Maternal Super Obesity and Neonatal Morbidity after Term Cesarean Delivery

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Abstract

Objective To estimate the association between maternal super obesity (body mass index [BMI] ≥ 50 kg/m²) and neonatal morbidity among neonates born via cesarean delivery (CD).

Methods Retrospective cohort of singleton neonates delivered via CD ≥ 37 weeks in the Maternal-Fetal Medicine Unit Cesarean Registry. Maternal BMI at delivery was stratified as 18.5 to 29.9 kg/m², 30 to 39.9 kg/m², 40 to 49.9 kg/m², and ≥ 50 kg/m². Primary outcomes included acute (5-minute Apgar score < 5 , cardiopulmonary resuscitation and ventilator support < 24 hours, neonatal injury, and/or transient tachypnea of the newborn) and severe (grade 3 or 4 intraventricular hemorrhage, necrotizing enterocolitis, seizure, respiratory distress syndrome, hypoxic ischemic encephalopathy, meconium aspiration, ventilator support ≥ 2 days, sepsis and/or neonatal death) neonatal morbidity. Odds of neonatal morbidity were estimated for each BMI category adjusting for clinical and operative characteristics.

Results Of 41,262 maternal–neonatal dyads, 36% of women were nonobese, 49% had BMI of 30 to 39.9 kg/m², 12% had BMI of 40 to 49.9 kg/m², and 3% were super obese. Compared with nonobese women, super obese women had twofold odds of acute (5 vs. 10%; adjusted odds ratio [aOR]: 1.81, 95% confidence interval [CI]: 1.59–2.73) and severe (3 vs. 6%; aOR: 2.08; 95% CI: 1.59–2.73) neonatal morbidity.

Conclusion Among term infants delivered via CD, maternal super obesity is associated with increased risk of neonatal morbidity.

Keywords

- ▶ cesarean delivery
- ▶ neonatal morbidity
- ▶ obesity
- ▶ super obesity

Maternal obesity in the United States has reached epidemic proportions, and super obesity, defined as body mass index (BMI) ≥ 50 kg/m², is the fastest growing obesity group in the United States.¹ Maternal obesity is a well-recognized independent risk factor for cesarean delivery (CD).^{2–4} Class III obese (BMI ≥ 40 kg/m²) nulliparous women are three to four times more likely to undergo CD compared to normal weight women,^{3,5} and more than half of multiparous women with class III obesity attempting a vaginal birth after cesarean (VBAC) deliver via repeat CD.⁶ Among super obese women, approximately half deliver via CD and more than one-third of

super obese nulliparous women undergo a scheduled primary CD.^{7,8} Obesity is well characterized as increasing the risk of maternal complications after CD, including vertical hysterotomy,⁹ postoperative wound infections,^{10,11} and thromboembolism.¹² Less is understood about maternal super obesity and the risk of neonatal complications during and after CD. Available literature suggests that neonates born via elective CD or failed trial of labor are more likely to experience morbidity, particularly respiratory compromise, compared to neonates born vaginally.^{13,14} However, little is known about whether maternal super obesity is associated with an

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increased risk of neonatal morbidity, including respiratory complications, compared to nonobese women delivering via CD.

Because super obese women are at a substantially increased risk of delivering via CD, the objective of this study was to investigate the relationship between maternal super obesity and neonatal morbidity among term infants born via CD.

Materials and Methods

This is a retrospective cohort analysis of the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development Maternal-Fetal Medicine Unit Cesarean Registry, which was conducted from 1999 to 2002 in 19 academic centers.¹⁵ Briefly, study nurses who were blinded to delivery mode (CD or VBAC) and outcomes collected demographic data, obstetrical history, intrapartum events and neonatal outcomes for each participant. Study nurses abstracted charts for neonatal complications. For this analysis, we included women delivering nonanomalous singleton infants. We included women delivering via CD with and without labor as labor has been shown to decrease, but not eliminate, the risk of neonatal respiratory complications after CD.¹⁶ AS the primary objective of this study was to assess the relationship between maternal obesity and neonatal morbidity after CD, we excluded women who delivered via VBAC. While this dataset does include women who delivered vaginally after prior CD, we chose not to include them in order to assess the effect of obesity on neonatal outcomes among infants delivering via the same mode of delivery. By including women only delivering via CD, we were able to examine if cesarean indication or operative characteristics, which differ by obesity group, influence the risk of neonatal morbidity. We also excluded women who had BMI < 18.5 kg/m², those who delivered multiple gestations, and those with infants who were stillborn, weighed < 500 g, had gestational age < 37 weeks, or had major congenital anomalies. We further excluded women with missing information on delivery mode, delivery BMI, and key neonatal information, including plurality, anomalies, live born status, birth weight, and gestational age at the time of birth.

Our primary exposure was maternal BMI at time of delivery categorized as 18.5 to 29.9 kg/m², 30 to 39.9 kg/m², 40 to 49.9 kg/m², and ≥50 kg/m². BMI was calculated by measured maternal height and weight, which were abstracted from medical charts by study nurses. We chose BMI at time of delivery and not prepregnancy BMI because it is a more reliable and complete variable and more accurately reflects gestational weight gain and maternal habitus at time of CD. The two primary outcomes were composite measures for acute and severe neonatal morbidity. Acute neonatal morbidity was defined as neonatal outcomes requiring treatment of the neonate in the delivery room or within 24 hours of delivery and included one of more of the following: 5-minute Apgar score < 5, cardiopulmonary resuscitation within 24 hours of delivery, ventilator support for less than 24 hours after delivery, neonatal birth injury (brachial plexus injury,

fracture, facial nerve injury, skin laceration), and transient tachypnea of the newborn (TTN). Severe neonatal morbidity was defined as severe outcomes requiring treatment after the immediate delivery period (>24 hours) and included one or more of the following: grade 3 or 4 intraventricular hemorrhage, necrotizing enterocolitis, seizure, respiratory distress syndrome (RDS), hypoxic ischemic encephalopathy, meconium aspiration (MA), ventilator support for more than 2 days, sepsis, and neonatal death. We also examined arterial umbilical cord pH < 7.1 and neonatal intensive care unit (NICU) admission as secondary outcomes. As this study was conducted in 19 centers with different practices of obtaining cord blood gases at time of CD and NICU admission, we elected to exclude these outcomes from the composite outcome measures.

Maternal demographics, clinical and delivery characteristics, and outcomes were compared across the four BMI categories using chi-square test for trend. As our outcomes were rare (≤10% of the cohort), logistic regression models were used to estimate odds ratios and 95% confidence intervals for the association between obesity and neonatal morbidity. Based on the literature, we selected clinically relevant and operative characteristics that are known to be associated with both maternal obesity and neonatal morbidity, including maternal age, race, gestational age, maternal diabetes, prior CD, labor, type of anesthesia, and skin and uterine incision. Covariates were retained in the model if they were statistically significant at $p < 0.05$. An interaction term was included in the model to assess the association between maternal BMI and neonatal morbidity by cesarean indication (elective repeat, emergency, indicated; a priori, $p < 0.1$ was considered statistically significant). Emergency CD was defined as CD for those with nonreassuring fetal status, cord prolapse and placental abruption. Indicated CD included those with contraindication to labor (e.g., history of non low-transverse incision), fetal malpresentation, suspected macrosomia, and preeclampsia.

Prior studies have associated prolonged incision-to-delivery time with both maternal obesity and neonatal morbidity at time of CD.^{17,18} For those maternal–neonatal dyads with available information, we explored whether incision-to-delivery time (assessed as a continuous variable) or prolonged incision-to-delivery time (defined as 90th percentile or longer from incision-to-delivery in minutes) impacted the association between maternal obesity and neonatal morbidity. As with other covariates, we considered $p < 0.05$ to be statistically significant.

Analyses were performed using STATA (version 13, Stata-Corp, College Station, TX). The University of North Carolina at Chapel Hill Institutional Review Board reviewed and deemed this study exempt.

Results

Our cohort included 41,262 maternal–neonatal dyads (→ Fig. 1); 36% of women had BMI of 18.5 to 29.9 kg/m², 49% had BMI of 30 to 39.9, 12% had BMI of 40 to 49.9 kg/m², and 3% had BMI ≥ 50 kg/m². With increasing severity of obesity, women were more

Fig. 1 Study cohort selection from Maternal-Fetal Medicine Unit Cesarean Registry (1999–2002).

likely to be Black, have pregestational diabetes and chronic hypertension, and pregnancy complications, including gestational diabetes and/or hypertensive disorders of pregnancy (gestational hypertension, preeclampsia, or eclampsia). As BMI increased, women were less likely to undergo emergency CD and more likely to undergo elective CD (►Table 1).

For the entire cohort, neonatal morbidity was uncommon: acute newborn morbidity (2.5%), severe neonatal morbidity (3.6%), 5-minute Apgar score < 5 (0.4%), and umbilical cord blood pH < 7.1 (6.7%), with the exception of NICU admission (13%) (►Table 2). Acute newborn morbidity, severe neonatal morbidity, cord blood pH, and NICU admission were most frequent among super obese women. Respiratory complications, including TTN, ventilator support, RDS, and MA, were the most common morbidities in all the obese groups and were the most frequent among super obese women. There were no statistically significant differences in neonatal mortality across BMI categories.

In multivariable models, increasing maternal BMI was associated with an increased risk of both acute and severe neonatal morbidity, after adjusting for gestational age, maternal diabetes, chorioamnionitis, general anesthesia, skin and uterine incision and CD indication (►Table 3). Adjusted odds ratios were similar to unadjusted risk ratio with regard to effect magnitude. Uterine incision and labor were statistically significant only in severe neonatal morbidity models. Maternal race and prior CD were not statistically significant in

either model. No statistically significant interaction was observed for CD indication and maternal obesity in either model (all $p > 0.1$). For the maternal-neonatal dyads with available information ($n = 27,290$), incision-to-delivery time was not significant in either adjusted model.

Comment

In this large study of maternal-neonatal dyads delivered via CD, we found that maternal super obesity was associated with approximately double the risk of both acute and severe neonatal morbidity among term infants delivered via CD. We explored neonatal outcomes requiring immediate resuscitation in the delivery room and those outcomes requiring continued treatment after delivery. Neither incision-to-delivery time as a continuous variable nor prolonged incision-to delivery time was not significant for either outcome, suggesting that maternal obesity confers the increased risk for neonatal morbidity.

Other studies have examined neonatal morbidity among obese women. Maternal obesity was associated with severe complications related to birth asphyxia, including Apgar score of 0 to 3 at 5 and 10 minutes, MA, and neonatal seizures, in a dose-dependent manner.¹⁹ Super obesity (BMI ≥ 50 kg/m²) was associated with a fivefold risk for NICU admission compared to neonates born to non-super obese women (BMI < 50 kg/m²).²⁰ However, neither of these large Scandinavian studies included information about mode of delivery. In a

Table 1 Maternal and delivery characteristics of women by BMI category in the MFMU Cesarean Registry ($n = 41,262$), 1999 to 2002

Characteristic	BMI: 18.5–29.9 ($n = 14,688$)	BMI: 30–39.9 ($n = 20,070$)	BMI: 40–49.9 ($n = 5,195$)	BMI: ≥ 50 ($n = 1,109$)	p-Value
Maternal age (y), median (IQR)	29 (24–33)	29 (24–33)	28 (24–33)	27 (23,32)	<0.001
Gestational age ≥ 41 wk at delivery	1,613 (10.8)	2,584 (12.9)	673 (13.0)	143 (12.9)	<0.001
Nulliparous	4,506 (30.3)	5,337 (26.6)	1,291 (24.9)	286 (25.8)	<0.001
Black race	2,958 (18.9)	5,407 (26.9)	2,243 (43.2)	656 (59.2)	<0.001
Chronic hypertension	92 (0.6)	314 (1.6)	227 (4.3)	87 (7.8)	<0.001
Hypertensive disease of pregnancy	743 (5.0)	1,843 (9.2)	762 (14.7)	205 (18.5)	<0.001
Gestational diabetes	584 (3.9)	1,573 (7.8)	667 (12.8)	159 (14.3)	<0.001
Pregestational diabetes	113 (0.8)	347 (1.7)	189 (3.6)	73 (6.6)	<0.001
Tobacco	1,772 (11.9)	2,315 (11.5)	793 (15.3)	185 (16.7)	<0.001
Prior cesarean delivery	8,957 (60.2)	12,886 (64.2)	3,382 (65.1)	705 (63.6)	<0.001
Chorioamnionitis	904 (6.1)	1,318 (6.6)	279 (5.4)	55 (5.0)	0.16
Labor	7,358 (49.4)	9,370 (46.7)	2,392 (46.0)	490 (44.2)	<0.001
Cesarean indication					<0.001
Indicated	6,510 (43.7)	8,937 (44.5)	2,090 (40.2)	490 (44.2)	
Emergency	2,144 (14.4)	2,569 (12.8)	694 (13.4)	134 (12.1)	
Elective repeat	6,234 (41.9)	8,937 (44.5)	2,411 (46.4)	485 (43.7)	
Skin incision					0.01
Pfannenstiel	8,368 (56.2)	10,284 (51.2)	2,744 (52.8)	537 (48.4)	
Vertical	1,659 (11.1)	2,785 (13.9)	701 (13.5)	222 (20.0)	
Unknown	4,861 (32.7)	7,001 (34.9)	1,750 (33.7)	350 (31.6)	
Uterine incision					0.002
Low transverse	9,867 (66.3)	12,864 (64.1)	3,352 (64.5)	692 (62.4)	
Non low-transverse	198 (1.3)	284 (1.4)	111 (2.1)	68 (6.1)	
Unknown	4,823 (32.4)	6,922 (34.5)	1,732 (33.3)	349 (31.5)	
General anesthesia	762 (5.1)	961 (4.8)	256 (4.9)	71 (6.4)	0.82
Incision-to-delivery time (min), ^a median (IQR)	9 (6–12)	10 (7–14)	11 (8–16)	13 (9–19)	<0.001
Incision-to-delivery time ≥ 90 th percentile (min) ^a	713 (7.1)	1,344 (10.3)	572 (1.6)	193 (25.5)	<0.001

Abbreviations: BMI, body mass index; MFMU, Maternal-Fetal Medicine Unit.

^a $n = 27,290$.Note: p -value test for trend or Kruskal-Wallis, as appropriate. All values are n (%) unless indicated as median (interquartile range).

large Swedish cohort, Blomberg found that infants delivered via CD had a decreased risk of adverse neonatal outcomes compared to those delivered vaginally.²¹ In that cohort, the risk of adverse neonatal outcomes was the lowest among infants delivered via emergency CD, suggesting that time to delivery may be an important component to understanding this risk. However, operative characteristics, including incision-to-delivery time, were not included in this study. In contrast to these other large studies, we were able to assess the effect of operative characteristics. By including only women delivering via CD, we were able adjust for operative characteristics that have been shown to be associated with both maternal super obesity and neonatal morbidity, including incision-to-delivery time, type of anesthesia, and opera-

tive techniques. However, we could not estimate the effect of delivery mode on this association.

Several studies have investigated neonatal outcomes among infants delivered via CD and characterized operative characteristics that may contribute to this risk. In a single-center study ($n = 2,266$), Conner et al found that maternal obesity was associated with both increased incision-to-delivery time and composite neonatal morbidity (5-minute Apgar score < 7 , arterial umbilical cord pH < 7.1 , base excess ≤ 8 mmol/L, and NICU or special care nursery admission).²² Our study indicates an association between maternal obesity and increased risk of neonatal morbidity among infants delivered via CD; however, prolonged incision-to-delivery time did not alter the association between maternal obesity and neonatal

Table 2 Neonatal outcomes by maternal BMI among term singleton infants delivered via cesarean in the MFMU Cesarean Registry ($n = 41,262$)

Outcome	BMI: 18.5–29.9, n (%)	BMI: 30–39.9, n (%)	BMI: 40–49.9, n (%)	BMI: 50, n (%)	<i>p</i> -Value
At least one acute newborn morbidity	807 (5.4)	1,260 (6.3)	441 (8.5)	107 (9.2)	<0.001
5-min Apgar score < 5	49 (0.3)	71 (0.4)	26 (0.5)	4 (0.4)	0.18
CPR within 24 h of life	41 (0.3)	47 (0.2)	13 (0.3)	4 (0.4)	0.90
Ventilator support within 24 h of life	169 (1.1)	274 (1.4)	105 (2.0)	25 (2.3)	<0.001
Any birth injury ^a	144 (1.0)	183 (0.9)	41 (0.8)	8 (0.7)	0.19
TTN	506 (3.4)	835 (4.2)	316 (6.1)	77 (6.9)	<0.001
At least one severe neonatal morbidity	443 (3.0)	726 (3.6)	247 (4.8)	67 (6.0)	<0.001
IVH grade 3 or 4	1 (0.01)	1 (0.0)	0 (0)	0 (0)	–
Necrotizing enterocolitis	4 (0.03)	4 (0.02)	1 (0.02)	0 (0)	–
Seizures	25 (0.2)	31 (0.2)	10 (0.2)	2 (0.2)	0.78
RDS	306 (2.1)	446 (2.2)	157 (3.0)	42 (3.8)	<0.001
HIE	14 (0.1)	19 (0.1)	6 (0.1)	0 (0)	0.84
Meconium aspiration	125 (0.8)	246 (1.2)	103 (2.0)	19 (1.7)	<0.001
Ventilator support ≥ 2 d	83 (0.6)	157 (0.8)	64 (1.2)	14 (1.3)	<0.001
Sepsis	45 (0.3)	84 (0.4)	32 (0.6)	12 (1.1)	<0.001
Neonatal death	6 (0.04)	10 (0.1)	4 (0.1)	1 (0.1)	0.63
Cord pH < 7.1 ^b	331 (6.2)	529 (6.3)	199 (9.1)	56 (11.0)	<0.001
NICU admission	1,756 (11.8)	2,634 (13.1)	881 (17.0)	214 (19.3)	<0.001

Abbreviations: CPR, cardiopulmonary resuscitation; HIE, hypoxic ischemic encephalopathy; IVH intraventricular hemorrhage; NICU, neonatal intensive care unit; RDS, respiratory distress syndrome; TTN, transient tachypnea of the newborn.

^aBirth injury includes brachial plexus or nerve injury, fracture, skin laceration, and other injuries.

^b $n = 16,467$.

Note: Bold denotes composite outcome. *P*-value test for trend.

Table 3 Logistic regression models for maternal BMI and neonatal morbidity

Maternal and delivery characteristics	Acute neonatal morbidity ($n = 41,262$)	Severe neonatal morbidity ($n = 41,262$)
	Adjusted OR (95% CI)	
BMI: 18.5–29.9 kg/m ² (ref)	–	–
BMI: 30–39.9 kg/m ²	1.19 (1.01–1.41)	1.26 (1.11–1.42)
BMI: 40–49.9 kg/m ²	1.59 (1.40–1.80)	1.63 (1.38–1.92)
BMI: ≥ 50 kg/m ²	1.81 (1.46–2.25)	2.08 (1.59–2.73)
Gestational age (ref: 39 wk)	–	–
37–39 wk	1.34 (1.21–1.49)	1.60 (1.39–1.84)
≥ 40 wk	1.16 (1.05–1.29)	1.47 (1.27–1.70)
Maternal diabetes	1.47 (1.30–1.66)	1.34 (1.14–1.59)
Chorioamnionitis	1.79 (1.56–2.06)	2.19 (1.79–2.58)
General anesthesia	1.74 (1.51–1.99)	2.12 (1.79–2.51)
Cesarean indication		
Elective (ref)	–	–
Emergency	2.12 (1.88–2.40)	2.48 (2.08–2.97)
Indicated	1.10 (0.99–1.22)	0.97 (0.82–1.14)

Table 3 (Continued)

Maternal and delivery characteristics	Acute neonatal morbidity (n = 41,262)	Severe neonatal morbidity (n = 41,262)
	Adjusted OR (95% CI)	
Skin incision		
Vertical (ref)	–	–
Pfannenstiel	1.20 (1.06–1.35)	1.36 (1.16–1.59)
Unknown	0.78 (0.68–0.90)	0.71 (0.32–1.54)
Uterine incision ^a		
Low transverse (ref)	–	–
Non low-transverse		1.85 (1.37–2.52)
Unknown		1.27 (0.60–2.71)
Labor ^a	–	1.26 (1.10–1.47)

Abbreviations: BMI, body mass index; CI, confidence interval; OR, odds ratio; ref, reference.

^aUterine incision and labor were not significant in acute morbidity model.

morbidity. From the same dataset that was used for our study, Edwards et al demonstrated that among infants delivered by prelabor CD with spinal anesthesia, a 10-point increase in maternal BMI was associated with a 0.01-point decrease in cord blood arterial pH. Among women with BMI > 35, Pfannenstiel skin incision compared to vertical skin incision was associated with a higher frequency of umbilical cord base deficit >12 mmol/L.²³ In a different single-center retrospective cohort study, Sutton et al demonstrated that vertical skin incision was associated with decreased neonatal morbidity (5-minute Apgar score < 7 and cord blood pH < 7.1). As super obese women were more likely to undergo CD with vertical skin incision, we evaluated skin incision as a potential confounder. In both the acute and severe neonatal morbidity models, Pfannenstiel skin incision was associated with an increased risk of neonatal morbidity. Our results and those from Sutton et al suggest, but do not confirm, that while Pfannenstiel skin incision may be associated with a decreased risk of maternal complications among obese women,^{10,24,25} this operative approach may also be associated with an increased risk of neonatal morbidity.

The primary strength of our study is the large sample size. The study sample comprises women from a variety of tertiary care centers in the United States, which makes these outcomes generalizable to many obstetrical settings with the exception of community and small hospitals. Our sample size allowed us to assess these rare neonatal outcomes among term super obese women, which would not be possible in a single-center study. We were able to examine severe neonatal outcomes rarely seen in term neonates, including meconium aspiration, RDS, need for prolonged ventilator support, and sepsis. Our study confirms that neonates born to obese women, and particularly super obese women, are at increased risk not only of adverse short-term outcomes such as low Apgar score, but also of those adverse outcomes that require continued treatment and may be associated with long-term sequelae.^{26,27}

Our study has limitations. This study reflects obesity rates in the United States from 1999 to 2002, when 28% of reproductive-

age women were obese compared to 32% in 2012.^{28,29} Additionally, further limitations include missing data, residual confounding, and the potential effect of trainees' involvement in the surgery on outcomes. Approximately one-third of women had missing data for incision-to-delivery time; thus, we were unable to assess if this interval was a significant covariate in models with our full cohort. We also do not have information about infant or childhood developmental outcomes. There may be unmeasured risk factors associated with obesity and neonatal morbidity, including maternal habitus and operative technique such as taping of the pannus during surgery. In a nationwide survey, obstetricians report that their preferred surgical approach for CD among women with BMI ≥ 40 kg/m² is Pfannenstiel skin incision with taping of the pannus.³⁰ By taping the pannus, weight may be displaced above the maternal great vessels, which may decrease placental perfusion flow and increase risk of neonatal hypoxia, leading to an increased risk of neonatal morbidity.

Our results suggest that compared to nonobese women, maternal super obesity approximately doubles the risk of neonatal morbidity among term, singleton nonanomalous neonates. Our study did not find that incision-to-delivery time significantly affects this association at the time of CD. This information may be useful for counseling super obese women as they have an a priori risk of approximately 50% chance of delivering via CD. Our study, along with others, underscores the need to understand the mechanism of increased risk for neonatal morbidity, particularly respiratory compromise, among infants born via CD to super obese mothers.

Note

This paper was presented at the 2016 Society for Maternal-Fetal Medicine's Annual Meeting in Atlanta, GA, as two poster presentations (final abstract IDs: 221 and 650).

Conflict of Interest

None.

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