Effect of Maternal Body Mass Index on Postpartum Hemorrhage

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ABSTRACT

Background: It is unclear whether obesity is a risk factor for postpartum hemorrhage. The authors hypothesized that obese women are at greater risk of hemorrhage than women with a normal body mass index.

Methods: The authors conducted a cohort study of women who underwent delivery hospitalization in California between 2008 and 2012. Using multilevel regression, the authors examined the relationships between body mass index with hemorrhage (primary outcome), atonic hemorrhage, and severe hemorrhage (secondary outcomes). Stratified analyses were performed according to delivery mode.

Results: The absolute event rate for hemorrhage was 60,604/2,176,673 (2.8%). In this cohort, 4% of women were underweight, 49.1% of women were normal body mass index, 25.9% of women were overweight, and 12.7%, 5.2%, and 3.1% of women were in obesity class I, II, and III, respectively. Compared to normal body mass index women, the odds of hemorrhage and atonic hemorrhage were modestly increased for overweight women (hemorrhage: adjusted odds ratio [aOR], 1.06; 99% CI, 1.04 to 1.08; atonic hemorrhage: aOR, 1.07; 99% CI, 1.05 to 1.09) and obesity class I (hemorrhage: aOR, 1.08; 99% CI, 1.05 to 1.11; atonic hemorrhage; aOR, 1.11; 99% CI, 1.08 to 1.15). After vaginal delivery, overweight and obese women had up to 19% increased odds of hemorrhage or atonic hemorrhage; whereas, after cesarean delivery, women in any obesity class had up to 14% decreased odds of severe hemorrhage.

Conclusions: The authors' findings suggest that, at most, maternal obesity has a modest effect on hemorrhage risk. The direction of the association between hemorrhage and body mass index may differ by delivery mode. **(Anesthesiology 2018; 128:774-83)**

POSTPARTUM hemorrhage is a leading cause of maternal morbidity and mortality in the United States.[1–3] Furthermore, between 1994 and 2006, the rate of postpartum hemorrhage increased by 26%.[4] Well-known risk factors, including multiple gestation, polyhydramnios, placenta previa, and abruption, only explain a small portion of the hazard.[5] As part of regional and national efforts to reduce rates of severe peripartum morbidity,[6–8] clarification of less well-established risk factors for postpartum hemorrhage is needed to advance risk assessment. Risk assessment is of important clinical relevance to obstetricians and anesthesiologists. Both sets of providers play key roles in the triage, management, and peripartum care planning for women at risk for postpartum hemorrhage.

In the United States, the prevalence of maternal obesity has been steadily rising, with more than half of pregnant women classified as overweight or obese.[9,10] A panel of obstetric experts have speculated that the rising prevalence of maternal obesity in developed countries may explain the increase in postpartum hemorrhage incidence, and they have called for more research to examine whether obesity is a key risk factor.[11] However, ongoing controversy surrounds the potential association between maternal body mass index (BMI) and postpartum hemorrhage. Data from several population-based studies suggest that obese women are at increased risk of postpartum hemorrhage or atonic hemorrhage.[12,13] In other studies, obesity is reported to have a protective effect[14] or no association with postpartum hemorrhage.[15–17]

What We Already Know about This Topic

- Postpartum hemorrhage is a leading cause of maternal morbidity and mortality. The incidence of postpartum hemorrhage is increasing. The incidence of maternal obesity is also increasing; however, the link between obesity and postpartum hemorrhage is unclear.

What This Article Tells Us That Is New

- Obesity was not found to be a strong risk factor for postpartum hemorrhage.

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Postpartum hemorrhage risk is known to vary according to mode of delivery.[18,19] However, the joint effect of obesity and mode of delivery on hemorrhage risk has not been previously explored and may clarify some aspects of the previously noted controversy. Tissue injury and surgical morbidity occur more commonly in obese women than in nonobese women.[20,21] These factors may contribute to a greater risk of postpartum hemorrhage for obese women undergoing cesarean delivery than for women undergoing vaginal delivery with comparable BMI. Therefore, the risk of postpartum hemorrhage may not be uniform in each BMI class across all modes of delivery. Examining the individual and joint contributions of obesity and mode of delivery to postpartum hemorrhage would clarify the interplay between these two potentially important risk factors, and would possibly allow more tailored approaches to postpartum hemorrhage prevention and management.

In this study, our primary aim was to investigate the association between maternal BMI with postpartum hemorrhage. We hypothesized that obese women are at greater risk of postpartum hemorrhage than women with a normal BMI. As secondary aims, we performed exploratory analyses to examine the independent associations of maternal BMI with atonic and severe postpartum hemorrhage, as well as to examine the joint effects of maternal BMI and delivery mode on hemorrhage risk.

Materials and Methods

We performed a retrospective cohort study analyzing linked vital statistics birth data and hospital discharge data of women who underwent delivery hospitalizations in California between January 1, 2008, and December 31, 2012. The linked dataset allows for evaluation of prepregnancy BMI data not available in hospital discharge data. Births that occurred in military hospitals, birth centers, or at home are not reported in state hospital discharge data and thus were excluded from the study cohort. We also excluded all terminations, deliveries at earlier than 20 weeks' gestation, and women with missing prepregnancy BMI or birth dates. Stanford University Institutional Review Board (Stanford, California) approved the study.

The exposure of interest was prepregnancy BMI (hereafter referred to as maternal BMI). Maternal BMI was categorized using World Health Organization Internal Classification.[22] Specifically, categories comprise: underweight (BMI less than 18.5 kg/m^2), normal BMI (BMI between 18.5 and 24.9 kg/m^2), overweight (BMI between 25 and 29.9 kg/m^2), obese class I (BMI between 30 and 34.9 kg/m^2), obese class II (BMI between 35 and 39.9 kg/m^2), and obese class III (BMI greater than or equal to 40 kg/m^2).

The primary outcome measure was postpartum hemorrhage, which was identified in our dataset using International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes 666.x. In our secondary analyses, we examined the associations between maternal obesity with atonic postpartum hemorrhage and severe postpartum hemorrhage. We then evaluated the effect of delivery mode on each hemorrhage outcome measure. Atonic hemorrhage was classified by ICD-9-CM codes 666.1, and severe hemorrhage classified jointly by ICD-9-CM codes for postpartum hemorrhage and transfusion. Transfusion was identified by ICD-9-CM codes 99.0x.

Statistical Analysis

Statistical analysis was performed with SAS 9.3 (SAS Institute Inc, USA). Prior to data analyses, the statistical plan for the primary and secondary study aims was reviewed by all study investigators in August 2015. The study design and analytic plan was assessed by members of the Stanford Child Health Research Institute at Stanford University (Stanford, California) in September 2015.

We performed descriptive analyses to characterize the patient characteristics across increasing categories of BMI. Cochran-Armitage trend test was used to assess the crude associations between each hemorrhage outcome with increasing BMI class. To assess the independent associations between each hemorrhage outcome with BMI class, we performed multilevel mixed effects regression analyses adjusting for potential confounding variables as fixed effects: maternal age (younger than 20, 20 to 24, 25 to 29, 30 to 34, 35 to 39, 40 yr or older), race/ethnicity (Non-Hispanic White, Non-Hispanic Black; Non-Hispanic Asian; Hawaiian or Pacific Islander; American Indian or Alaskan Native; Hispanic; Non-Hispanic Other), insurance (government-assisted; private; self-insured or other), highest educational level (less than high school; high school or graduate educational test; some college; college degree), trimester when prenatal care was commenced (first, second, third), parity (nulliparous *vs.* multiparous), and gestational age at delivery (20 to 31, 32 to 36, 37 to 40, 41 weeks or older), and mode of delivery, and the following ICD-9-CM diagnosis or procedure codes: chronic hypertension, preexisting or gestational diabetes, multiple gestation, prior cesarean, labor before delivery, prolonged labor, induction of labor, chorioamnionitis, placental abruption, polyhydramnios, placenta previa, fibroids, and stillbirth (see appendix, table A1, for list of ICD-9-CM codes). Individual hospitals in California were accounted for as random effects in the multilevel model. As five different comparisons were made (underweight, overweight, obesity class I, II, and III *vs.* normal BMI) in each regression model, a conservative cutoff of $P \leq 0.01$ was chosen to minimize the chance of a type 1 error after multiple testing, with CIs of 99% to present odds ratios. In our primary analysis, we did not plan to adjust for hypertensive disorders of pregnancy (gestational hypertension, mild preeclampsia, severe preeclampsia or eclampsia) or diabetes (preexisting or gestational) because these conditions were assumed to be on the causal pathway between obesity and postpartum hemorrhage.

We examined models incorporating interaction terms to evaluate variation in the effect of BMI class on the risk of

postpartum hemorrhage, atonic hemorrhage, and severe hemorrhage according to mode of delivery. In the stratified models for vaginal and instrumental delivery, placenta previa and labor were not included as covariates because women with placenta previa invariably undergo cesarean delivery and labor precedes vaginal delivery. We also performed a sensitivity analysis to account for clustering according to the hospital where the delivery occurred using a generalized estimating equation. This approach averages the effect of BMI class across all hospitals.

We did not perform a sample size estimation *a priori*. However, we performed power analysis after identifying our analytic sample and before formal data analysis. The power calculation was based on the number of women with normal BMI (N = 1,068,211) and obese class III women (N = 66,591) in the analytic sample, a minimum detectable and clinically relevant odds ratio of 2.0 for postpartum hemorrhage in obesity class III women compared to normal BMI women, and an estimated postpartum hemorrhage prevalence of 2% among normal BMI women. To address the problem of multiple testing, we applied a Bonferroni corrected α 0.05/5 = 0.01 (based on five BMI classes being compared with a normal BMI group). Based on these parameters, we determined that our analytic sample had adequate power ($\beta > 0.999$), and therefore, was sufficiently large to detect a clinically relevant difference between study groups.

Results

A cohort flow diagram is presented in figure 1. Of 2,475,786 women who underwent delivery hospitalization in California between 2008 and 2012, the final cohort consisted of 2,176,673 women. Deliveries occurred among 276 hospitals in California. We assumed that missing data were missing at random. The distribution of BMI groups was: underweight (4%), normal BMI (49.1%), overweight (25.9%), obese class I (12.7%), obese class II (5.2%), and obese class III (3.1%). There were significant differences in the distribution of patient characteristics across the BMI groups that are described in table 1. The absolute event rate for postpartum hemorrhage—our primary outcome—was 60,604/2,176,673 (2.8%). The overall frequency of atonic hemorrhage was 2.2% and severe hemorrhage was 0.4%. Figure 2 shows the rates of hemorrhage according to BMI class. Rates of postpartum hemorrhage and severe postpartum hemorrhage were similar across all BMI groups (*P* for trend > 0.05, respectively), whereas rates of atonic hemorrhage differed across BMI groups (*P* for trend = 0.01).

Table 2 presents the results of the main effects multivariable analyses assessing the independent effects of obesity on postpartum hemorrhage, atonic hemorrhage, and severe hemorrhage. Compared to women with a normal BMI, the odds of postpartum hemorrhage and atonic hemorrhage were increased for overweight women (postpartum hemorrhage: adjusted odds ratio [aOR], 1.06; 99% CI, 1.04 to 1.08; atonic hemorrhage: aOR, 1.07; 99% CI, 1.05 to 1.09) and for women with obesity class I (postpartum hemorrhage: aOR, 1.08; 99% CI, 1.05 to 1.11; atonic hemorrhage: aOR, 1.11; 99% CI, 1.08 to 1.15). However, women with obesity classes II and III were not at increased risk of postpartum hemorrhage or atonic hemorrhage, whereas

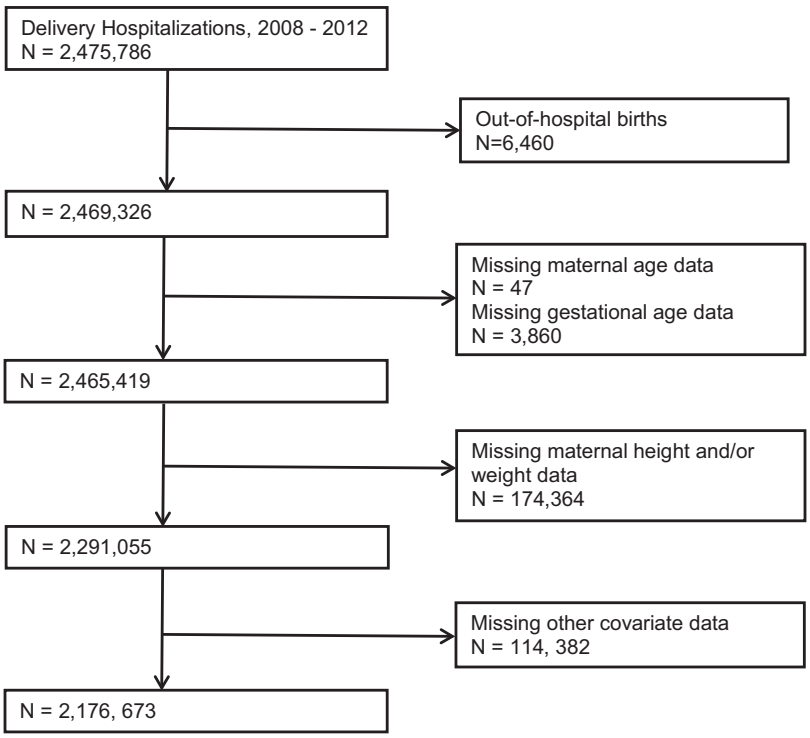

Fig. 1. Flow diagram.

Table 1. Patient Characteristics

Characteristic	BMI < 18.5 kg/m² (n = 86,252)	BMI = 18.5–25 kg/m² (n = 1,068,211)	BMI = 25–29.9 kg/m² (n = 564,495)	BMI = 30–34.9 kg/m² (n = 277,306)	BMI = 35–39.9 kg/m² (n = 113,818)	BMI ≥ 40 kg/m² (n = 66,591)	*P* Value
Age (yr)							< 0.001
< 20	12,760 (14.8%)	105,585 (9.9%)	41,996 (7.5%)	16,877 (6.1%)	5,401 (4.8%)	2,229 (3.3%)	
20–24	21,278 (24.6%)	216,606 (20.3%)	119,755 (21.2%)	61,273 (22.1%)	25,286 (22.2%)	14,003 (21%)	
25–29	21,529 (25%)	272,278 (25.5%)	156,544 (27.7%)	79,216 (28.6%)	34,018 (29.9%)	21,095 (31.7%)	
30–34	18,965 (22%)	278,241 (26%)	143,258 (25.4%)	69,335 (25%)	29,313 (25.7%)	17,823 (26.8%)	
35–39	9,654 (11.2%)	155,924 (14.6%)	80,858 (14.3%)	39,716 (14.3%)	15,696 (13.8%)	9,235 (13.9%)	
≥ 40	2,066 (2.4%)	39,577 (3.7%)	22,084 (3.9%)	10,889 (3.9%)	4,104 (3.6%)	2,206 (3.3%)	
Race							< 0.001
White Non-Hispanic	25,457 (29.5%)	347,983 (32.6%)	137,628 (24.4%)	60,848 (21.9%)	27,568 (24.2%)	16,799 (25.2%)	
Black Non-Hispanic	4,842 (5.6%)	50,530 (4.7%)	32,780 (5.8%)	18,507 (6.7%)	9,201 (8.1%)	7,809 (11.7%)	
Asian Non-Hispanic	22,033 (25.5%)	150,880 (14.1%)	33,704 (6%)	8,727 (3.2%)	1,967 (1.7%)	536 (0.8%)	
Hawaiian/Pacific Islander	3,329 (3.9%)	42,961 (4%)	17,635 (3.1%)	7,302 (2.6%)	2,719 (2.4%)	1,384 (2.1%)	
Hispanic	30,222 (35%)	471,398 (44.1%)	339,796 (60.2%)	180,081 (64.9%)	71,414 (62.7%)	39,291 (59%)	
American Indian/Alaska Native	305 (0.4%)	3,591 (0.4%)	2,509 (0.4%)	1,642 (0.6%)	878 (0.8%)	725 (1.1%)	
Other	64 (0.1%)	868 (0.1%)	443 (0.1%)	199 (0.1%)	71 (0.1%)	47 (0.1%)	
Insurance							< 0.001
Government	40,778 (47.3%)	463,565 (43.4%)	304,309 (53.9%)	161,586 (58.3%)	64,858 (57%)	38,814 (58.3%)	
Private	41,757 (48.4%)	570,085 (53.4%)	245,013 (43.4%)	109,159 (39.3%)	46,605 (40.9%)	26,508 (39.8%)	
Self-insured/Other	3,717 (4.3%)	34,561 (3.2%)	15,173 (2.7%)	6,561 (2.4%)	2,355 (2.1%)	1,269 (1.9%)	
Education							< 0.001
Less than high school	17,323 (20.1%)	214,850 (20.1%)	157,770 (28%)	81,048 (29.2%)	29,057 (25.6%)	15,118 (22.7%)	
High school/GED	22,098 (25.6%)	248,563 (23.3%)	152,889 (27.1%)	83,226 (30%)	36,648 (32.2%)	22,722 (34.1%)	
Some college	14,911 (17.3%)	182,488 (17.1%)	106,728 (18.9%)	58,095 (21%)	27,132 (23.8%)	17,708 (26.6%)	
College degree(s)	31,920 (37%)	422,310 (39.5%)	147,108 (26%)	54,937 (19.8%)	20,981 (18.4%)	11,043 (16.6%)	
Onset of prenatal care							< 0.001
First trimester	40,778 (47.3%)	463,565 (43.4%)	304,309 (53.9%)	227,612 (82.1%)	93,302 (82%)	54,284 (81.5%)	
Second trimester	41,757 (48.4%)	570,085 (53.4%)	245,013 (43.4%)	40,204 (14.5%)	16,762 (14.7%)	9,970 (15%)	
Third trimester	3,717 (4.3%)	34,561 (3.2%)	15,173 (2.7%)	9,490 (3.4%)	3,754 (3.3%)	2,337 (3.5%)	
Gestational age at delivery (weeks)							< 0.001
< 32	891 (1%)	9,705 (0.9%)	6,062 (1.1%)	3,558 (1.3%)	1,699 (1.5%)	1,076 (1.6%)	
32–36^{+6}	6,454 (7.5%)	66,940 (6.3%)	36,306 (6.4%)	19,286 (6.9%)	8,502 (7.5%)	5,523 (8.3%)	
37–40^{+6}	73,499 (85.2%)	908,960 (85.1%)	478,860 (84.8%)	234,303 (84.5%)	95,331 (83.7%)	55,314 (83.1%)	
≥ 41	5,408 (6.3%)	82,606 (7.7%)	43,267 (7.7%)	20,159 (7.3%)	8,286 (7.3%)	4,678 (7%)	
Parity							< 0.001
Nulliparous	47,142 (54.7%)	486,349 (45.5%)	193,897 (34.4%)	83,269 (30%)	33,335 (29.3%)	19,301 (29%)	
Multiparous	39,110 (45.3%)	581,862 (54.5%)	370,598 (65.6%)	194,037 (70%)	80,483 (70.7%)	47,290 (71%)	

(*Continued*)

Table 1. (Continued)

Characteristic	BMI < 18.5 kg/m^2 (n = 86,252)	BMI = 18.5–25 kg/m^2 (n = 1,068,211)	BMI = 25–29.9 kg/m^2 (n = 564,495)	BMI = 30–34.9 kg/m^2 (n = 277,306)	BMI = 35–39.9 kg/m^2 (n = 113,818)	BMI ≥ 40 kg/m^2 (n = 66,591)	*P* Value
Plurality							< 0.001
Singleton	85,104 (98.7%)	1,051,255 (98.4%)	556,037 (98.5%)	273,045 (98.5%)	111,885 (98.3%)	65,368 (98.2%)	
Multiparous	1,148 (1.3%)	16,956 (1.6%)	8,458 (1.5%)	4,261 (1.5%)	1,933 (1.7%)	1,223 (1.8%)	
Chronic hypertension	398 (0.5%)	8,599 (0.8%)	10,221 (1.8%)	9,111 (3.3%)	6,337 (5.6%)	6,536 (9.8%)	< 0.001
Gestational hypertension	923 (1.1%)	16,743 (1.6%)	13,790 (2.4%)	9,257 (3.3%)	4,894 (4.3%)	3,572 (5.3%)	< 0.001
Mild preeclampsia	953 (1.1%)	14,863 (1.4%)	11,444 (2.0%)	7,423 (2.7%)	3,720 (3.3%)	2,629 (3.9%)	< 0.001
Severe preeclampsia or eclampsia	755 (0.9%)	10,255 (1.0%)	6,962 (1.2%)	4,085 (1.5%)	2,029 (1.8%)	1,379 (2.1%)	< 0.001
Fibroids	682 (0.8%)	13,149 (1.2%)	7,937 (1.4%)	4,188 (1.5%)	1,838 (1.6%)	1,171 (1.8%)	< 0.001
Diabetes mellitus	133 (0.1%)	3,801 (0.4%)	4,885 (0.9%)	4,678 (1.7%)	3,054 (2.7%)	2,819 (4.2%)	< 0.001
Previous cesarean	7,913 (9.2%)	140,855 (13.2%)	104,677 (18.5%)	62,263 (22.4%)	29,164 (25.6%)	20,134 (30.2%)	< 0.001
Stillbirth	58 (0.1%)	808 (0.1%)	444 (0.1%)	227 (0.08%)	107 (0.09%)	69 (0.1%)	0.04
Previa	604 (0.7%)	7,526 (0.7%)	3,651 (0.7%)	1,606 (0.6%)	585 (0.5%)	302 (0.5%)	< 0.001
Prolonged labor	1,171 (1.3%)	13,852 (1.3%)	5,107 (0.9%)	1,912 (0.7%)	730 (0.6%)	397 (0.6%)	< 0.001
Labor	31,935 (37%)	396,640 (37.1%)	206,787 (36.6%)	102,272 (36.9%)	42,168 (37.1%)	25,104 (37.7%)	< 0.001
Chorioamnionitis	1,801 (2.1%)	24,976 (2.3%)	12,615 (2.2%)	5,532 (2%)	2,140 (1.9%)	1,198 (1.8%)	< 0.001
Abruption	903 (1.1%)	9,355 (0.9%)	4,699 (0.8%)	2,356 (0.9%)	978 (0.9%)	544 (0.8%)	< 0.001
Polyhydramnios	236 (0.3%)	4,087 (0.4%)	2,758 (0.5%)	1,744 (0.6%)	876 (0.8%)	633 (0.9%)	< 0.001
Induction	10,888 (12.6%)	152,078 (14.2%)	86,149 (15.3%)	45,403 (16.4%)	20,322 (17.9%)	12,473 (18.7%)	< 0.001
Mode of delivery							< 0.001
Vaginal	61,438 (71.2%)	721,708 (67.6%)	355,529 (63%)	161,243 (58.1%)	59,932 (52.6%)	29,791 (44.7%)	
Assisted vaginal	4,887 (5.7%)	46,242 (4.3%)	16,840 (3%)	6,264 (2.3%)	2,119 (1.9%)	1,043 (1.6%)	
Cesarean	19,927 (23.1%)	300,261 (28.1%)	192,126 (34%)	109,799 (39.6%)	51,767 (45.5%)	35,757 (53.7%)	

Data presented as n (%). +6 indicates six additional days.

BMI = body mass index; GED = graduate educational test.

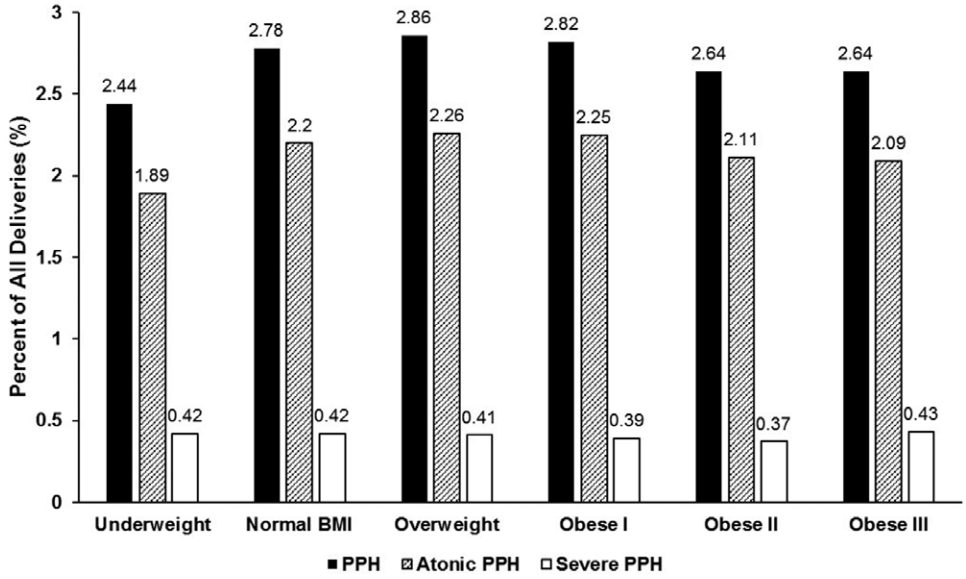

Fig. 2. Obesity class I, II, and III refer to World Health Organization obesity classes I, II, and III. PPH = postpartum hemorrhage.

Table 2. Results of the Multilevel Logistic Regression Analyses Showing the Relationship between Maternal Body Mass Index and Postpartum Hemorrhage Outcomes

BMI (kg/m^2)	PPH*, aOR (99% CI)	Atonic PPH*, aOR (99% CI)	Severe PPH*, aOR (99% CI)
< 18.5	0.92 (0.87–0.96)	0.89 (0.84–0.94)	1.05 (0.94–1.17)
18.5–24.9	Reference	Reference	Reference
25–29.9	1.06 (1.04–1.08)	1.07 (1.05–1.09)	0.94 (0.89–0.99)
30–34.9	1.08 (1.05–1.11)	1.11 (1.08–1.15)	0.85 (0.8–0.91)
35–39.9	1.01 (0.97–1.05)	1.04 (1.0–1.09)	0.78 (0.71–0.87)
≥ 40	1.01 (0.96–1.07)	1.03 (0.98 –1.09)	0.85 (0.76–0.97)

*Hierarchical models adjusted for maternal age, race/ethnicity, insurance, education, chronic hypertension, trimester when prenatal care was initiated, gestational age at delivery, parity, plurality, previous cesarean section, labor, prolonged labor, induction of labor, chorioamnionitis, placental abruption, polyhydramnios, previa, fibroids, stillbirth, and mode of delivery. Hospital site was considered as a random effect, to account for patient clustering.

aOR = adjusted odds ratio; BMI = body mass index; PPH = postpartum hemorrhage.

being underweight was associated with reduced odds of postpartum hemorrhage (aOR, 0.92; 99% CI, 0.87 to 0.96) and atonic hemorrhage (aOR, 0.89; 99% CI, 0.84 to 0.94). Being overweight or obese class I, II, or III was associated with reduced odds of severe postpartum hemorrhage (*e.g.*, for obesity class III, severe postpartum hemorrhage aOR, 0.85; 99% CI, 0.76 to 0.97). We explored whether adjustment for diabetes and hypertensive disorders of pregnancy further influenced the relations between BMI class and postpartum hemorrhage (data presented in the appendix, table A2). Addition of these covariates further modestly attenuated the associations between overweight (aOR, 1.04; 99% CI, 1.01 to 1.07) and obesity class I (aOR, 1.05; 99% CI, 1.01 to 1.09) with postpartum hemorrhage suggesting potential association of these comorbidities with enhancement in hemorrhage risk. We also ran a generalized estimating equation model for our primary outcome to assess whether the point estimates differed compared to those obtained in our mixed effects logistic regression model. The results of this model clustering on hospital were very similar to those of our main findings (data not presented), with no substantial changes in the strength or direction of association between BMI classes with postpartum hemorrhage.

Because we observed evidence of interaction between obesity and mode of delivery ($P < 0.2$) in models with postpartum hemorrhage, atonic hemorrhage, and severe hemorrhage as dependent variables, we performed stratified analyses according to delivery mode (table 3). The study cohort comprised 1,389,641 (63.8%) vaginal deliveries, 77,395 (3.6%) instrumental deliveries, and 709,637 (32.6%) cesarean deliveries. The presence, strength, and magnitude of the relations between BMI class and each hemorrhage outcome differed according to delivery mode. Among those undergoing vaginal delivery, overweight and women of any class of obesity class had up to 19% increased odds of postpartum hemorrhage or atonic hemorrhage, as compared to normal BMI women. In contrast, no associations were found between being overweight or any obesity class status with postpartum hemorrhage, atonic hemorrhage, or severe hemorrhage in the instrumental delivery cohorts. In the cesarean delivery cohort,

Table 3. Adjusted Odds Ratios for the Relationship between Maternal Body Mass Index and Postpartum Hemorrhage Outcomes, Stratified by Mode of Delivery

	PPH		Atonic PPH		Severe PPH	
BMI (kg/m^2)	n (%)	aOR (99% CI)	n (%)	aOR (99% CI)	n (%)	aOR (99% CI)
Vaginal delivery*						
< 18.5	1,504 (2.4%)	0.92 (0.86–0.99)	1,164 (1.9%)	0.90 (0.83–0.97)	203 (0.3%)	1.1 (0.91–1.33)
18.5–24.9	20,432 (2.8%)	Reference	16,036 (2.2%)	Reference	2,173 (0.3%)	Reference
25–29.9	11,090 (3.1%)	1.09 (1.06–1.13)	8,720 (2.4%)	1.1 (1.06–1.14)	1,050 (0.3%)	0.97 (0.88–1.08)
30–34.9	5,325 (3.3%)	1.16 (1.12–1.21)	4,233 (2.6%)	1.19 (1.14–1.25)	479 (0.3%)	0.97 (0.85–1.11)
35–39.9	1,953 (3.3%)	1.12 (1.05–1.19)	1,524 (2.5%)	1.13 (1.05–1.21)	151 (0.2%)	0.81 (0.65–1.01)
≥ 40	1,042 (3.5%)	1.15 (1.06–1.25)	805 (2.7%)	1.15 (1.05–1.27)	99 (0.3%)	1.02 (0.78–1.34)
Instrumental delivery*						
< 18.5	177 (3.6%)	0.96 (0.81–1.12)	134 (2.7%)	0.85 (0.67–1.08)	36 (0.8%)	1.23 (0.78–1.97)
18.5–24.9	1,913 (4.1%)	Reference	1,585 (3.4%)	Reference	291 (0.6%)	Reference
25–29.9	743 (4.4%)	1.09 (0.99–1.19)	617 (3.7%)	1.1 (0.97–1.25)	100 (0.6%)	0.91 (0.67–1.23)
30–34.9	274 (4.4%)	1.13 (0.99–1.3)	223 (3.6%)	1.12 (0.92–1.37)	38 (0.6%)	0.91 (0.58–1.44)
35–39.9	80 (3.8%)	0.97 (0.77–1.23)	70 (3.3%)	1.05 (0.75–1.45)	12 (0.6%)	0.84 (0.39–1.82)
≥ 40	54 (5.2%)	1.29 (0.96–1.72)	42 (4.0%)	1.22 (0.79–1.86)	9 (0.9%)	1.32 (0.54–3.24)
Cesarean delivery*						
< 18.5	333 (1.7%)	0.96 (0.78–1.18)	127 (0.6%)	0.88 (0.76–1.02)	98 (0.5%)	0.94 (0.74–1.19)
18.5–24.9	5,910 (2.0%)	Reference	2,048 (0.7%)	Reference	1,605 (0.5%)	Reference
25–29.9	3,427 (1.8%)	1.09 (0.97–1.23)	1,186 (0.6%)	0.99 (0.93–1.05)	902 (0.5%)	0.91 (0.83–1.00)
30–34.9	1,782 (1.6%)	1.13 (0.95–1.36)	553 (0.5%)	0.95 (0.88–1.02)	415 (0.4%)	0.77 (0.67–0.87)
35–39.9	809 (1.6%)	0.97 (0.71–1.32)	257 (0.5%)	0.91 (0.82–1.00)	200 (0.4%)	0.76 (0.64–0.91)
≥ 40	543 (1.5%)	1.28 (0.88–1.88)	180 (0.5%)	0.87 (0.79–0.98)	134 (0.4%)	0.76 (0.62–0.94)

*Rates of PPH were row percentages with the denominator based on the number of women in each BMI class. Models adjusted for maternal age, race/ethnicity, insurance, education, chronic hypertension, trimester when prenatal care was initiated, gestational age at delivery, parity, plurality, previous cesarean delivery, prolonged labor, induction of labor, chorioamnionitis, placental abruption, polyhydramnios, fibroids, and stillbirth. Hospital site was considered as a random effect, to account for patient clustering within site. Labor and placenta previa were also adjusted for in the models for cesarean delivery.

aOR = adjusted odds ratio; BMI = body mass index; PPH = postpartum hemorrhage.

belonging to obesity class III had a 13% decreased odds of atonic hemorrhage compared to normal BMI women. The odds of severe hemorrhage were even lower for obesity class I (aOR, 0.77; 99% CI, 0.67 to 0.87), class II (aOR, 0.76; 99% CI, 0.64 to 0.91), and class III (aOR, 0.76; 99% CI, 0.62 to 0.94) compared to normal BMI women.

Discussion

In this large population-based cohort study, we observed only a very small effect of maternal BMI on the risk of postpartum hemorrhage. We did not find strong evidence of positive dose–response relationships between BMI class with postpartum hemorrhage, atonic hemorrhage, or severe hemorrhage. These findings suggest that maternal obesity is not an important risk factor for postpartum hemorrhage.

There is a notable lack of clarity in the association between BMI class and postpartum hemorrhage reported in observational studies.[11] In a number of population-based studies from Denmark, Canada, Finland, and the United States comparing perinatal outcomes between obese and nonobese women with singleton pregnancies, obesity was not associated with postpartum hemorrhage.[15–17,23] Data from other studies suggest that obese women are at reduced risk of hemorrhage and morbidity. Among 743,630 pregnant women who delivered in Washington State between 2004 and 2013, obese class III had a 30% decreased odds of severe postpartum hemorrhage compared with normal BMI.[24] In a single-center study, Paglia *et al.* reported that nonobese women had a 1.8-fold increased odds of severe hemorrhage compared to obese women.[14] Butwick *et al.* reported that among women experiencing uterine atony during cesarean delivery, obese women were at reduced risk of hemorrhage-related morbidity compared to nonobese women.[25] These findings are consistent with the inverse association we observed between maternal obesity and severe hemorrhage, especially among women undergoing cesarean delivery.

In contrast to our main findings, two population-wide studies have reported a positive association between obesity and postpartum hemorrhage. In a study examining 1,114,071 Swedish women with singleton pregnancies, the risk of atonic hemorrhage was increased by 14, 47, and 114% in women from obesity classes I, II, and III, respectively compared to nonobese women.[12] In a Japanese study of 97,157 women with singleton pregnancies, obese women had 1.1-fold and 1.9-fold increased risk of postpartum hemorrhage compared to nonobese women after vaginal and cesarean delivery, respectively.[13] Residual confounding, instead of a true effect of obesity, may explain at least part of the increased risk of hemorrhage observed in these studies.

In our study, maternal obesity was more prevalent and we accounted for a larger set of relevant confounders to provide more clarity about the associations between maternal obesity and postpartum hemorrhage. Although we had adequate power to detect a minimum odds ratio of 2, the point estimates in our primary analysis were substantially lower despite being statistically significant for overweight and obesity class I women. These findings suggest that the relations between maternal BMI and postpartum hemorrhage are of questionable clinical significance. We acknowledge that differences between medical care systems and practices, racial compositions, and national obesity rates may also explain why the reported associations between BMI class and postpartum hemorrhage vary across different populations.

The small effect of BMI on postpartum hemorrhage risk has important clinical ramifications. Risk assessment is a critical aspect of postpartum hemorrhage prevention. By identifying at-risk patients, providers can ensure that adequate resources and staff are available to manage hemorrhage prior to delivery. This key aspect of care is described in the consensus bundle for obstetric hemorrhage published by The National Partnership for Maternal Safety.[8] Similarly, in their latest postpartum hemorrhage guidelines, the American College of Obstetricians and Gynecologists suggest that a risk assessment tool be considered.[26] Well-established risk factors, such as chorioamnionitis, multiple gestation, and hypertensive disorders of pregnancy,[18,19,27] are likely to be considered for inclusion in these tools. However, based on our findings, consideration of obesity in these risk assessment tools may not be warranted.

Several potential explanations can be offered for the small effect of BMI on postpartum hemorrhage risk and the reduced risk of severe hemorrhage. First, the findings of our sensitivity analysis suggest that effect of obesity may be partly influenced by the presence of diabetes and/or hypertensive disorders. The addition of these factors to our regression models modestly attenuated the weak positive association between obesity and postpartum hemorrhage. Second, uterine atony is recognized as the leading etiology for postpartum hemorrhage.[18,19] In our study, we observed no monotonic increase in the rate of atonic hemorrhage with increasing BMI. This may be because uterine contractility or oxytocin signaling does not differ markedly across BMI classes. Data from *in vitro* studies suggest that no differences in contraction strength or frequency in myometrial strips exist between obese *versus* nonobese women,[28] and oxytocin receptor gene and protein expression in myometrial strips are not related to maternal BMI.[29] However, other work suggests that myometrial samples taken from obese women contract with less force and less frequency compared to those from nonobese women.[30] Third, compared to nonobese patients, obese patients have a hypercoagulable state (manifest by higher plasma fibrinogen, factor VII, factor VIII, von Willebrand factor, and plasminogen activator inhibitor levels),[31] which may mitigate the severity of blood loss and the need for transfusion during a major bleed. Fourth, because obese women have larger blood volumes than nonobese women,[32] patients may tolerate more blood loss (assuming isovolemic hemodilution) before reaching a transfusion trigger or experiencing the consequences of hemorrhagic shock.

Our study has several strengths. In this large population-based study, which included more than 2 million women, we were able to characterize a diverse obstetric cohort to study an outcome with a low prevalence. The overall prevalence of postpartum hemorrhage, atonic hemorrhage, and severe hemorrhage are in line with those reported in other population-wide studies.[4,5,19] Through the use of linked administrative discharge data and vital statistics data, we had access to detailed patient information, including prepregnancy BMI, to examine the association between maternal obesity and postpartum hemorrhage. Previous epidemiologic studies of postpartum hemorrhage in the United States lack maternal BMI data.[4,5,19] Our study has a number of limitations. A potential limitation is the accuracy and validity of maternal discharge data and birth certificate data for classifying key variables. Although postpartum hemorrhage was classified using administrative data, validation studies report high positive predictive values (greater than 80%) for ICD-9-CM codes.[33,34] Several studies have assessed the reliability of BMI data on birth certificates. In a study comparing birth certificate to medical record data in 1,204 births, Bodnar *et al.* demonstrated good agreement in the prepregnancy BMI categorization for normal BMI, overweight, and obese class II and III women.[35] Using data from the Women, Infants, and Children Program in Florida, Park *et al.* also found that prepregnancy weight, height, and BMI from birth certificates are reliable and are valid for use in population-based studies.[36] Chen *et al.*, using data from the 1988 National Maternal and Infant Health Survey, observed a high correlation (0.9) between self-reported and recorded prepregnancy BMI data.[37] We did not account for weight gain during pregnancy. Because gestational weight gain decreases with increasing BMI,[38] this may partially explain why the differences in postpartum hemorrhage risk were modest between obese and normal BMI women. Further studies are needed to examine the influence of gestational weight gain on hemorrhage risk. Prolonged labor and induction of labor may be on the causal pathway between maternal obesity and postpartum hemorrhage; therefore, adjustment for these variables may have influenced the strength of our observed associations. We could not account for residual confounders in our analysis, such as exposure to antenatal anemia, antenatal anticoagulation, mode of analgesia or anesthesia. Therefore, residual confounding may partially explain the weak positive association between being overweight or obesity class I and postpartum hemorrhage. In our stratified analyses, variation in the size of each delivery cohort and resultant type 2 error may explain the differential findings according to delivery mode. Because blood loss data are not captured in our data source, we used transfusion codes

as a proxy for severe hemorrhage, an approach also used in previous population-wide studies.[1,2,39] We could not determine whether transfusion was given during the acute period of active blood loss or for treating postpartum anemia after arrest of bleeding. Therefore, it is unclear whether transfusion is a marker of bleeding severity *versus* anemia severity after postpartum hemorrhage.

In summary, our findings demonstrate that obesity is not a strong risk factor for postpartum hemorrhage. A detrimental effect on postpartum hemorrhage from obesity is likely to be much lower than previously reported in selected analyses and may only have modest clinical relevance.

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Competing Interests

The authors declare no competing interests.

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Appendix

Table A1. International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) Codes Used to Identify Diagnoses and Procedures

Chronic hypertension = 401.x-405.x; 642.0x-642.2x; 642.7x; 642.9x
Diabetes = 249.xx-250.xx, 648.0x
Multiple gestation = V27.2–V27.8, 651.x
Prior cesarean = 654.2x
Labor prior to delivery = 644.x, 656.3x, 660–663.x, 665.1x,
Prolonged labor = 662.x
Induction of labor = 73.01; 73.1; 73.4, 659.0x-659.1x
Chorioamnionitis = 658.4x
Placental abruption = 641.2x
Polyhydramnios = 657.x
Placenta previa = 641.0x-641.1x
Fibroids = 218.x, 654.1x
Stillbirth = V27.1, V27.3, V27.4, V27.6, V27.7

Table A2. Multilevel Logistic Regression Analysis Showing the Relationship between Maternal Body Mass Index and Postpartum Hemorrhage Including Diabetes and Hypertensive Disorders of Pregnancy as Covariates

BMI (kg/m^2)	PPH*, aOR (99% CI)
< 18.5	0.92 (0.87–0.98)
18.5–24.9	Reference
25–29.9	1.04 (1.01–1.07)
30–34.9	1.05 (1.01–1.09)
35–39.9	0.97 (0.92–1.02)
≥ 40	0.96 (0.9–1.03)

*Hierarchical model adjusted for maternal age, race/ethnicity, insurance, education, chronic hypertension, trimester when prenatal care was initiated, gestational age at delivery, parity, multiple gestation, previous cesarean section, labor, prolonged labor, induction of labor, chorioamnionitis, placental abruption, polyhydramnios, previa, fibroids, diabetes (preexisting or gestational), gestational hypertension, preeclampsia, stillbirth, and mode of delivery. Hospital site was considered as a random effect, to account for patient clustering.

aOR = odds ratio; BMI = body mass index; PPH = postpartum hemorrhage.