Original Research

Outcomes of Term Induction in Trial of Labor After Cesarean Delivery

Analysis of a Modern Obstetric Cohort

Justin R. Lappen, MD, David N. Hackney, MD, MS, and Jennifer L. Bailit, MD, MPH

OBJECTIVE: To evaluate outcomes of induction of labor, compared with expectant management, in women attempting trial of labor after cesarean delivery (TOLAC) in a large obstetric cohort.

METHODS: We performed a secondary analysis of data from the Consortium on Safe Labor that included women with term (37 weeks of gestation or greater) singleton gestations and a history of one prior cesarean delivery who attempted TOLAC. Induction of labor was compared with expectant management by week of gestation from 37 to 40 weeks in both high- and low-risk cohorts. The primary outcome was failed TOLAC. Secondary outcomes included composite maternal morbidity (hysterectomy, transfusion, intensive care unit (ICU) transfer, venous thromboembolism, death), composite neonatal morbidity (5-minute Apgar score less than 5, cord pH less than 7.0, asphyxia, hypoxic ischemic encephalopathy, neonatal death), and neonatal ICU admission. Multivariate logistic regression was performed with adjustment for confounding factors.

RESULTS: We identified 6,033 women attempting TOLAC of whom 1,626 (27.0%) underwent induction of labor and 4,407 (73.0%) did not. Compared with expectant management, induction was associated with an increased risk of failed TOLAC at 37–39 weeks of gestation but not at 40 weeks of gestation (37 weeks of gestation, 48.5% compared with 34.3%, adjusted odds ratio [OR] 1.53, 95% confidence interval [CI] 1.02–2.28]; 38 weeks of gestation, 47.0% compared with 33.0%, adjusted OR 1.74, 95% CI 1.29–2.34; 39 weeks of gestation, 45.6% compared with 29.8%, adjusted OR 2.16, 95% CI 1.76–2.67; 40 weeks of gestation, 37.9% compared with 29.4%, adjusted OR 1.21, 95% CI 0.90–1.66). Induction was associated with an increased risk of composite maternal morbidity at 39 weeks of gestation (adjusted OR 1.87, 95% CI 1.22–2.87) and neonatal ICU admission at 37 weeks of gestation (adjusted OR 2.51, 95% CI 1.62–3.90). Induction was not associated with an increased risk of neonatal morbidity.

CONCLUSION: Induction of labor in women with one prior cesarean delivery, compared with expectant management, is associated with an increased risk of failed TOLAC. Apart from small increases in maternal morbidity at 39 weeks and neonatal ICU admission at 37 weeks of gestation, induction is not associated with an increased risk of severe maternal or neonatal morbidity.

(Obstet Gynecol 2015;126:115–23)
DOI: 10.1097/AOG.0000000000000922

LEVEL OF EVIDENCE: II

The rate of vaginal birth after cesarean delivery in the United States, after peaking in 1996, has rapidly declined and was 9% in 2011. In contrast, the rate

From the Division of Maternal Fetal Medicine, MetroHealth Medical Center, Case Western Reserve University School of Medicine, and the Division of Maternal Fetal Medicine, Department of Obstetrics and Gynecology, University Hospitals Case Medical Center, Cleveland, Ohio.

Presented at the Society for Maternal-Fetal Medicine's 35th Annual Meeting, February 2–7, 2015, San Diego, California.

The data included in this paper were obtained from the Consortium on Safe Labor, which was supported by the Intramural Research Program of the Eunice Kennedy Shriver *National Institute of Child Health and Human Development, National Institutes of Health, through Contract No. HHSN267200603425C. Institutions involved in the Consortium include, in alphabetical order: Baystate Medical Center, Springfield, MA; Cedars-Sinai Medical Center Burnes Allen Research Center, Los Angeles, CA; Christiana Care Health System, Newark, DE; Georgetown University Hospital, MedStar Health, Washington, DC; Indiana University Clarian Health, Indianapolis, IN; Intermountain Healthcare and the University of Utah, Salt Lake City, UT; Maimonides Medical Center, Brooklyn, NY; MetroHealth Medical Center, Cleveland, OH; Summa Health System, Akron City Hospital, Akron, OH; The EMMES Corporation, Rockville, MD (Data Coordinating Center); University of Illinois at Chicago, Chicago, IL; University of Miami, Miami, FL; and the University of Texas Health Science Center at Houston, Houston, TX.*

The named authors alone are responsible for the views expressed in this manuscript, which does not necessarily represent the decisions or the stated policy of the Eunice Kennedy Shriver *National Institute of Child Health and Human Development.*

Corresponding author: Justin R. Lappen, MD, Fellow, Division of Maternal Fetal Medicine, Department of Obstetrics and Gynecology, MetroHealth Medical Center, Case Western Reserve University School of Medicine, 2500 MetroHealth Drive, Suite G240, Cleveland, OH; e-mail: jlappen@metrohealth.org.

Financial Disclosure
The authors did not report any potential conflicts of interest.

ISSN: 0029-7844/15

of labor induction has more than doubled since 1990 to more than 23% in 2011.[1] Prior studies assessing outcomes of labor induction for women attempting trial of labor after cesarean delivery (TOLAC) have reported an increased risk of failed TOLAC and uterine rupture with induction.[2–8] Additionally, an analysis by Grobman et al reported an increased risk of maternal morbidity (uterine rupture, transfusion, thromboembolism, and hysterectomy) with induction among women without a history of prior vaginal delivery attempting TOLAC.[9] The results of these studies, however, are based on the comparison of induction with spontaneous labor.

The prevailing obstetric teaching, that induction of labor is associated with an increased risk of cesarean delivery, stems from observational studies that compare induction with spontaneous labor at a particular gestational age.[10–15] Given that women cannot choose to enter spontaneous labor, the true clinical alternative to induction is expectant management of the pregnancy, which results in either spontaneous labor or induction at a later gestational age. Therefore, the appropriate comparison group for assessing outcomes of induction of labor at a given gestational age is women who do not undergo induction at the same gestational age and are expectantly managed.[16] Results of studies comparing induction with expectant management conflict with the historical literature and demonstrate a decreased risk of cesarean delivery with induction.[17–19]

Notably, this emerging body of literature has excluded women with a history of cesarean delivery attempting TOLAC. Comparing induction with expectant management for women attempting TOLAC may modify the presence or direction of the association between induction and TOLAC outcomes. Therefore, the primary objective of our study is to characterize the prospective likelihood of failed TOLAC and secondarily assess maternal and neonatal outcomes of induction of labor, compared with expectant management, by week of gestation between 37 and 40 completed weeks.

MATERIALS AND METHODS

Our study is a secondary analysis of data from the Consortium on Safe Labor, which was a retrospective cross-sectional study conducted by the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development to characterize current labor and delivery clinical practice and outcomes. Twelve clinical centers including 19 hospitals participated in the Consortium on Safe Labor, which represented all nine American College of Obstetricians and Gynecologists districts. Data were collected on 228,668 deliveries occurring between 2002 and 2008. The majority of the births (87%) occurred between 2005 and 2007. Participating institutions submitted detailed information from patient electronic medical records, including maternal demographic characteristics; maternal medical, reproductive, and antenatal histories; labor and delivery data; and postpartum maternal and neonatal outcome data. Validation of key variables was performed and the electronic medical record data were noted to be highly accurate with greater than 95% concordance for most subgroups. The Consortium on Safe Labor data set contained predefined variables for induction of labor, trial of labor, and unlabored cesarean delivery. Complete details of the study methodology have been previously published.[20]

From the initial 228,668 deliveries in the total Consortium on Safe Labor data set, we arrived at our study cohort through the following exclusion criteria (Fig. 1): women without a history of cesarean delivery and those with more than one prior cesarean delivery (n=208,635), multiple gestation (n=293), congenital or chromosomal anomalies (n=1,077), delivery before 37 weeks of gestation and 0-day gestational age (n=3,177), and unknown labor type (n=247). From the remaining 15,239 potential TOLAC candidates, we excluded all women undergoing repeat cesarean delivery without a trial of labor, including those for whom TOLAC was contraindicated (eg, placenta previa). Therefore, our final cohort for analysis included 6,033 women undergoing TOLAC of whom 1,626 (27.0%) underwent induction of labor and 4,407 (73.0%) did not.

For the primary analysis of this study, induction of labor was defined to include all medically indicated and elective inductions. This definition of induction was chosen to minimize confounding by indication for induction inherent to a retrospective data source. However, given that expectant management may not be recommended when a medical indication for delivery is present, we repeated our analysis after creating a secondary, "low-risk" cohort and redefining the induction group to only include nonmedically indicated inductions of labor.[21] To generate the "low-risk" cohort, we excluded all women with chronic maternal medical conditions that may result in indicated delivery, including chronic hypertension, gestational and pregestational diabetes mellitus, human immunodeficiency virus, and cardiovascular disease (n=500 as demonstrated in Table 1 for the total "low-risk" cohort of 5,533 patients). Given that the development of a pregnancy-related indication for delivery such as preeclampsia or fetal compromise is

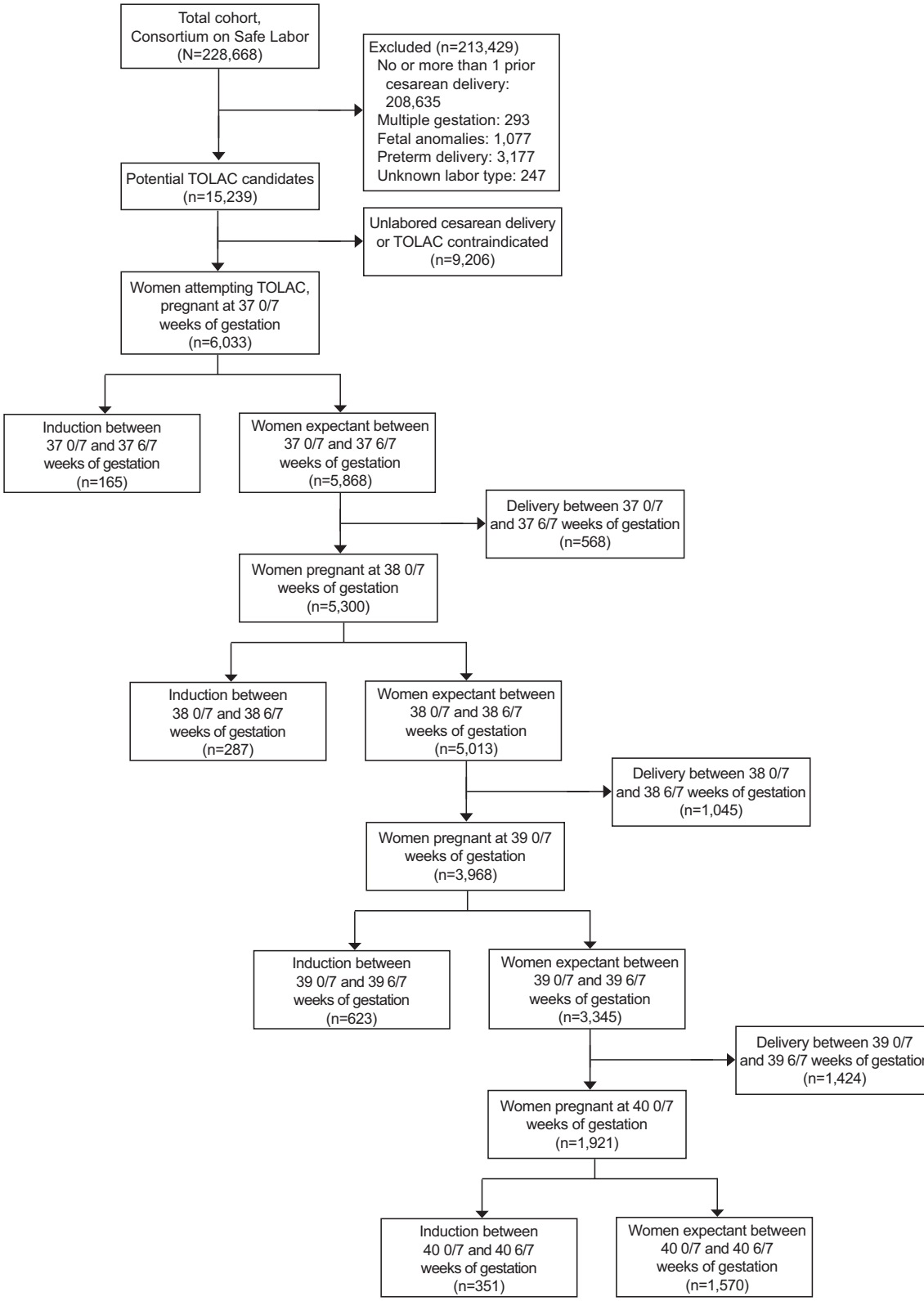

Fig. 1. Flow diagram of cohort selection and comparison groups for elective induction compared with expectant management by week of pregnancy. TOLAC, trial of labor after cesarean delivery.

Lappen. Outcomes of Induction of Labor in TOLAC. Obstet Gynecol 2015.

Table 1. Demographic and Obstetric Characteristics of Women Attempting Trial of Labor After Cesarean Delivery

Characteristic	Total Cohort (n=6,033)
Age (y)	29.6±5.6
BMI (kg/m^2)	31.7±6.3
Birth weight (g)	3,396±452
Race	
White	2,983 (49.4)
African American	1,324 (22.0)
Latina	1,086 (18.0)
Other	640 (10.6)
Insurance status	
Private	3,751 (62.2)
Public	1,862 (30.8)
Other	420 (7.0)
Hospital type	
University teaching	2,264 (37.5)
Community teaching	3,304 (54.8)
Community nonteaching	465 (7.7)
History of vaginal delivery	3,061 (49.3)
Chronic hypertension	108 (1.8)
Pregnancy-related hypertensive disorders*	218 (3.6)
Diabetes†	352 (5.8)
Cardiovascular disease	26 (0.4)
HIV	14 (0.2)
Patients excluded in secondary cohort‡	500 (8.2)
Nonmedically indicated induction of labor	1,007 (62.0)

BMI, body mass index; HIV, human immunodeficiency virus.
Data are mean±standard deviation or n (%).
* Includes gestational hypertension, preeclampsia, and eclampsia.
† Includes gestational and pregestational diabetes.
‡ Includes chronic hypertension, diabetes, cardiovascular disease, and HIV.

a risk of expectant management, these women were retained in the cohort and analyzed as part of the expectant management group. To generate the nonmedically indicated induction group, we identified patients using previously defined methodology from publications from the Consortium on Safe Labor.[19,22] Briefly, the database contained predefined variables for labor induction by indication, which could be broadly categorized as "indicated," "elective," and "no recorded indication." In our study, we defined nonmedically indicated induction to include all those categorized as "elective" and "no recorded indication" given that the results of prior analyses suggest that patients coded as "no recorded indication" from this data set likely represent elective inductions.[22]

Both study cohorts were then analyzed according to whether a patient underwent induction of labor or expectant management at each week of gestation between 37 and 40 completed weeks. The induction groups were defined using the aforementioned criteria for the primary and secondary "low-risk" cohorts, respectively. For both cohorts, the expectant management group was defined to include all women delivering at gestational ages at or greater than that of women being induced.[23]

The primary outcome measure was failed TOLAC. Failed TOLAC was not a predefined variable in the data set and was defined as any women attempting TOLAC who delivered by repeat cesarean delivery. Secondary outcome measures included composite maternal morbidity, composite neonatal morbidity, and neonatal intensive care unit (NICU) admission. Composite maternal morbidity was defined as: hysterectomy, transfusion, intensive care unit admission, venous thromboembolism (deep venous thrombosis and pulmonary embolism), or death. Composite neonatal morbidity was defined as: 5-minute Apgar score less than 5, arterial cord pH less than 7.0, neonatal death, or the clinical diagnoses of asphyxia or hypoxic–ischemic encephalopathy. Given the association of uterine rupture with severe maternal and neonatal morbidity, uterine rupture was also assessed as a separate secondary outcome. Uterine rupture was defined as a disruption of the uterine muscle and visceral peritoneum and was a predefined variable distinct from asymptomatic uterine scar dehiscence, which was coded separately.

Multivariate logistic regression was performed with adjustment for potential confounding factors. Maternal outcomes were adjusted for age, body mass index (calculated as weight (kg)/[height (m)]^2), and history of prior vaginal birth, whereas neonatal outcomes were adjusted for history of prior vaginal delivery and neonatal sex. Given that Bishop score was not known contemporaneously for expectantly managed women, it could not be included in the multivariate model. Lastly, maternal race, a factor that has been demonstrated to affect the success of TOLAC,[24] was dropped from the final regression models because it did not significantly affect the adjusted odds ratios.

Categorical variables were assessed using χ^2 and Fisher's exact test, whereas continuous variables were assessed using unpaired *t* test and Wilcoxon rank-sum test where appropriate. Results are presented as odds ratios (ORs) or adjusted ORs with 95% confidence interval (CI) and *P* values. All statistical analysis was performed using STATA 13.1. Institutional review board approval by MetroHealth Medical Center and University Hospitals Case Medical Center was obtained before initiation of this study (institutional review board project # EM-14-21).

RESULTS

Our total study cohort included 6,033 women (Fig. 1). The demographic and obstetric characteristics of our study cohort are presented in Table 1. The population was racially and ethnically diverse. The average body mass index was in the range of class I obesity (31.7±5.8). A total of 62.2% of patients had private insurance and 92.8% delivered in a teaching hospital (37.5% university and 54.8% community teaching hospitals). Approximately half of the cohort (49.3%) had a history of a prior vaginal delivery. Women with and without a history of vaginal delivery were equally likely to undergo labor induction (26.4% compared with 27.5%, P=.32). Nonmedically indicated inductions of labor represented the majority of inductions in the cohort. Amniotomy, oxytocin, or both represented the primary induction methodology (1,309/1,626 patients [81%]). Prostaglandin use was rare, occurring in only 0.3% of the total study cohort. Medical comorbidities were proportional to expected rates in a general obstetric population. Nine stillbirths occurred in the cohort (three at 37 weeks of gestation, four at 38 weeks of gestation, one at 39 weeks of gestation, and one at 40 weeks of gestation).

The results of the analysis of the primary study cohort are presented in Table 2. Comparing induction of labor with expectant management by week of gestation, the frequency of failed TOLAC was higher at each week of gestation with induction of labor. In multivariate logistic regression controlling for confounding factors, induction was associated with an increased risk of failed TOLAC at 37–39 weeks of gestation but not at 40 weeks of gestation (37 weeks of gestation=48.5% compared with 34.3%, adjusted OR 1.53, 95% CI 1.02–2.28; 38 weeks of gestation=47.0% compared with 33.0%, adjusted OR 1.74, 95% CI 1.29–2.34; 39 weeks of gestation=45.6% compared with 29.8%, adjusted OR 2.16, 95% CI 1.76–2.67; and 40 weeks of gestation=37.9% compared with 29.4%, adjusted OR 1.21, 95% CI 0.90–1.66). Regarding secondary outcome measures, induction was associated with an increased risk of composite maternal morbidity at 39 weeks of gestation (adjusted OR 1.87, 95% CI 1.22–2.87). This association was attributable to a statistically significant increase in the risk of transfusion (5.0% compared with 2.3%, P<.01), which was concentrated among women failing their TOLAC attempt. Induction was also associated with an increased risk of NICU admission at, but not beyond, 37 weeks of gestation (adjusted OR 2.51, 95% CI 1.62–3.90). Induction of

Table 2. Multivariate Analysis of Maternal and Neonatal Outcomes of Labor Induction Compared With Expectant Management for Women Attempting Trial of Labor After Cesarean Delivery

Week Gestation and Outcome	Induction	Expectant Management	Adjusted OR (95% CI)
Week 37	n=165	n=5,868	
Failed TOLAC	80 (48.5)	2,012 (34.3)	1.53 (1.02–2.28)*
Adverse maternal composite	2 (1.2)	162 (2.8)	0.49 (0.12–2.02)
Adverse neonatal composite	2 (1.2)	30 (0.5)	2.39 (0.57–10.08)
NICU admission	25 (15.2)	385 (6.6)	2.51 (1.62–3.90)†
Week 38	n=287	n=5,013	
Failed TOLAC	135 (47.0)	1,652 (33.0)	1.74 (1.29–2.34)†
Adverse maternal composite	6 (2.1)	140 (2.8)	0.64 (0.26–1.58)
Adverse neonatal composite	1 (0.3)	27 (0.5)	0.64 (0.09–4.74)
NICU admission	21 (7.3)	307 (6.1)	1.20 (0.76–1.90)
Week 39	n=623	n=3,345	
Failed TOLAC	284 (45.6)	998 (29.8)	2.16 (1.76–2.67)†
Adverse maternal composite	33 (5.3)	83 (2.5)	1.87 (1.22–2.87)†
Adverse neonatal composite	1 (0.2)	20 (0.6)	0.27 (0.04–1.98)
NICU admission	28 (4.5)	211 (6.3)	0.70 (0.47–1.04)
Week 40	n=351	n=1,570	
Failed TOLAC	133 (37.9)	462 (29.4)	1.21 (0.90–1.66)
Adverse maternal composite	8 (2.3)	33 (2.1)	1.06 (0.48–2.38)
Adverse neonatal composite	5 (1.4)	9 (0.6)	2.51 (0.84–7.56)
NICU admission	24 (6.8)	112 (7.1)	0.95 (0.60–1.50)

OR, odds ratio; CI, confidence interval; TOLAC, trial of labor after cesarean delivery; NICU, neonatal intensive care unit.
Data are n (%) unless otherwise specified.
Maternal model adjusted for history of vaginal delivery, body mass index, and age. Newborn model adjusted for history of vaginal delivery and newborn sex.
* P=.038.
† P<.001.

labor was not associated with a statistically significant increased risk of composite neonatal morbidity.

The results of the secondary analysis of the "low-risk" cohort are presented in Table 3. After adjustment for confounding factors, nonmedically indicated induction of labor in the "low-risk" cohort was associated with an increased risk of failed TOLAC at 38 and 39 weeks of gestation but not at 37 and 40 weeks of gestation (37 weeks of gestation=42.1% compared with 33.8%, adjusted OR 1.53, 95% CI 0.85–2.77; 38 weeks of gestation=55.6% compared with 32.4%, adjusted OR 2.67, 95% CI 1.81–3.93; 39 weeks of gestation=48.0% compared with 29.4%, adjusted OR 2.34, 95% CI 1.86–2.95; and 40 weeks of gestation=37.5% compared with 29.3%, adjusted OR 1.27, 95% CI 0.91–1.76). Nonmedically indicated induction was associated with an increased risk of composite maternal morbidity at 39 weeks of gestation (adjusted OR 2.14, 95% CI 1.36–3.35). Again, this association was attributable to a significantly increased risk of transfusion among women failing their TOLAC attempt. In regard to secondary neonatal outcome measures in the "low-risk" cohort, nonmedically indicated induction was no longer associated with an increased risk of NICU admission at 37 weeks of gestation. Conversely, nonmedically indicated induction was associated with a decrease in the risk of NICU admission at 39 weeks of gestation (adjusted OR 0.52, 95% CI 0.31–0.88). No association between nonmedically indicated induction and adverse neonatal outcome was present.

Overall, 19 women (0.3%) experienced a uterine rupture in this cohort, of whom four had an induction of labor. Induction of labor was not associated with a statistically significant increase in the risk of uterine rupture when assessed either in comparison with expectant management by week of gestation or by exposure to induction for the entire cohort (Table 4).

DISCUSSION

In the current analysis, when comparing induction of labor with expectant management in a cohort of women with one prior cesarean delivery, we found that induction increased the risk of failed TOLAC. This association was present both for the entire study cohort and for a secondary "low-risk" cohort of nonmedically indicated inductions. As demonstrated by recent observational data, the magnitude and

Table 3. Multivariate Analysis of Maternal and Neonatal Outcomes of Nonmedically Indicated Induction of Labor Compared With Expectant Management for Women Attempting Trial of Labor After Cesarean Delivery in the "Low-Risk" Cohort

Week Gestation and Outcome	Induction	Expectant Management	Adjusted OR (95% CI)
Week 37	n=76	n=5,457	
Failed TOLAC	32 (42.1)	1,846 (33.8)	1.53 (0.85–2.77)
Adverse maternal composite	0	150 (2.7)	NA
Adverse neonatal composite	0	27 (0.5)	NA
NICU admission	9 (11.8)	342 (6.3)	1.97 (0.97–3.99)
Week 38	n=171	n=4,743	
Failed TOLAC	95 (55.6)	1,539 (32.4)	2.67 (1.81–3.93)*
Adverse maternal composite	4 (2.3)	129 (2.7)	0.64 (0.20–2.04)
Adverse neonatal composite	1 (0.6)	24 (0.5)	1.11 (0.15–8.26)
NICU admission	12 (7.0)	276 (5.8)	1.16 (0.64–2.12)
Week 39	n=475	n=3,249	
Failed TOLAC	228 (48.0)	956 (29.4)	2.34 (1.86–2.95)*
Adverse maternal composite	28 (5.9)	79 (2.4)	2.14 (1.36–3.35)*
Adverse neonatal composite	0	18 (0.6)	NA
NICU admission	16 (3.4)	200 (6.2)	0.52 (0.31–0.88)*
Week 40	n=285	n=1,544	
Failed TOLAC	107 (37.5)	453 (29.3)	1.27 (0.91–1.76)
Adverse maternal composite	7 (2.5)	32 (2.1)	1.13 (0.48–2.65)
Adverse neonatal composite	2 (0.7)	10 (0.6)	1.09 (0.24–5.00)
NICU admission	17 (6.0)	108 (7.0)	0.83 (0.49–1.42)

OR, odds ratio; CI, confidence interval; TOLAC, trial of labor after cesarean delivery; NA, not applicable; NICU, neonatal intensive care unit.

Data are n (%) unless otherwise specified.

Maternal model adjusted for history of vaginal delivery, body mass index, and age. Newborn model adjusted for history of vaginal delivery and newborn sex.

* $P \leq .01$.

Table 4. Risk of Uterine Rupture Assessed by Week of Gestation and for the Total Study Cohort

Week of Gestation	Induction	Expectant Management	OR (95% CI)
37	2 (1.2)	17 (0.3)	4.22 (0.97–18.43)
38	1 (0.3)	16 (0.3)	1.09 (0.14–8.26)
39	0	13 (0.4)	NA
40	1 (0.3)	4 (0.3)	1.12 (0.12–10.04)
Total	4 (0.2)	15 (0.3)	0.72 (0.24–2.17)

OR, odds ratio; CI, confidence interval; NA, not applicable.
Data are n (%) unless otherwise specified.
Percentage based on primary study cohort with n for induction and expectant management groups as depicted in Table 2.

direction of the association between induction of labor and cesarean delivery depend on the definition of the comparison group.[16,21] In women without a history of cesarean delivery, induction of labor has been associated with a decreased risk of cesarean delivery when compared with expectant management.[17–19] For women attempting TOLAC, however, studies analyzing outcomes of labor induction have only used spontaneous labor as the comparison group, which may bias against induction. The use of an expectant management comparison group represents one of the primary contributions of our study to the literature. Despite this difference in methodology, our analysis found a similar association between induction and failed TOLAC as demonstrated by prior investigations that used a spontaneous labor comparison group.[2,7,25]

We observed an isolated increase in the risk of composite maternal morbidity with induction at 39 weeks of gestation, which was attributable to an increased risk of transfusion among women failing their TOLAC attempt. The fact that this finding was isolated to 39 weeks of gestation likely represents the fact that the largest number of inductions occurred at this gestational age and therefore our study was underpowered to detect a difference at other weeks of gestation. The finding that induction for women attempting TOLAC is associated with an increased risk of transfusion is consistent with the findings of Grobman et al. However, unlike the study by Grobman,[9] our study did not demonstrate an increase in other markers of severe maternal morbidity or uterine rupture. However, given the rarity of severe maternal morbidity and uterine rupture, our study had limited power to detect a difference between groups. Information on the indications for and volume of transfusion was not available.

In regard to neonatal outcomes, we did not detect a difference in composite neonatal morbidity with induction of labor, which is consistent with other publications assessing outcomes of induction compared with expectant management over a gestational age range that includes the early-term period.[18,19] Additionally, our findings are consistent with other studies on induction in women attempting TOLAC, which have not demonstrated an increased risk of neonatal morbidity.[9] However, despite the large sample size of our cohort, the infrequency of adverse neonatal outcomes reflects a lack of power to discern a difference in these rare events. Our study also detected an increased risk of NICU admission at 37 weeks of gestation, which was no longer present when analyzing nonmedically indicated inductions of labor in the "low-risk" cohort. This finding suggests that the NICU admissions were potentially related to the underlying medical indication for the induction, a lack of statistical power to detect a difference, or an increased risk of respiratory morbidity for early term births at 37 weeks of gestation.[26] Additionally, this increase in the risk of NICU admission may be secondary to precautionary measures and may not represent a true increased risk of neonatal morbidity because there was no standard protocol for NICU admission.

There were multiple strengths to this analysis, including the use of a large, reliable data set generated from a multicenter U.S. cohort of laboring women representative of the current obstetric population, and practice patterns. Compared with studies that use administrative data, the use of medical record data improves the accuracy of variables of particular importance to studies of induction compared with expectant management such as gestational age, the classification of labor type or onset, indication for delivery, maternal or fetal medical conditions, and maternal and neonatal outcome data. The validation of key variables directly from medical records minimizes, but does not eliminate, misclassification and ascertainment bias. The definition of "trial of labor" in the original Safe Labor cohort was a patient with two or more documented intrapartum cervical examinations. This definition

may overestimate the determination of who was having a trial of labor and thus artificially increased the rate of failed TOLAC in the expectant management group (eg, patient in latent labor with two examinations before a planned repeat cesarean delivery counted as failed TOLAC). This misclassification would bias our results toward the null. Thus, any finding of a significant difference between failed TOLAC in induction and expectant management groups may be an underestimate of the magnitude of the association. Lastly, in addition to assessing pertinent outcomes such as failed TOLAC and uterine rupture, we assessed other maternal and neonatal outcome measures that reflect severe morbidity.

Our study has several limitations, including the retrospective nature of the data. Additionally, we were unable to control for all obstetric factors that may affect the success of induction, such as Bishop score, because contemporaneous data were not available for the expectant management group. Other factors related to the success of TOLAC such as the indication for the previous cesarean delivery or history of successful vaginal birth after cesarean delivery were not included in regression models because data on these predictors were unavailable. Factors inherent to the original Safe Labor cohort deserve mention. The original publication from the Consortium on Safe Labor reported that intrapartum cesarean deliveries occurred at less advanced cervical dilation for induced compared with spontaneous labors and also reported an overall rate of TOLAC success of 57%, which is slightly lower than previously published data.[4,5,23] These findings may reflect a change in commitment to TOLAC by patients and physicians, a change in obstetric practice after previously published studies regarding the risks of TOLAC, or the current medicolegal climate surrounding TOLAC. Overall, each of these factors may bias our results against labor induction.

Lastly, since the collection of this data set, the American College of Obstetricians and Gynecologists and the Society for Maternal-Fetal Medicine have recommended the avoidance of nonmedically indicated inductions before 39 weeks of gestation.[27] As a result, data regarding nonmedically indicated induction before 39 weeks of gestation may not be considered clinically appropriate in current obstetric practice. However, by including both medically and nonmedically indicated inductions in this study, the results remain generalizable and clinically pertinent because medically indicated early-term inductions remain common.

In conclusion, induction of labor for women with one prior cesarean delivery, in comparison with expectant management, is associated with an increased risk of failed TOLAC. Despite the change in methodology to use expectant management as the comparison group, our findings support previous literature that used spontaneous delivery in the same week. The results of studies comparing induction with expectant management among women without a history of cesarean delivery should not be generalized to women attempting TOLAC. Our study findings should not alter current obstetric practice, which supports an individualized approach to the use of induction in appropriate candidates attempting TOLAC.

REFERENCES

1. Martin JA, Hamilton BE, Ventrura SJ, Osterman MJ, Matthews TJ. Births: final data for 2011. Natl Vital Stat Rep 2013;62:1–69, 72.
2. Landon MB, Hauth JC, Leveno KJ, Spong CY, Leindecker S, Varner MW, et al. Maternal and perinatal outcomes associated with a trial of labor after prior caesarean delivery. N Engl J Med 2004;351:2581–9.
3. Macones GA, Peipert J, Nelson DB, Odibo A, Stevens EJ, Stamilio DM, et al. Maternal complications with vaginal birth after cesarean delivery: a multicenter study. Am J Obstet Gynecol 2005;193:1656–62.
4. Ravasia DJ, Wood SL, Pollard JK. Uterine rupture during induced trial of labor among women with a previous cesarean delivery. Am J Obstet Gynecol 2000;183:1176–9.
5. Zelop CM, Shipp TD, Repke JT, Cohen A, Caugey A, Lieberman E. Uterine rupture during induced or augmented labor in women with one prior cesarean delivery. Am J Obstet Gynecol 1999;181:882–6.
6. Lydon-Rochelle M, Holt VL, Easterling TR, Martin DP. Risk of uterine rupture during labor among women with a prior cesarean delivery. N Engl J Med 2001;345:3–8.
7. Vaginal birth after previous cesarean delivery. Practice Bulletin No. 115. American College of Obstetricians and Gynecologists. Obstet Gynecol 2010;116:450–63.
8. Rossi AC, Prefumo F. Pregnancy outcomes of induced labor in women with previous cesarean section: a systematic review and meta-analysis. Arch Gynecol Obstet 2015;291:273–80.
9. Grobman WA, Gilbert S, Landon MB, Spong CY, Leveno KJ, Rouse DJ, et al. Outcomes of induction of labor after one prior cesarean. Obstet Gynecol 2007;109:262–9.
10. Yeast JD, Jones A, Poskin M. Induction of labor and the relationship to cesarean delivery: a review of 7001 consecutive inductions. Am J Obstet Gynecol 1999;180:628–33.
11. Smith KM, Hoffman MK, Sciscione A. Elective induction of labor in nulliparous women increases the risk of cesarean delivery. Obstet Gynecol 2003;101:45S.
12. Hoffman MK, Vahratian A, Sciscione AC, Troendle JF, Zhang J. Comparison of labor progression between induced and noninduced multiparous women. Obstet Gynecol 2006;107:1029–34.
13. Vahratian A, Zhang J, Troendle JF, Sciscione AC, Hoffman MK. Labor progression and risk of cesarean delivery in electively induced nulliparas. Obstet Gynecol 2005;105:698–704.
14. Luthy DA, Malmgren JA, Zingheim RW. Cesarean delivery after elective induction in nulliparous women: the physician effect. Am J Obstet Gynecol 2004;191:1511–5.

15. Seyb ST, Berka RJ, Socol ML, Dooley SL. Risk of cesarean delivery with elective induction of labor at term in nulliparous women. Obstet Gynecol 1999;94:600–7.
16. Caughey AB, Nicholson JM, Cheng YW, Lyell DJ, Washington AE. Induction of labor and cesarean delivery by gestational age. Am J Obstet Gynecol 2006;195:700–5.
17. Cheng YW, Kaimal AJ, Snowden JM, Nicholson JM, Caughey AB. Induction of labor compared to expectant management in low-risk women and associated perinatal outcomes. Am J Obstet Gynecol 2012;207:502.e1–8.
18. Gibson KS, Waters TP, Bailit JL. Maternal and neonatal outcomes in electively induced low-risk term pregnancies. Am J Obstet Gynecol 2014;211:249.e1–16.
19. Darney BG, Snowden JM, Cheng YW, Jacob L, Nicholson JM, Kaimal A, et al. Elective induction of labor at term compared with expectant management: maternal and neonatal outcomes. Obstet Gynecol 2013;122:761–9.
20. Zhang J, Landy HJ, Branch DW, Burkman R, Haberman S, Gregory KD, et al. Contemporary patterns of spontaneous labor with normal neonatal outcomes. Obstet Gynecol 2010; 116:1281–7.
21. Caughey AB. Nonmedically indicated induction of labor: are the benefits worth the costs? Am J Obstet Gynecol 2015;212: 7–8.
22. Laughon SK, Zhang J, Grewal J, Sundaram R, Beaver J, Reddy UM. Induction of labor in a contemporary obstetric cohort. Am J Obstet Gynecol 2012;206:486.e1–9.
23. Glantz JC. Term labor induction compared with expectant management. Obstet Gynecol 2010;115:70–6.
24. Grobman WA, Lai Y, Landon MB, Spong CY, Leveno KJ, Rouse DJ, et al. Development of a nomogram for prediction of vaginal birth after cesarean delivery. Obstet Gynecol 2007; 109:806–12.
25. Sims EJ, Newman RB, Hulsey TC. Vaginal birth after cesarean: to induce or not to induce. Am J Obstet Gynecol 2001;184: 1122–4.
26. Consortium on Safe Labor, Hibbard JU, Wilkins I, Sun L, Gregory K, Haberman S, et al. Respiratory morbidity in late preterm births. JAMA 2010;304:419–25.
27. Nonmedically indicated early-term deliveries. Committee Opinion No. 561. American College of Obstetricians and Gynecologists. Obstet Gynecol 2013;121:911–5.