Class III obesity is an independent risk factor for unsuccessful induction of labor

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**BACKGROUND:** Although obesity is a known risk factor for cesarean delivery, there is a paucity of data on the course of induction of labor in these patients.

**OBJECTIVE:** With emerging data on the safety of 39-week inductions, we aimed to: (1) determine if Class III obesity, including morbid obesity, is an independent risk factor for nonachievement of complete dilation and vaginal delivery after induction of labor, (2) evaluate the characteristics of the induction of labor course and immediate complications, and (3) evaluate the number of induction agents necessary to be associated with vaginal deliveries. We hypothesized that as body mass index increased, it would take longer to achieve complete cervical dilation, more induction agents would be required, and there would be a higher rate of cesarean delivery.

**STUDY DESIGN:** This was a retrospective cohort study of singleton gestations undergoing induction of labor from 2013 to 2020 at a single center. Study groups were defined as nonobese (body mass index <30 kg/m²), non-Class III obesity (body mass index of 30−39.9 kg/m²), and Class III obesity (body mass index ≥40 kg/m²). The primary outcome was achievement of complete cervical dilation. Secondary outcomes included time from start of induction to complete dilation, cesarean delivery rates, doses of misoprostol used, combination of induction agents used, and incidence of chorioamnionitis and postpartum hemorrhage. Univariate and multivariate logistic regression analyses were used to estimate risks. A secondary analysis was performed on nulliparous patients.

**RESULTS:** A total of 3046 individuals met the inclusion criteria. As body mass index increased, the indications for induction were more likely to be maternal. Rate of achievement of complete dilation decreased with increasing body mass index (973 [88.5%] in the body mass index <30 group vs 455 [70.8%] in the body mass index ≥40 group; adjusted odds ratio, 0.3; 95% confidence interval, 0.2−0.4). The rate of cesarean delivery also increased (149 [13.5%] in the body mass index <30 group vs 207 [30.9%] in the body mass index ≥40 group; adjusted odds ratio, 3.2; 95% confidence interval, 2.5−4.2), as did the time to complete dilation (15.3 hours in the body mass index <30 group vs 18.8 hours in the body mass index ≥40 group; P<.001). Morbidly obese patients required higher doses and more types of induction agents. Misoprostol was used as the sole induction agent in 362 (35.1%) of patients in the body mass index <30 group vs 160 (25.4%) of patients in the body mass index ≥40 group (adjusted odds ratio, 0.6; 95% confidence interval, 0.5−0.8). In the body mass index ≥40 group, a greater number required a combination of misoprostol, mechanical ripening, and oxytocin for induction (147 [14.3%] in the body mass index <30 group vs 158 [25.0%] in the body mass index ≥40 group; adjusted odds ratio, 1.7; 95% confidence interval, 1.3−2.3). For nulliparous patients, the rate of cesarean delivery was significantly higher with increasing body mass index (118 [18.3%] in the body mass index <30 group and 157 [48.2%] in the body mass index ≥40 group; P<.001), with 5 more hours spent in labor (18.3 hours in the body mass index <30 group vs 23.3 hours in the body mass index ≥40 group; P<.001). Nulliparous patients were also more likely to require multiple induction agents (122 [20.3%] for body mass index <30 vs 108 [33.6%] for body mass index ≥40; P<.001).

**CONCLUSION:** Class III obesity is an independent risk factor for nonachievement of complete dilation and vaginal delivery following induction of labor. Furthermore, inductions in these patients require more time and are more likely to require multiple agents.

**Key words:** cesarean delivery, class III obesity, induction agents, induction of labor

**Introduction**

The prevalence of obesity has been increasing for decades and continues to trend upward.1,2 Because more than one-third of the adult population in the United States is obese, obstetricians are treating an increasing number of obese pregnant patients.3 It is well known that obesity is an independent risk factor for adverse obstetrical outcomes including increased postpartum bleeding.4 It is also significantly associated with an...
increased risk for cesarean delivery, which is often performed for failed induction of labor (IOL) in this population.³

IOL is a relatively common practice with increasing incidence. Induction rates were 9.9% in 1990 vs 23% in 2018.¹ Furthermore, the ARRIVE trial showed evidence to support elective IOL at 39 weeks’ gestation in low-risk nulliparous women, which has contributed to an additional rise in this practice.⁴,⁵

Varying rates of successful IOL in the obese population have been reported, ranging between 50% and 63%.⁵⁻⁹ Studies have demonstrated that obese individuals may require adjustments in induction agent dosage and duration of use.⁵ Multiple studies have shown increasing oxytocin requirements in the obese population.¹⁰,¹¹ It has also been reported that misoprostol is less successful than mechanical cervical dilation when given at the same dosages as in nonobese patients.⁵

There are limited data on IOL in patients with Class III obesity (body mass index [BMI] >40 kg/m²). The aims of this study were to: (1) determine if Class III obesity was an independent risk factor for failed IOL, (2) evaluate the characteristics of the IOL course and immediate complications in these patients, and (3) evaluate which induction agents were associated with successful vaginal deliveries.

Methods
We performed a retrospective cohort study of all IOLs at a single tertiary-care center from 2013 to 2020. We included all singleton inductions at ≥34 weeks’ gestation with viable cephalic fetuses. We excluded individuals in spontaneous labor, individuals with contraindications to IOL (malpresentation, previa, or HIV with a high viral load), those with history of cesarean delivery or any subsequent pregnancy in the study period, and those who experienced fetal demise before presentation for delivery. Maternal demographic characteristics, obstetrical history, medical history, pregnancy characteristics, labor outcomes, and neonatal characteristics were collected from the medical record. This study was approved by the institutional review board of the University of Maryland, Baltimore (HP-00067821).

Maternal BMI was calculated using the last maternal height and weight recorded before delivery. The data were divided into BMI categories as defined by National Institutes of Health—World Health Organization classification of BMI as nonobese (<30 kg/m²), non-Class III obesity (30–39.9 kg/m²), and Class III obesity, which was further stratified into morbid obesity (40–49.9 kg/m²) and extreme morbid obesity (≥50 kg/m²).

Labor inductions were carried out similarly for all individuals. Although this was not controlled, standard management was used across the institution. The standard management technique was to begin with 25 µg of misoprostol vaginally every 4 hours for cervical dilation <4 cm. Intracervical Foley balloon was placed at the providers’ discretion when additional cervical ripening was needed, or when the contraction pattern precluded further misoprostol use (>3 contractions in 10 minutes). Oxytocin was initiated once cervical ripening was completed or when >4 misoprostol doses were used. Oxytocin was titrated per protocol with a maximum dose of 40 units.¹² Any oxytocin use before delivery was categorized as oxytocin administered during an induction process. The protocol for oxytocin was to increase by 2 units every 30 minutes to reach adequate Montevideo units or adequate frequency of contractions.¹² Artificial rupture of membranes was performed at the discretion of the provider. Routine use of fetal scalp electrode and intravenous pressure catheter was not done. Arrest disorder was not defined by a strict protocol but by the individual provider. However, generally at this institution, a diagnosis of arrest of dilation was made if there were adequate contractions for 6 hours without cervical change, or inadequate contractions for 4 hours without cervical change.¹³

The primary outcome was defined as achievement of complete cervical dilation. Secondary outcomes included time from start of induction (defined as time of first induction agent) to complete dilation, time from start of induction to delivery, cesarean delivery rates, clinical chorioamnionitis (temperature of at least 38°C before delivery and antibiotics administered for that indication), and postpartum hemorrhage (defined as blood loss >1000 mL).¹⁴ Methods of induction were evaluated, including agents administered, doses of misoprostol required, and the combination of methods used.

The primary and secondary outcomes were compared between the BMI groups. The primary outcome was stratified into 4 groups by BMI criteria. A BMI <30 kg/m² was used as the...
reference group. For univariate analysis, continuous variables were analyzed by their distribution. For normally distributed data, one-way analysis of variance (ANOVA) was completed, and Kruskal–Wallis ANOVA and Mann–Whitney U tests were used for non-normally distributed data. Categorical variables were analyzed by the chi-square test. Two separate subanalyses were completed: one in nulliparous individuals and the other in individuals with BMI of ≥50 kg/m². Odds ratios were calculated relative to the reference group (BMI <30 kg/m²) and adjusted for confounders (neonatal birthweight, gestational age at delivery, maternal age, starting dilation, starting effacement, cesarean delivery, and parity). A Kaplan–Meier survival analysis was used to evaluate time in hours from start of induction to complete cervical dilation by BMI category. Statistical analysis was completed via IBM SPSS Statistics, version 28.0 (IBM Corp, Chicago, IL). P value <.001 was considered significant with Bonferroni correction.

Results
During the study period, a total of 3900 patients underwent IOL. A total of 3046 met inclusion criteria and were included in the final analysis. Excluded patients were those with gestational age <34 weeks (n=235), multiple pregnancies within the study period (n=142), multifetal gestation (n=68), fetal demise (n=41), lethal fetal anomalies (n=20), history of cesarean delivery (n=323), and contraindications to labor induction (n=35) (Figure 1). A total of 1110 patients (36.4%) were in the reference group of BMI <30 kg/m². There were 1293 (42.4%) individuals with a BMI between 30 and 39.9 kg/m². In the study group there were 643 patients (21.1% of total), of which 472 (15.6% of total) had a BMI of 40 to 49.9 kg/m², and 171 patients (5.6% of total) had a BMI of ≥50 kg/m². As the BMI category increased, the rate of maternal medical conditions also increased, including the frequency of hypertension, diabetes mellitus (both gestational and pregestational), asthma, and preeclampsia. In addition, as the BMI category increased, the indication for induction was more frequently for maternal indications than for fetal indications (Table 1).

The rate of achieving complete dilation decreased with increasing BMI, with an incidence of 973 (88.5%) for individuals with BMI <30, and 455 (70.8%) for individuals with Class III obesity (adjusted odds ratio [aOR], 0.3; 95% confidence interval [CI], 0.2–0.4). Time to complete dilation was longer with each increase in BMI category: 15.3 hours (interquartile range [IQR], 15.9) for BMI <30 and 18.8 hours (IQR, 16.8) for individuals with Class III obesity (P<.001). Time to delivery also increased with each BMI category: 16.0 hours (IQR, 15.9) for BMI <30 and 19.4 hours (IQR, 17.3) for Class III obesity (P<.001). The rate of cesarean delivery was higher in individuals with a BMI >40 kg/m². The indication for cesarean delivery was more likely to be for arrest of dilation or maternal request in the BMI >40 kg/m² group (90 [43.3%] in BMI >40 kg/m² vs 32 [21.5%] in BMI <30 kg/m² group for arrest of dilation and 29 [13.9%] in BMI >40 kg/m² vs 6 [4%] in BMI <30 kg/m² group for maternal request; P<.001 for both) (Table 2). The survival analysis demonstrated a significant increase in time to achieve complete dilation with increasing BMI (Figure 2). The rates of chorioamnionitis, neonatal intensive care unit (NICU) admission, and third- or fourth-degree laceration did not differ between the groups (P>.05). After adjusting for the increased cesarean rate, there was no significant difference in postpartum hemorrhage rates between the BMI groups (aOR, 1.2; 95% CI, 0.8–2.1) (Table 2).

Moreover, patients with Class III obesity had higher requirements for dosages and types of induction agents. In addition, the use of misoprostol as the only induction agent was reduced in individuals with BMI of ≥40 kg/m² (aOR, 0.6; 95% CI, 0.5–0.8) relative to individuals with BMI <30 kg/m². The median number of doses of misoprostol given was 1 (0–6) in the BMI <30 kg/m² group and 2 (2) in the BMI ≥40 kg/m² group.

**Figure 1**
Patient population and final study population

Patients that we excluded from final analysis with reasoning.

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Finally, the use of 3 induction methods (oxytocin, misoprostol, and mechanical ripening) was increased in the BMI $\geq 40$ kg/m$^2$ group (aOR, 1.7; 95% CI, 1.3—2.3) when compared with nonobese individuals (Table 3).

Individuals with a BMI $\geq 40$ kg/m$^2$ who achieved vaginal delivery (VD) required fewer doses of misoprostol, with a median of 2 (2) in individuals who achieved VD and 3 (3) in those who did not. In addition, the use of oxytocin, misoprostol, and mechanical dilation was less frequent in those who

| TABLE 1 Demographics | BMI <30 (1110) | BMI 30—39.9 (1293) | BMI 40—49.9 (472) | BMI $\geq$50 (171) | $P$ value |
|-----------------------|--------------|-------------------|-----------------|-----------------|----------|
| Age                   | 26 (9)       | 28 (10)           | 28 (8)          | 28 (7)          |          |
| Black                 | 419 (56.3)   | 853 (66.0)        | 311 (76.5)      | 110 (64.3)      | .001     |
| White                 | 345 (28.1)   | 302 (23.4)        | 75 (17.9)       | 41 (24.2)       |          |
| Hispanic              | 40 (4.1)     | 39 (3.0)          | 7 (1.9)         | 5 (3.2)         |          |
| Asian                 | 59 (4.8)     | 44 (3.4)          | 1 (0.4)         | 6 (3.3)         |          |
| Other                 | 85 (6.7)     | 55 (4.3)          | 12 (3.4)        | 9 (5.0)         |          |
| Parity                | 0.001        |                   |                 |                 |          |
| 0                     | 641 (58.3)   | 639 (49.4)        | 232 (49.2)      | 94 (55.0)       |          |
| 1                     | 244 (22.2)   | 291 (22.5)        | 99 (14.8)       | 33 (19.3)       |          |
| 2                     | 133 (12.1)   | 185 (14.3)        | 79 (16.7)       | 18 (10.5)       |          |
| $\geq$3               | 95 (8.6)     | 178 (13.7)        | 62 (13.1)       | 26 (15.2)       |          |
| Prepregnancy BMI      | 25.8 (5.5)   | 33.6 (5.5)        | 42.9 (4.9)      | 53.4 (7.4)      | .001     |
| BMI at delivery       | 26.5 (4.6)   | 34.2 (5.1)        | 43.6 (4.1)      | 54.4 (8.1)      | .001     |
| Total weight gain     | 26 (17.0)    | 25 (21.0)         | 22 (27.0)       | 21 (24.0)       | .022     |
| 1-h glucose screening test | 105 (37.3)  | 110 (39.5)        | 112 (40.5)      | 114 (46.5)      | .001     |
| Positive GBS          | 290 (26.3)   | 415 (32.3)        | 186 (39.6)      | 58 (33.9)       | .001     |
| HTN                   | 64 (5.8)     | 168 (13.0)        | 117 (24.8)      | 81 (47.4)       | .001     |
| GDM                   | 77 (7.0)     | 135 (10.4)        | 60 (12.7)       | 24 (14.6)       | .001     |
| Diabetes mellitus     | 17 (1.5)     | 33 (2.6)          | 30 (6.4)        | 10 (5.8)        | .001     |
| Preeclampsia          | 112 (10.2)   | 151 (11.7)        | 64 (13.6)       | 29 (17.1)       | .036     |
| Asthma                | 174 (15.9)   | 239 (18.5)        | 113 (23.9)      | 47 (27.5)       | .001     |
| Postdates             | 115 (10.5)   | 153 (11.8)        | 43 (9.1)        | 7 (4.1)         | .001     |
| Fetal                 | 290 (26.4)   | 221 (17.1)        | 80 (16.9)       | 16 (9.4)        |          |
| Maternal              | 331 (30.1)   | 525 (40.6)        | 250 (53.0)      | 111 (64.9)      |          |
| Elective              | 194 (17.6)   | 236 (18.3)        | 60 (12.7)       | 21 (12.3)       |          |
| PROM                  | 150 (13.6)   | 132 (10.2)        | 34 (7.2)        | 15 (4.5)        |          |
| Other                 | 20 (1.8)     | 26 (2.0)          | 6 (1.1)         | 1 (0.6)         |          |
| GA at delivery        | 39.2 (1.9)   | 39.2 (2.0)        | 39.0 (1.8)      | 38.6 (1.8)      | .001     |
| Dilatation            | 1 (1.5)      | 1 (1.0)           | 1 (2.5)         | 1 (2)           | .001     |
| Effacement            | 50 (30)      | 25 (30)           | 25 (50)         | 25 (50)         | .001     |
| Station               | -4 (2)       | -4 (2)            | -4 (2)          | -5 (2)          | .001     |
| BW                    | 3015 (682)   | 3210 (650)        | 3220 (789)      | 3265 (567)      | .001     |
| BW percentile         | 25.5 (38.6)  | 38.2 (45.6)       | 42.5 (52.4)     | 46.5 (44.9)     | .001     |

Legend data presented as number (percentage) or median (interquartile range).

BMI, body mass index; BW, birthweight; GA, gestational age; GBS, group B Streptococcus; GDM, gestational diabetes mellitus; HTN, hypertension; PROM, premature rupture of membranes.

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achieved VD (83 [18.3%] for VD vs 78 [37.3%] for no VD; \( P < .001 \)). The frequency of oxytocin use was not different between the groups (314 [67.5%] for VD vs 155 [72.4%] for no VD; \( P = .199 \)). The time to full dilation was not different between those who achieved VD (18.6 [IQR, 16.9]) and those who did not (22.6 [IQR, 19.9]; \( P = .055 \)), but time to delivery was different (18.8 [IQR, 17.3] for VD and 23.6 [IQR, 22.9] for no VD; \( P < .001 \)).

In nulliparous patients, achievement of complete dilation decreased with increasing BMI; 540 (83.9%) patients in the BMI \(< 30\) kg/m\(^2\) group achieved full dilation vs 186 (57.1%) of those with BMI \(\geq 40\) kg/m\(^2\) (\( P < .001 \)). The time to complete dilation progressively increased with each BMI category, with 18.3 hours (IQR, 17.6) for BMI \(< 30\) kg/m\(^2\) and 23.3 hours (IQR, 18.5) for BMI \(\geq 40\) kg/m\(^2\) (\( P < .001 \)). Time to delivery also increased with each BMI category, with 20.0 hours (IQR, 18.1) for BMI \(< 30\) kg/m\(^2\) and 29.6 hours (IQR, 19.5) for BMI \(\geq 40\) kg/m\(^2\) (\( P < .001 \)).

Finally, we specifically evaluated individuals with a BMI of \(\geq 50\) kg/m\(^2\). The rate of achieving complete dilation was lower at 66.1% (113/171) in the BMI \(\geq 50\) kg/m\(^2\) group (aOR, 0.2; 95% CI, 0.2−0.4) compared with the BMI \(< 30\) kg/m\(^2\) group. Rates of cesarean delivery and a diagnosis of labor arrest disorder were higher among individuals with BMI \(\geq 50\) kg/m\(^2\) (38.0%; aOR, 4.1; 95% CI, 3.2−5.1).

Table 4

| Outcomes                      | BMI <30 (1110) | BMI \(\geq 40\) (643) |
|-------------------------------|---------------|------------------------|
| Achieved complete dilation    | 973 (88.5)    | 455 (70.8)             |
| Cesarean delivery             | 149 (13.5)    | 207 (30.9)             |
| Arrest disorder               | 32 (21.5)     | 90 (43.3)              |
| Postpartum hemorrhage         | 72 (6.6)      | 91 (14.3)              |
| Third/fourth-degree laceration| 25 (2.6)      | 8 (1.6)                |
| Chorioamnionitis              | 51 (4.6)      | 32 (5.0)               |
| NICU admission                | 229 (21.0)    | 114 (17.8)             |

Data presented as number (percentage).

aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; NICU, neonatal intensive care unit; OR, odds ratio.

*Compared with BMI \(< 30\)

Adjusted for age, parity, estimated gestational age at delivery, birthweight, starting dilation, and starting effacement

Adjusted for age, parity, estimated gestational age at delivery, birthweight, starting dilation, and cesarean delivery.

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FIGURE 2

Induction of labor to complete cervical dilation by BMI group

Time in hours from start of induction to complete cervical dilation stratified by BMI group.

BMI, body mass index.

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TABLE 3
Agents for induction of labor

| Agents                                      | BMI <30 (1110) | BMI ≥40 (643) |
|---------------------------------------------|----------------|--------------|
|                                             | n (%)          | OR, 95% CI   | aOR, 95% CI   |
| Mechanical ripening                         | 276 (25.1)     | 1.5 (1.2–1.8) | 1.3 (1.0–1.7) |
| Oxytocin                                    | 655 (59.5)     | 1.6 (1.3–1.9) | 1.6 (1.3–2.0) |
| Misoprostol                                  | 835 (75.9)     | 2.0 (1.5–2.6) | 1.6 (1.2–2.1) |
| Artificial rupture of membranes             | 426 (39.3)     | 1.1 (0.9–1.4) | 1.1 (1.0–1.2) |
| Oxytocin alone                              | 194 (18.8)     | 0.5 (0.3–0.6) | 0.6 (0.3–0.7) |
| Misoprostol alone                           | 362 (35.1)     | 0.6 (0.5–0.8) | 0.6 (0.5–0.8) |
| Oxytocin, misoprostol, and mechanical ripening | 147 (14.3)     | 2.0 (1.5–2.6) | 1.7 (1.3–2.3) |

Data are presented as number (percentage).
aOR, adjusted odds ratio; BMI, body mass index; CI, confidence interval; OR, odds ratio.

1Adjusted for age, parity, estimated gestational age at delivery, starting dilation, starting effacement, and birthweight.
2Adjusted for BMI <30

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CI, 2.8–6.1; and 46.2%; aOR, 2.8; 95% CI, 1.3–5.9) than among those with BMI <30 kg/m². The time to complete dilation was 19.2 (IQR, 15.9) and time to delivery was 24.2 hours (IQR, 19.4) in individuals with BMI ≥50 kg/m², and longer compared with the reference group (P<0.001 for both). Of note, the rate of postpartum hemorrhage was higher in individuals with BMI ≥50 kg/m² than in those with BMI <30 kg/m² (aOR, 2.2 [1.3–3.7]). The median number of doses of misoprostol given was 2 (2) in the BMI ≥50 kg/m² group (P<0.001). There was less single-agent induction in individuals with BMI ≥50 kg/m² (oxytocin alone: 194 [18.8%] for <30 kg/m² vs 16 [9.6%] for ≥50 kg/m²; misoprostol alone: 362 [35.1%] for <30 kg/m² vs 32 [19.3%] for ≥50 kg/m²; P<.001 for both). There was more use of misoprostol, oxytocin, and mechanical ripening in the BMI ≥50 kg/m² group (31.9%) than in the control group (14.3%) (aOR, 2.8; 95% CI, 1.8–4.2) (Table 5).

Discussion

Principal findings

The main finding of this study was that individuals with Class III obesity had significantly increased times to complete dilation and delivery compared with their nonobese counterparts. In addition, the number of induction agents and the number of doses of misoprostol required were significantly higher in individuals with Class III obesity. These effects were even more significant in the subset of nulliparous individuals evaluated. There were no differences in rates of chorioamnionitis, postpartum hemorrhage, obstetrical anal sphincter injuries, or NICU admissions between the BMI categories.

Results

Although it is well-known that obesity is an independent risk factor for adverse obstetrical outcomes and cesarean delivery, we sought to evaluate the impact that induction has on the rate of cesarean delivery in these patients. Since the ARRIVE trial, induction at term has become more popular in low-risk populations. Our study demonstrates that in individuals with Class III obesity, induction does not lead to a lower rate of cesarean delivery and that the time from induction start to delivery is much longer when compared with that of nonobese individuals.

Current literature demonstrates a significantly higher cesarean delivery rate in individuals with Class III obesity. Using a birth certificate registry, Garabedian et al demonstrated a 47.1% incidence of cesarean delivery for BMI from 40 to 49.9 kg/m² and a 56.1% incidence for BMI ≥50 kg/m², which is similar to the rates that we found in individuals undergoing induction in similar BMI categories. Wolfe et al demonstrated that 29% of individuals with Class III obesity had a failed induction, whereas our rate was lower at 18.9%. Lassiter et al evaluated time to delivery in 75 individuals with BMI >40 and found an average of 22.9 hours from induction to delivery, which was similar to an average of 19.4 hours in our patients with the same BMI. However, that study did not evaluate time to complete dilation, nor was there a subanalysis of nulliparous individuals. Pevzner et al found that within the group of patients with a BMI >40 that achieved VD, the average time to delivery was 24.3 hours, which was much longer than even that of our subset with a BMI ≥50 kg/m², even when accounting for a possible 4-hour second stage of labor. Thus, in individuals with successful IOL, duration of labor in our study was shorter than previously reported in the literature. Previous studies have demonstrated that obese patients have longer labors and higher oxytocin requirements compared with nonobese patients. Therefore, a standard induction protocol may not be generalizable to obese individuals and may have a negative impact on VD rates in these patients. Because there were many medically indicated inductions in our cohort, we sought to identify if any induction agents were more efficacious than others in the morbidly obese population. Our study demonstrated that as BMI increases, so does the necessity of using 3 induction agents. This was especially true in individuals with BMI ≥50 kg/m². In this subset of patients, >30% required prostaglandins, mechanical dilation, and oxytocin. Thus, counseling before labor may be useful in this population to set expectations for their induction course.

Finally, we observed that the duration from start of induction to complete dilation increased with increasing BMI category. For example, the time
required to reach full dilation was approximately 4 hours longer for the BMI ≥50 population when compared with nonobese individuals. Nulliparous patients in this group spent 5 hours more in the first stage of labor. Multiple studies have evaluated the time to birth in morbidly obese populations, but few have evaluated the time to complete dilation.16 We consider it important to view complete dilation as an endpoint because second-stage arrest is multifactorial and does not inherently constitute a failure of IOL.

Clinical implications
Patients with extreme morbid obesity, especially nulliparous patients, have lower rates of successful IOL when compared with their nonobese counterparts. This leads to a higher rate of cesarean deliveries in this patient population. We know these patients are already at increased risk for morbidity from cesarean delivery, such as wound infection and postpartum hemorrhage.9 Therefore, any information about how to increase the success of these inductions has important clinical implications on reducing cesarean delivery rates and subsequently reducing morbidity in these patients. For example, consideration should be given to placing mechanical modes of induction earlier in the IOL process. Furthermore, the current threshold of failed IOL may need to be reevaluated on the basis of maternal BMI. Finally, the time from induction start to delivery is significantly longer for the obese population. Before induction, patients should be counseled on the expected duration of induction.

Research implications
At our institution, the induction protocol calls strictly for 25 µg of misoprostol every 4 hours. Previous studies have demonstrated higher efficacy with higher doses of misoprostol, with only a small increased risk of uterine hyperstimulation.19 Further studies in obese individual are needed to determine if 50 µg of misoprostol every 4 to 6 hours may be superior for induction given that our study demonstrated that a significantly higher cumulative dose of misoprostol is required for successful induction.19,20 Additional research into the labor course for obese patients and what constitutes a failed IOL may allow for additional vaginal deliveries to be achieved in this population. Finally, it is important to investigate the best course of action when induction is indicated in high-BMI patients, especially those with a BMI ≥50 kg/m², and whether there is a point at which the risk of failed induction (and the maternal and fetal morbidities that occur with primary cesarean delivery in labor) outweighs the risk of elective primary cesarean delivery.

Strengths and limitations
Strengths of this study include its large sample size and high number of individuals with BMI ≥50 (n=171). This study also collected data from a racially diverse population representative of our urban tertiary-care center. Furthermore, although our induction process was not protocolized, it was relatively homogeneous secondary to this study being completed at a single site with a largely uniform induction process. The weaknesses of this study include its retrospective nature. In addition, we did not obtain information about when active labor was reached or at what cervical dilation a cesarean delivery was performed (ie, at what cervical dilation).

### TABLE 4

| Subanalysis of primigravida (total n=970) | BMI <30 (644) | BMI ≥40 or more (326) | P value |
|-----------------------------------------|--------------|-----------------------|--------|
| Gestational age at delivery             | 39.2 (2.3)   | 38.6 (1.5)            | .001   |
| Induction indication                    |              |                       | .001   |
| Postdates                               | 77 (12.0)    | 23 (7.1)              |        |
| Fetal                                   | 161 (25.0)   | 40 (12.3)             |        |
| Maternal                                | 197 (30.6)   | 197 (60.4)            |        |
| Elective                                | 103 (16.0)   | 31 (9.5)              |        |
| Prelabor rupture of membranes           | 97 (15.1)    | 30 (9.2)              |        |
| Other                                   | 9 (1.4)      | 5 (1.5)               |        |
| Number of misoprostol doses             | 1 (1)        | 2 (2)                 | .001   |
| Mechanical ripening                     | 206 (32)     | 143 (43.9)            | .001   |
| Multiple induction agents               | 122 (20.3)   | 108 (33.6)            | .001   |
| Artificial rupture of membranes         | 238 (37.4)   | 122 (38.0)            | .888   |
| Achieved completed dilation             | 540 (83.9)   | 186 (57.1)            | .001   |
| Cesarean delivery                       | 118 (18.3)   | 157 (48.2)            | .001   |
| Arrest disorders                        | 27 (22.9)    | 76 (48.1)             | .001   |
| Chorioamnionitis                        | 45 (7.0)     | 27 (8.3)              | .517   |
| Estimated blood loss                    | 300 (150)    | 350 (150)             | .001   |
| Postpartum hemorrhage                   | 32 (5.0)     | 43 (13.3)             | .001   |
| Birthweight                             | 2993 (763)   | 3230 (760)            | .001   |
| Birthweight (%)                         | 23.6 (39.9)  | 45.6 (51.0)           | .001   |
| NICU admission                          | 143 (22.4)   | 71 (21.8)             | .832   |
| Start of induction to fully diluted      | 18.3 (17.6)  | 23.3 (18.5)           | .001   |
| Start of induction to delivery          | 20.0 (18.1)  | 29.6 (19.5)           | .001   |

BMI, body mass index; NICU, neonatal intensive care unit.

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longer induction times compared with mandates setting expectations with tion protocol for these patients. It also requires additional studies to and higher doses of induction agents. inductions last longer and require more

Data on last cervical exam would provide additional information to determine which patients failed IOL but who did not reach active labor. Finally, we were limited by our database of only individuals who underwent an IOL. We did not have data on individuals who elected to forgo IOL and proceed directly with cesarean delivery.

Conclusions
Class III obesity is an independent risk factor for failed IOL. These patients’ inductions last longer and require more and higher doses of induction agents. This requires additional studies to determine if there is an optimal induction protocol for these patients. It also mandates setting expectations with patients and counseling on potentially longer induction times compared with those of their nonobese counterparts.

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