labor analgesia for obese class III women compared to nonobese women. All statistical analyses were performed using STATA Version 14.0 (StataCorp., College Station, TX).

Results

We identified 24,363,280 deliveries that occurred between 2009 and 2015 using the updated birth certificate that resulted in a live birth. We excluded 6,757,394 cases because of residency outside the United States, out-of-hospital delivery, cesarean delivery without labor, and short or tall height. Also excluded were 385,206 records with missing height or weight, mode of delivery or neuraxial labor analgesia use data. We assumed missing data were missing completely at random. A flow diagram depicting women who met exclusion criteria and our final analytic cohort is presented in Figure 1. Our final analytic cohort comprised 17,220,680 deliveries, which accounts for 61.5% of 28 million births that occurred between

2009 and 2015 in the US. In our analytic sample, 12, 275, 920 (71.3%) women used neuraxial labor analgesia.

Within our study cohort, 15,128 (0.1%) subjects were underweight, 2,182,797 (12.7%) had a normal BMI, 6,368,656 (37%) were overweight, 4,881,938 (28.3%) were obesity class I, 2,330,028 (13.5%) were obesity class II, and 1,442,133 (8.4%) were obesity class III. Patient characteristics according to BMI class and mode of delivery data are presented in Table 1. Of note, 88.6% of women in our study cohort had vaginal delivery.

The unadjusted rate of neuraxial labor analgesia use differed according to BMI class (Figure 2). Compared to normal BMI women, the rate was lowest among underweight women (59.7%) and highest among women in obesity class III (75.6%) ($P<0.001$, respectively). After adjusting for sociodemographic, antenatal, obstetric and peripartum factors, attendant at delivery, and state, the rates of neuraxial labor analgesia remained lowest for underweight women (65.1%) and highest in the obesity class III women (73.1%) compared to normal BMI women ($P<0.001$, respectively) (Figure 2).

The results of the unadjusted and adjusted logistic regression analyses are presented in Table 2. Using women with normal BMI as the reference group, the unadjusted RR (model 1) of receiving neuraxial labor analgesia was modestly increased for overweight (RR 1.03; 95% CI=1.03–1.03), obesity class I women (RR 1.05; 95% CI=1.05–1.05), obesity class II women (RR 1.08; 95% CI=1.08–1.08), and obesity class III women (RR 1.11; 95% CI=1.11–1.11). In contrast, the unadjusted risk of neuraxial labor analgesia was decreased for underweight women (RR 0.88; 95% CI=0.86–0.89). The sequential addition of each set of covariates marginally altered these risk estimates. In the final model (model 5), women in obesity class II or III were at slightly increased risk of receiving neuraxial labor analgesia (aRR (adjusted RR) 1.05 (95% CI=1.05–1.05), respectively), and underweight women had a slightly decreased risk (aRR 0.94; 95% CI=0.92–0.95). The point estimates for all variables included in our final model are presented in Appendix Table 1. In addition, we accounted for clustering according to the US state where the delivery occurred using a generalized estimating equation (GEE); this analysis was done post-hoc. Because there is a limit to the size of the matrices that can be computed with this approach, we used a 0.3% random sample of our study population using our GEE approach; data are presented in Appendix Table 2. The point estimates for overweight and women in each obese class were similar to those in model 5.

In the sensitivity analysis examining only vaginal deliveries, the risks of receiving neuraxial labor analgesia for each BMI class after adjusting for all patient-level covariates (model 5) were similar to those observed in primary analyses: underweight women: aRR 0.93 (95% CI=0.91–0.94); overweight women: aRR 1.02 (95% CI=1.02–1.02); obesity class I women: aRR 1.03 (95% CI=1.03–1.04); obesity class II women: aRR 1.04 (95% CI=1.04–1.04); and obesity class III: aRR 1.05 (95% CI=1.04–1.05). We also confirmed that interaction was present between BMI and a history of live births, and performed stratified analyses according to patients' history of prior live birth (Appendix Table 3). The point estimates in each stratified model were similar to those observed in model 5.

The results of our post-hoc subgroup analysis examining unadjusted rates of neuraxial labor analgesia among morbidly obese women (BMI ≥ 50 kg/m²) are presented in the Appendix Table 4. The unadjusted rates among superobese women were: 77.0%, 76.2%, 75.2% and 75.0% for BMI 50–60 kg/m², 60–70 kg/m², 70–80 kg/m² and over 80 kg/m² groups, respectively.

Table 3 presents the unadjusted and the adjusted absolute risk differences in the rates of neuraxial labor analgesia use across BMI classes. Compared to women with normal BMI, the adjusted risk difference (ARD) in neuraxial labor analgesia use increased from 1.4% (95% CI=1.3–1.5) for overweight women to 4.2% (95% CI=4.0–4.2) for obesity class III. In contrast, a negative ARD was observed (–3.8%; 95% CI = –4.7 to –2.9) for underweight women compared to women with normal BMI.

Discussion

Based on US national vital statistics data from over 17 million deliveries, we observed only modest differences in the rate of neuraxial labor analgesia according to BMI class, with a nonadjusted risk difference of 7.4% and an adjusted risk difference of 4.2% between women of obese class III and women with normal BMI.

Given the perceived benefits of neuraxial labor analgesia among obese women (optimized respiratory function, attenuated sympathetic mediated changes related to labor and painful contractions, and mitigation of the risk of difficult or failed intubation for intrapartum cesarean delivery),^{9–12} we expected to observe large differences in rates of neuraxial labor analgesia between obese women and women with normal BMI. However, the likelihood of receiving neuraxial labor analgesia was only modestly increased in our unadjusted analysis. Furthermore, despite obesity being strongly linked with obstetric comorbidities, such as gestational hypertension, preeclampsia,^{23,24} and gestational diabetes²⁵, the magnitude of the associations between maternal BMI and neuraxial labor analgesia remained relatively unchanged after accounting for these and other obstetric confounders in our adjusted analyses. These findings suggest that selected confounders minimally influence the relation between BMI class and neuraxial labor analgesia.

Limited data exist describing the relations between maternal BMI with neuraxial labor analgesia. Our findings are consistent with those of Biel et al. who examined these relations among a cohort of women who delivered in California between 2007 and 2010.¹³ Among primiparous women, a positive ‘dose-response’ relation was observed between maternal BMI class and the likelihood of receiving neuraxial labor analgesia compared to normal BMI women; for class I, II, and III obesity, the aRRs were 1.14, 1.18, and 1.21, respectively. Similar findings were observed among parous women. The Biel et al. study did not account for obstetric confounders;¹³ this may explain why the point estimates were marginally higher than those observed in our analysis.

Several explanations may contribute to our main findings. Because rates of neuraxial labor analgesia were high across all BMI classes, any difference in rates of neuraxial labor analgesia between normal BMI and obesity class III women are unlikely to be substantial.

Limited differences in labor pain severity or pain sensitivity between obese and nonobese women may explain why there are only small differences in rates and the likelihood of neuraxial labor analgesia use between obese and normal BMI women. Based on data from two prospective observational studies, Melzack et al. reported only a weak positive correlation (correlation coefficient (r) = 0.23 to 0.36) between BMI and labor pain severity,²⁶ whilst Ranta et al. reported no differences in labor pain severity between obese and nonobese women.²⁷ Moreover, studies in nonpregnant humans and animal models have not consistently demonstrated a positive association between obesity and sensitivity to experimentally-induced pain.²⁸ Other patient-level factors may explain our findings. For example, obese patients' labor analgesia preferences may not markedly differ from those of nonobese patients. Lastly, several studies have reported that obesity is linked to an increased likelihood of epidural catheter failure.^{6,7,11,29} Therefore, the small differences in the likelihood of receiving neuraxial labor analgesia between BMI classes may be due, in part, to some obese women experiencing unsuccessful neuraxial blockade in their index or prior pregnancies.

The observation that underweight women were less likely to receive neuraxial labor analgesia compared to nonobese women was an unexpected finding. Although data from systematic reviews indicate that women who are underweight are at increased risk of perinatal morbidity, including small-for-gestational-age and low-birthweight babies, and preterm birth,^{30,31} factors contributing to the lower use of neuraxial labor analgesia in this group are not known. Further research is needed to examine whether biological or clinical factors (e.g., lower fetal weight, lower labor pain severity, or a shorter duration of labor) explain the moderately lower rates of neuraxial labor analgesia among underweight women.

The main strengths of our analysis include a national dataset comprising over 17 million deliveries between 2009 and 2015. This allowed us to account for obstetric anesthetic practices within a contemporary population-based cohort. We performed sequential log-linear regression analyses and subgroup analyses that account for a large set of demographic and obstetric characteristics. However, several limitations should be acknowledged, including issues inherent to a retrospective observational study design. We could not account for medical contraindications to neuraxial blockade, such as severe thrombocytopenia. However, contraindications to neuraxial blockade are uncommon and are likely to be nondifferential by BMI class. Additionally, our study does not include physician-level or hospital-level factors that may influence rates of neuraxial labor analgesia, such as availability of anesthesia and obstetric providers, and type of hospital (teaching or community). Future studies should consider models that include hospitals as random effects to account for hospital-level variation in neuraxial labor analgesia rates. However, because the effect of BMI was small and remained relatively unchanged in our sequential models, any potential differential effect from these patient-level or hospital-level factors would need to be substantial to markedly alter the point estimates in our final model.

Birth certificate data may be less reliable than hospital data with regard to maternal comorbid conditions, with pregnancy and labor related complications being underreported on birth certificates.^{32–35} The quality of data reporting on birth certificates may also vary by hospital and state.³³ However, any misclassification of covariates is likely to be

nondifferential with respect to BMI class. Although we could not determine the accuracy of the data for neuraxial labor analgesia use, a prior review reported on the accuracy of anesthetic and analgesic data in birth datasets.³⁶ The sensitivity of anesthetic and analgesic data was moderate-to-good (range 62 to 97%), with high positive predictive values (range 83 to 100%) and specificity (range 96 to 100%).³⁶ Furthermore, in another review of selected medical and health data from birth certificates and hospital medical records among 1095 births in two US states, the sensitivity for neuraxial labor analgesia use was high (ranging from 85%–96%).³³

We examined the association between BMI at delivery and neuraxial analgesia because this accounts for gestational weight gain and reflects maternal body habitus of patients at the time of neuraxial block placement. Additionally, BMI is a commonly used independent variable for assessing risks associated with childbirth and is a readily available indicator of obesity for large observational studies. However, we acknowledge that, by using the World Health Organization BMI categories,¹⁶ an individual with class III obesity based on pregnancy weight may be different than an individual with class III obesity who is not pregnant. Lastly, our findings may not be reflective of the entire population of women who delivered in the US between 2009 and 2015 because states adopted the 2003 revision of the birth certificate at different times.

We did not examine whether, among women receiving neuraxial labor analgesia, maternal or perinatal outcomes differ according to BMI class. Therefore, there is a pressing need for studies examining whether maternal outcomes are improved in obese women receiving neuraxial labor analgesia compared with nonneuraxial or no analgesia. Biel et al. reported neuraxial labor analgesia was associated with a reduced risk of spontaneous vaginal delivery across all parity and BMI categories.¹³ However, the validity of these associations are uncertain because of residual confounding and the potential for reverse causation. Future population-wide studies should account for nuanced clinical data, which include the timing of specific events. This information will advance our understanding of the complex relationships between BMI, anesthetic and obstetric intrapartum interventions, and perinatal outcomes. These data will be important for refining future labor analgesia recommendations from national anesthesia societies for this cohort of parturients.

In conclusion, using national vital statistics data, we observed a small effect of maternal BMI on the use of neuraxial labor analgesia. Given that neuraxial labor analgesia is perceived to be beneficial for obese parturients, future studies are needed to compare maternal and perinatal outcomes among obese women receiving neuraxial labor analgesia compared with non-neuraxial techniques or no labor analgesia.

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Appendix 1. Adjusted Relative Risks for the Association between Body Mass Index and Neuraxial Labor Analgesia*

	aRR (95% CI)	P value
BMI (kg/m ²)		

	aRR (95% CI)	P value
<18.5	0.93 (0.92–0.94)	<0.001
18.5–24.9	Reference	
25–29.9	1.02 (1.02–1.02)	<0.001
30–34.9	1.04 (1.04–1.04)	<0.001
35–39.9	1.05 (1.05–1.05)	<0.001
40	1.06 (1.06–1.06)	<0.001
Maternal age (y):		
< 15	1.23 (1.22–1.24)	<0.001
15–19	1.07 (1.06–1.07)	<0.001
20–24	1.04 (1.04–1.04)	<0.001
25–29	1.01 (1.01–1.01)	<0.001
30–34	1.01 (1.00–1.01)	<0.001
35–39	Reference	
40–44	0.99 (0.99–0.99)	<0.001
45–54	0.98 (0.97–0.99)	<0.001
Race/Ethnicity:		
Non-Hispanic White	Reference	
Non-Hispanic Black	0.96 (0.96–0.96)	<0.001
Non-Hispanic AIAN	0.87 (0.86–0.87)	<0.001
Non-Hispanic Asian	1.00 (1.00–1.00)	0.16
Non-Hispanic NHOPI	0.88 (0.88–0.89)	<0.001
Non-Hispanic mixed race	1.00 (0.99–1.00)	0.15
Hispanic	0.91 (0.91–0.91)	<0.001
Insurance:		
Medicaid	Reference	
Private insurance	1.06 (1.06–1.06)	<0.001
Self-pay	0.88 (0.88–0.89)	<0.001
Other	1.04 (1.04–1.04)	<0.001
Maternal education:		
8 th grade or less	Reference	
9 th –12 th grade	1.24 (1.24–1.25)	<0.001
High school graduate	1.31 (1.31–1.32)	<0.001
Some college	1.36 (1.36–1.37)	<0.001
Associate degree	1.36 (1.35–1.36)	<0.001
Bachelor's degree	1.37 (1.36–1.37)	<0.001
Master's degree	1.37 (1.37–1.37)	<0.001
Doctorate or professional degree	1.39 (1.39–1.39)	<0.001
Marital status:		
Unmarried	Reference	

	aRR (95% CI)	P value
Married	0.98 (0.97–0.98)	<0.001
Pre-existing diabetes		
No	Reference	
Yes	1.02 (1.02–1.02)	<0.001
Pre-existing hypertension		
No	Reference	
Yes	1.02 (1.02–2.02)	<0.001
Number of prior live births:		
None	Reference	
1	0.87 (0.97–0.87)	<0.001
Previous Cesarean delivery		
No	Reference	
Yes	1.19 (1.19–1.19)	<0.001
Gestational diabetes		
No	Reference	
Yes	1.02 (1.01–1.02)	<0.001
Gestational hypertension or preeclampsia		
No	Reference	
Yes	1.02 (1.02–1.02)	<0.001
Type of Pregnancy:		
Single	Reference	
Twin	1.15 (1.15–1.15)	<0.001
Triplet or higher-order	1.26 (1.24–1.29)	<0.001
Prenatal care		
No	Reference	
Yes	1.18 (1.17–1.18)	<0.001
Gestational age at delivery (completed weeks)		
24–27	0.72 (0.71–0.73)	<0.001
28–31	0.88 (0.88–0.89)	<0.001
32–33	0.94 (0.93–0.94)	<0.001
34–36	0.98 (0.98–0.98)	<0.001
37–39	1.00 (1.00–1.00)	<0.001
40	Reference	
41	0.99 (0.99–0.99)	<0.001
42 weeks	0.98 (0.98–0.98)	<0.001
Induction of labor		
No	Reference	
Yes	1.21 (1.21–1.21)	<0.001
Labor augmentation		

	aRR (95% CI)	P value
No	Reference	
Yes	1.21 (1.21–1.22)	<0.001
Attendant at birth		
Doctor of medicine or osteopathy	Reference	
Midwife	0.83 (0.83–0.83)	<0.001
Other	0.87 (0.87–0.88)	<0.001
Fetal presentation at delivery:		
Cephalic	Reference	
Breech	1.07 (1.07–1.07)	<0.001
Other	0.99 (0.98–0.99)	<0.001
Missing		
Delivery year		
2009	Reference	
2010	1.02 (1.02–1.02)	<0.001
2011	1.04 (1.04–1.04)	<0.001
2012	1.06 (1.06–1.06)	<0.001
2013	1.06 (1.06–1.07)	<0.001
2014	1.06 (1.06–1.06)	<0.001
2015	1.07 (1.07–1.07)	<0.001

* Adjusted for US state.

aRR = adjusted relative risk; CI = confidence intervals

AIAN = American Indian or Alaska Native; BMI = body mass index; NHOPI = Native Hawaiian and Other Pacific Islander

Appendix 2. Adjusted Relative Risk for the Association between Body Mass Index and Neuraxial Labor Analgesia in a GEE model*

	GEE Model with clustering by state
BMI Class	aRR (95% CI)
Underweight	0.76 (0.56–1.08)
Normal BMI	Reference
Overweight	1.03 (1.01–1.05)
Obese class I	1.04 (1.02–1.05)
Obese class II	1.06 (1.04–1.07)
Obese class III	1.08 (1.05–1.11)

* The model was run on a random 0.3% sample of the study population that accounted for clustering by US state.

aRR = adjusted relative risk; CI = confidence intervals.

BMI = body mass index

Appendix 3. Adjusted Relative Risks for the Association between Body Mass Index and Neuraxial Labor Analgesia Stratified According to History of Prior Live Birth

	Women with no prior live births	Women with 1 or more prior live births
BMI Class	aRR (95% CI)	aRR (95% CI)
Underweight	0.95 (0.94–0.97)	0.91 (0.89–0.93)
Normal BMI	Reference	Reference
Overweight	1.02 (1.02–1.02)	1.03 (1.02–1.03)
Obese class I	1.04 (1.04–1.04)	1.05 (1.05–1.05)
Obese class II	1.05 (1.04–1.05)	1.06 (1.06–1.07)
Obese class III	1.05 (1.05–1.05)	1.08 (1.07–1.08)

aRR= adjusted relative risk; CI = confidence intervals

BMI = body mass index

Appendix 4. Neuraxial Labor Analgesia Rates in Morbidly Obese Women

	BMI: 50–60 kg/m ² (n=145,477)	BMI: 60–70 kg/m ² (n=13,863)	BMI: 70–80 kg/m ² (n=803)	BMI ≥ 80 kg/m ² (n=36)
Women receiving neuraxial labor analgesia	111,956 (77.0%)	10,563 (76.2%)	604 (75.2%)	27 (75.0%)

Data presented as n (%)

Rates presented are unadjusted frequencies.

BMI = Body mass index

Summary Statement

Morbidly obese women have a marginally increased risk of receiving neuraxial labor analgesia compared to women with a normal body mass index.

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Figure 1.
Flow chart

Figure 2. Unadjusted and Adjusted Rates of Neuraxial Labor Analgesia Use According to Body Mass Index Class

BMI = Body Mass Index.

Bars are unadjusted and adjusted rates of neuraxial labor analgesia. Whiskers are 95% confidence interval. Adjusted rate accounted for the following demographic and pregnancy-related factors: maternal age, race/ethnicity, highest level of education, insurance, marital status, pre-pregnancy hypertension, pre-pregnancy diabetes, prior cesarean delivery, prior live birth, prenatal care, plurality, gestational diabetes, gestational hypertension or preeclampsia, induction of labor, labor augmentation, gestational age at delivery, fetal presentation (classified as cephalic, breech, and other), attendant at birth (classified as doctor of medicine or osteopathy, midwife, and other), US state where the delivery occurred, and year of delivery.

Table 1

Demographic and obstetric characteristics

	Underweight N = 15,128	Normal BMI N = 2,182,797	Overweight N = 6,368,656	Obese I N = 4,881,938	Obese II N = 2,330,028	Obese III N = 1,442,133
Maternal age (y):						
< 15	41 (0.3)	3,966 (0.2)	7,796 (0.1)	4,413 (0.1)	1,438 (0.1)	541 (0)
15–19	2,650 (17.5)	281,137 (12.9)	594,072 (9.3)	398,394 (8.2)	177,974 (7.6)	91,498 (6.3)
20–24	4,925 (32.6)	585,644 (26.8)	1,499,573 (23.6)	1,186,154 (24.3)	610,272 (26.2)	389,663 (27.0)
25–29	3,793 (25.1)	579,792 (26.6)	1,817,122 (28.5)	1,445,409 (29.6)	704,153 (30.2)	448,461 (31.1)
30–34	2,470 (16.3)	486,547 (22.3)	1,608,966 (25.3)	1,202,603 (24.6)	544,855 (23.4)	335,835 (23.3)
35–39	1,033 (6.8)	202,936 (9.3)	692,466 (10.9)	527,487 (10.8)	238,449 (10.2)	146,257 (10.2)
40–44	207 (1.4)	40,209 (1.8)	140,164 (2.2)	110,771 (2.3)	50,088 (2.2)	28,549 (2.0)
45–54	9 (0.0)	2,566 (0.1)	8,497 (0.1)	6,707 (0.1)	2,799 (0.1)	1,329 (0.1)
Race/Ethnicity:						
Non-Hispanic White	6,386 (42.2)	1,172,869 (53.7)	3,500,900 (55.0)	2,539,356 (52.0)	1,195,160 (51.3)	734,559 (51.0)
Non-Hispanic Black	3,030 (20.0)	278,964 (12.8)	704,824 (11.1)	652,218 (13.4)	383,035 (16.4)	307,392 (21.3)
Non-Hispanic AIAN	136 (0.9)	12,573 (0.6)	41,108 (0.7)	43,290 (0.9)	26,493 (1.1)	18,160 (1.3)
Non-Hispanic Asian	1,609 (10.7)	238,717 (11.0)	489,967 (7.7)	203,864 (4.2)	46,324 (2.0)	11,894 (0.8)
Non-Hispanic NHOPI	34 (0.2)	2,299 (0.1)	7,861 (0.1)	10,009 (0.2)	7,652 (0.3)	6,596 (0.5)
Non-Hispanic mixed race	156 (1.0)	18,168 (0.8)	53,244 (0.8)	43,726 (0.9)	22,704 (1.0)	15,591 (1.1)
Hispanic	3,485 (23.1)	421,716 (19.3)	1,467,705 (23.0)	1,312,903 (26.9)	611,832 (26.3)	323,956 (22.5)
Missing	292 (1.9)	37,491 (1.7)	103,047 (1.6)	76,572 (1.5)	36,828 (1.6)	23,985 (1.7)
Insurance:						
Medicaid	8,778 (58.0)	971,603 (44.5)	2,569,374 (40.4)	2,158,384 (44.2)	1,129,392 (48.5)	766,418 (53.2)
Private insurance	4,287 (28.3)	992,868 (45.5)	3,173,899 (49.8)	2,253,127 (46.2)	995,770 (42.7)	568,742 (39.4)
Self-pay	968 (6.4)	93,255 (4.3)	248,609 (3.9)	167,412 (3.4)	66,471 (2.9)	30,837 (2.1)
Other	785 (5.2)	99,378 (4.5)	305,630 (4.8)	247,416 (5.1)	112,777 (4.8)	61,049 (4.2)
Missing	310 (2.1)	25,693 (1.2)	71,144 (1.1)	55,599 (1.1)	25,618 (1.1)	15,087 (1.1)
Maternal education:						
8 th grade or less	963 (6.4)	78,803 (3.6)	243,916 (3.8)	220,633 (4.5)	91,845 (3.9)	39,783 (2.8)

	Underweight N = 15,128	Normal BMI N = 2,182,797	Overweight N = 6,368,656	Obese I N = 4,881,938	Obese II N = 2,330,028	Obese III N = 1,442,133
9 th -12 th grade	3,466 (22.9)	337,833 (15.5)	796,267 (12.5)	636,110 (13.0)	310,282 (13.3)	193,809 (13.4)
High school graduate	4,624 (30.6)	538,883 (24.7)	1,490,410 (23.4)	1,239,109 (25.4)	657,448 (28.2)	442,160 (30.7)
Some college	2,580 (17.1)	387,683 (17.8)	1,203,001 (18.9)	1,059,019 (21.7)	572,117 (24.6)	392,797 (27.2)
Associate degree	682 (4.5)	131,468 (6.0)	454,746 (7.1)	386,655 (7.9)	197,352 (8.5)	126,237 (8.8)
Bachelor's degree	1,622 (10.7)	421,399 (19.3)	1,329,608 (20.9)	851,166 (17.5)	330,463 (14.2)	166,520 (11.5)
Master's degree	707 (4.7)	191,933 (8.8)	595,800 (9.4)	352,083 (7.2)	124,592 (5.3)	59,842 (4.1)
Doctorate or professional degree	235 (1.5)	68,799 (3.1)	185,512 (2.9)	87,943 (1.8)	25,316 (1.1)	9,891 (0.7)
Missing	249 (1.6)	25,996 (1.2)	69,396 (1.1)	49,220 (1.0)	20,613 (0.9)	11,094 (0.8)
Marital status:						
Married	6,655 (44.0)	1,250,110 (57.3)	3,903,620 (61.3)	2,832,703 (58.0)	1,258,073 (54.0)	721,220 (50.0)
Unmarried	8,473 (56.0)	932,687 (42.7)	2,465,036 (38.7)	2,049,235 (42.0)	1,071,955 (46.0)	720,913 (50.0)
Pre-existing diabetes						
Yes	49 (0.3)	4,572 (0.2)	19,025 (0.3)	24,842 (0.5)	20,698 (0.9)	24,348 (1.7)
No	15,008 (99.2)	2,174,724 (99.6)	6,341,499 (99.6)	4,851,163 (99.4)	2,306,376 (99.0)	1,415,807 (98.2)
Missing	71 (0.5)	3,501 (0.2)	8,132 (0.1)	5,933 (0.1)	2,954 (0.1)	1,978 (0.1)
Pre-existing hypertension						
Yes	60 (0.4)	7,512 (0.3)	33,463 (0.5)	51,444 (1.1)	47,411 (2.0)	66,303 (4.6)
No	14,997 (99.1)	2,171,784 (99.5)	6,327,061 (99.4)	4,824,561 (98.8)	2,279,663 (97.9)	1,373,852 (95.3)
Missing	71 (0.5)	3,501 (0.2)	8,132 (0.1)	5,933 (0.1)	2,954 (0.1)	1,978 (0.1)
Number of prior live births:						
None	6,881 (45.5)	1,017,437 (46.6)	2,865,819 (45.0)	2,074,517 (42.5)	979,953 (42.1)	632,462 (43.9)
1	8,133 (53.8)	1,156,360 (53.0)	3,478,319 (54.6)	2,788,218 (57.1)	1,341,042 (57.5)	803,707 (55.7)
Missing	114 (0.7)	9,000 (0.4)	24,518 (0.4)	19,203 (0.4)	9,033 (0.4)	5,964 (0.4)
Previous Cesarean delivery						
Yes	382 (2.5)	48,138 (2.2)	165,774 (2.6)	147,082 (3.0)	76,229 (3.3)	53,522 (3.7)
No	14,675 (97.0)	2,131,189 (97.6)	6,194,803 (97.3)	4,728,967 (96.9)	2,250,865 (96.6)	1,386,641 (96.2)
Missing	71 (0.5)	3,470 (0.2)	8,079 (0.1)	5,889 (0.1)	2,934 (0.1)	1,970 (0.1)
Prenatal care	13,197 (93.1)	2,063,843 (97.8)	6,099,010 (98.6)	4,690,619 (98.8)	2,240,349 (98.8)	1,385,238 (98.8)
Gestational diabetes						

	Underweight N = 15,128	Normal BMI N = 2,182,797	Overweight N = 6,368,656	Obese I N = 4,881,938	Obese II N = 2,330,028	Obese III N = 1,442,133
Yes	424 (2.8)	59,916 (2.8)	206,677 (3.3)	228,963 (4.7)	154,597 (6.6)	134,409 (9.3)
No	14,633 (96.7)	2,119,380 (97.0)	6,153,847 (96.6)	4,647,042 (95.2)	2,172,477 (93.3)	1,305,746 (90.6)
Missing	71 (0.5)	3,501 (0.2)	8,132 (0.1)	5,933 (0.1)	2,954 (0.1)	1,978 (0.1)
Gestational hypertension or preeclampsia						
Yes	308 (2.0)	37,529 (1.7)	167,447 (2.6)	224,853 (4.6)	168,073 (7.2)	158,748 (11.0)
No	14,749 (97.5)	2,141,767 (98.1)	6,193,077 (97.3)	4,651,152 (95.3)	2,159,001 (92.7)	1,281,407 (88.9)
Missing	71 (0.5)	3,501 (0.2)	8,132 (0.1)	5,933 (0.1)	2,954 (0.1)	1,978 (0.1)
Type of Pregnancy:						
Single	14,963 (98.9)	2,162,928 (99.1)	6,285,066 (98.7)	4,801,932 (98.4)	2,287,581 (98.2)	1,412,013 (97.9)
Twin	158 (1.0)	19,523 (0.9)	82,636 (1.3)	78,978 (1.6)	41,815 (1.8)	29,673 (2.1)
Triplet or higher-order	7 (0.1)	346 (0)	954 (0)	1,028 (0)	632 (0)	447 (0)
Gestational age at delivery (completed weeks)						
24–27	262 (1.7)	11,051 (0.5)	13,563 (0.2)	9,608 (0.2)	5,481 (0.3)	4,461 (0.3)
28–31	419 (2.8)	24,728 (1.1)	39,323 (0.6)	27,189 (0.6)	13,959 (0.6)	10,032 (0.7)
32–33	478 (3.2)	31,346 (1.5)	57,952 (0.9)	40,709 (0.8)	20,913 (0.8)	14,604 (1.0)
34–36	1,988 (13.1)	186,328 (8.6)	400,404 (6.3)	297,291 (6.1)	149,584 (6.4)	102,167 (7.1)
37–39	7,978 (52.8)	1,261,051 (57.8)	3,562,300 (55.9)	2,683,491 (55.0)	1,276,668 (54.8)	793,677 (55.0)
40	2,268 (15.0)	432,654 (19.8)	1,481,876 (23.3)	1,154,573 (23.6)	533,949 (22.9)	310,962 (21.6)
41	845 (5.6)	148,997 (6.8)	551,737 (8.7)	453,764 (9.3)	218,420 (9.4)	132,367 (9.2)
42 weeks	474 (3.1)	75,037 (3.4)	247,009 (3.9)	204,196 (4.2)	104,554 (4.5)	68,510 (4.7)
Missing	416 (2.7)	11,605 (0.5)	14,492 (0.2)	11,117 (0.2)	6,500 (0.3)	5,353 (0.4)
Induction of labor	2,909 (19.2)	499,055 (22.9)	1,706,540 (26.8)	1,538,810 (31.5)	851,156 (36.5)	614,853 (42.6)
Labor augmentation	3,251 (21.5)	545,644 (25.0)	1,682,227 (26.4)	1,324,896 (27.1)	634,192 (27.2)	381,824 (26.5)
Attendant at birth						
Doctor of medicine or osteopathy	13,625 (90.1)	1,942,489 (89.0)	5,648,256 (88.7)	4,337,576 (88.9)	2,085,601 (89.5)	1,311,672 (91.0)
Midwife	1,393 (9.2)	228,561 (10.5)	687,295 (10.8)	517,940 (10.6)	231,803 (10.0)	122,873 (8.5)
Other	98 (0.6)	10,709 (0.5)	30,455 (0.5)	24,361 (0.5)	11,686 (0.5)	6,941 (0.5)
Missing	12 (0.1)	1,038 (0.0)	2,650 (0.0)	2,061 (0.0)	938 (0.0)	647 (0.0)
Fetal presentation at delivery:						

	Underweight N = 15,128	Normal BMI N = 2,182,797	Overweight N = 6,368,656	Obese I N = 4,881,938	Obese II N = 2,330,028	Obese III N = 1,442,133
Cephalic	14,250 (94.2)	2,096,765 (96.0)	6,129,835 (96.2)	4,691,978 (96.1)	2,236,640 (96.0)	1,380,991 (95.8)
Breech	256 (1.7)	17,647 (0.8)	43,289 (0.7)	35,457 (0.7)	18,702 (0.8)	14,186 (1.0)
Other	303 (2.0)	32,089 (1.5)	90,026 (1.4)	73,835 (1.5)	37,882 (1.6)	25,445 (1.7)
Missing	319 (2.1)	36,296 (1.7)	105,506 (1.7)	80,668 (1.7)	36,804 (1.6)	21,511 (1.5)
Delivery mode:						
Vaginal	13,987(92.5)	2,048,902 (93.9)	5,817,704 (91.3)	4,292,182 (87.9)	1,959,908 (84.1)	1,117,128 (77.5)
Cesarean	1,141 (7.5)	133,895 (6.1)	550,952 (8.7)	589,756 (12.1)	370,120 (15.9)	325,005 (22.5)

Data presented as n (%). Frequency data are unadjusted.

AIAN = American Indian or Alaska Native; BMI = Body mass index; NHOP1 = Native Hawaiian and Other Pacific Islander

Table 2

Unadjusted and Adjusted Relative Risks for the Association between Body Mass Index and Neuraxial Labor Analgesia

BMI (kg/m ²)	Model 1 ^a	Model 2 ^b	Model 3 ^c	Model 4 ^d	Model 5 ^e
	RR (95% CI)	aRR (95% CI)	aRR (95% CI)	aRR (95% CI)	aRR (95% CI)
<18.5	0.88 (0.86–0.89)	0.91 (0.89–0.92)	0.91 (0.90–0.92)	0.94 (0.93–0.95)	0.93 (0.92–0.94)
18.5 – 24.9	Reference	Reference	Reference	Reference	Reference
25 – 29.9	1.03 (1.03–1.03)	1.04 (1.04–1.04)	1.03 (1.03–1.04)	1.02 (1.02–1.02)	1.02 (1.02–1.02)
30 – 34.9	1.05 (1.05–1.05)	1.07 (1.07–1.07)	1.07 (1.07–1.07)	1.04 (1.04–1.04)	1.04 (1.04–1.04)
35 – 39.9	1.08 (1.08–1.08)	1.10 (1.10–1.10)	1.09 (1.09–1.09)	1.05 (1.05–1.05)	1.05 (1.05–1.05)
40	1.11 (1.11–1.11)	1.13 (1.13–1.13)	1.11 (1.11–1.12)	1.06 (1.05–1.06)	1.06 (1.06–1.06)
Log likelihood	–16,426,217	–15,780,475	–15,674,365	–15,144,700	–15,057,758
AIC	32,852,446	31,561,010	31,348,797	30,289,502	30,115,733
BIC	32,852,533	31,561,449	31,349,294	30,290,247	30,117,309

AIC = Akaike information criteria; BIC = Bayesian information criteria; BMI = Body mass index; RR = relative risk; aRR = adjusted relative risk; CI = confidence intervals

^aModel 1 = only body mass index

^bModel 2 = adjusted for sociodemographic factors: maternal age; race/ethnicity; insurance class; maternal education; marital status.

^cModel 3 = adjusted for factors in Model 2, plus: antenatal factors (pre-pregnancy hypertension; pre-pregnancy diabetes) and prior cesarean delivery; number of prior live births.

^dModel 4 = adjusted for factors in Model 3, plus pregnancy/peripartum factors: prenatal care; plurality; gestational diabetes, gestational hypertension, induction, labor augmentation, gestational age at delivery, fetal presentation.

^eModel 5 = adjusted for factors in Model 4, plus: attendant at birth, year of delivery, and state

Table 3
Body Mass Index and Differences in the Unadjusted and Adjusted Rates of Neuraxial Labor Analgesia Use

	Underweight	Normal BMI	Overweight	Obesity Class I	Obesity Class II	Obesity Class III
Unadjusted Risk Difference (95% CI)	-8.44 (-9.22, -7.65)	Ref	2.16 (2.09, 2.23)	3.63 (3.56, 3.71)	5.26 (5.18, 5.35)	7.43 (7.34, 7.52)
* Adjusted Risk Difference (95% CI)	-3.80 (-4.69, -2.91)	Ref	1.40 (1.31, 1.48)	2.88 (2.80, 2.97)	3.57 (3.47, 3.67)	4.14 (4.02, 4.25)

CI = Confidence interval; BMI = Body mass index

* Adjusted for maternal age; race/ethnicity; insurance class; maternal education; marital status; pre-pregnancy hypertension; pre-pregnancy diabetes; prior cesarean delivery; prior live births, prenatal care; plurality; gestational diabetes, gestational hypertension, induction, labor augmentation, attendant at birth, year of delivery and US state where delivery occurred.