Labor Induction and the Risk of a Cesarean Delivery Among Nulliparous Women at Term

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OBJECTIVE: To estimate the association of labor induction with the risk of a cesarean delivery for nulliparous women presenting at term at a regional hospital.

METHODS: This was a retrospective cohort study of cesarean delivery among nulliparous women delivering a live, singleton, vertex pregnancy at term. We used clinical data from electronic hospital obstetric records at a large, regional, obstetric hospital, approximating a population-based cohort. Multivariable logistic regression was used to explore risk factors associated with cesarean delivery, and the fraction of cesarean deliveries attributable to the use of labor induction was estimated.

RESULTS: From a cohort of 24,679 women, 7,804 met inclusion criteria. Labor induction was used in 43.6% of cases, 39.9% of which were elective. Use of labor induction was associated with an increased odds of cesarean delivery (crude odds ratio 2.67, 2.40–2.96) and the association remained significant (adjusted odds ratio 1.93, 1.71–2.2) after adjustment for maternal demographic characteristics, medical risk, and pregnancy complications. The contribution of labor induction to cesarean delivery in this cohort was estimated to be approximately 20%.

CONCLUSION: Labor induction is significantly associated with a cesarean delivery among nulliparous women at term for those with and without medical or obstetric complications. Reducing the use of elective labor induction may lead to decreased rates of cesarean delivery for a population.

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See related editorial on page 4.

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The percentage of neonates born by cesarean delivery has increased steadily over the past decade in the United States, reaching 31.8% in the provisional birth data for 2007.[1] Cesarean delivery rates have risen in all age, racial, and ethnic groups. Many factors have contributed to this trend, including the adoption of evidence-based recommendations encouraging cesarean delivery for a breech presentation and concerns over the safety of a trial of labor for women with a previous cesarean delivery.[2] The increasing use of labor induction and the greater burden of chronic health risks, such as obesity, diabetes, and hypertension, among women of childbearing age may also play a role.[3–6] Studies analyzing birth certificate data could not attribute the rise in primary cesarean delivery to increases in maternal health risks.[7,8]

Although cesarean delivery has led to improvements in outcomes for women and neonates with medical indications, the potential benefits must be weighed against the health risks to the mother in their absence. These include higher rates of hysterectomy, postpartum hemorrhage, venous thromboembolism, wound complications, and hospital readmission.[9,10]

The purpose of this study was to estimate the association of labor induction with the risk of a caesarean delivery for nulliparous women presenting at term at a regional hospital. The study of a large community population, using clinical data derived from electronic obstetric records for maternal health risks and the use of labor induction, will contribute to our understanding of the forces driving cesarean delivery and suggest avenues for intervention.

MATERIALS AND METHODS

We conducted a retrospective cohort study of nulliparous women delivering a live, singleton, vertex pregnancy at term (the nulliparous term singleton vertex cohort) between May 2003 and December 2006 using clinical data derived from the electronic hospital obstetric records of a large regional obstetric hospital. Clinical data provide more reliable information about maternal health risks, pregnancy complications, and obstetric care than administrative databases and vital registries.[11,12] Although this is a single-institution study, the hospital provides obstetric care to more than 7,000 women each year, representing approximately 85% of women in the surrounding region. The patient population reflects the variability in race and ethnicity as well as socioeconomic diversity seen in the United States overall and, in turn, represents well the target population of U.S. births, particularly in the Eastern United States. For this reason, the patients studied approximate a population-based cohort.

The obstetric staff includes both staff and community providers, adding to the generalizability of study findings. This institution has relatively high rates of induction, and during the years for which these data are derived, there were no institutional guidelines or an institutional culture discouraging its use. More recently the institution has begun an initiative to eliminate elective induction before 39 weeks.

All data were derived from electronic hospital clinical records, which were recorded through direct entry by trained hospital nursing staff during the hospitalization for obstetric delivery. They include clinical information on the course of labor and delivery as well as pregnancy outcomes. Comorbidities and pregnancy complications were identified by the personal obstetrician of record. Ongoing internal quality monitoring occurs on a daily basis for both incomplete data and mistakes in data entry using an established algorithm. Historical validation to the paper electronic medical record demonstrated 97% concordance.

The dependent variable was method of delivery, vaginal compared with cesarean delivery, and was obtained from the clinical record. The main exposure of interest was the use of labor induction, which was identified by nurses through review of the obstetric record and dichotomized as spontaneous or induced labor in the warehouse data. Therefore, the use of induction was carefully classified and does not represent cases of labor augmentation. Indication for labor induction is noted in the patient record as a maternal indication, a fetal indication, fetal macrosomia, postterm pregnancy less than 41 weeks of completed gestation, postterm pregnancy greater than 41 weeks of completed gestation, or an elective indication. Women whose reason for induction was listed as postterm less than 41 weeks were classified as an elective induction. Bishop score is not recorded in these obstetric records. However, at this institution all women with a Bishop score less than 6 undergo preinduction cervical ripening with a Foley bulb; it was used as a surrogate measure indicating an unfavorable cervix.

Other exposures included pregnancy weight gain, neonatal birth weight, the presence of chronic hypertension, or pregnancy complications including gestational diabetes and pregnancy-induced hypertension. Prepregnancy body mass index (BMI) was derived from prepregnancy weight, which was self-reported and recorded in the medical record by the admitting nurse; height was either measured or self-reported. Performance improvement analyses at the study institution of the medical records database have shown a high degree of reliability of self-reported heights, as has been shown in other published studies. Body mass index was calculated as weight (kg)/height $(m)^2$, with obesity defined by National Heart, Lung and Blood Institute standard BMI categories: below average (less than 18.5), normal weight (18.5–24.9), overweight (25–29.9), obese (30–39.9), and extremely obese (40+).[13] Underweight was the reference category in the multivariable analysis.

Obstetric provider included two categories: "service," which refers to patients cared for by the teaching faculty at the institution, and "private," referring to patients cared for by independent community obstetricians. The source of insurance information was the hospital registration system; this variable was dichotomized as private insurance compared with no private insurance, where no private insurance is a combination of Medicaid and uninsured. Advanced maternal age is defined as 35 years or older, and teen as younger than 20 years of age. Race and ethnicity are self-identified by the patient, and the categories used by the institution are white, black, Hispanic, Asian, American Indian, and other. "Other than black race" was used as the reference category. Parity was defined as a dichotomous variable as nulliparous compared with multiparous. A diagnosis of pregestational diabetes represents a combination of type 1 and type 2 diabetes mellitus. Tobacco use was measured by self-reported smoking during pregnancy and was dichotomized as smoker compared with nonsmoker.

Gestational age was recorded at the time of delivery as completed weeks of gestation based on antenatal dating most often by a combination of last menstrual period validated by first-trimester ultrasonogram; birth weight was measured in grams. Gestational age of at least 37 completed weeks was categorized as term, and women delivered at 41 weeks or more were categorized as postterm. Birth weight was a categorical variable less than 4,000 g compared with 4,000 g or more.

Summary statistics and cross-tabulation of the data were used to describe the cohort. Pearson's χ^2 test was used to test associations between the exposure variables and cesarean delivery. Multiple logistic regression models were estimated to adjust for multiple factors for the entire sample and for restricted subgroups. Statistical tests of interaction of risk factors with labor induction were conducted through the use of interaction terms with a $P<.05$ considered to be significant. Exposures that had a significant interaction were further analyzed through stratification.

An analysis restricted to women without diabetes, hypertension, obesity, or birth weight 4,000 g or greater up to 41 weeks' gestational age, was completed in an attempt to examine the low-risk women and to eliminate potential residual confounding by indication associated with the use of labor induction. Women with a prepregnancy BMI in the obese range and neonates with a birth weight greater than 4,000 g were excluded from this subgroup because they are known to have higher rates of labor dystocia and are more likely to undergo cesarean delivery independent of the use of labor induction.

The contribution of labor induction to cesarean delivery was estimated by calculating the population attributable fraction in two ways. The first used the unadjusted relative risk (RR) for cesarean delivery associated with labor induction among low-risk women. This was used because the main confounders in the association between labor induction and cesarean delivery were maternal medical risks and complications. The second used an adjusted RR derived from the adjusted odds ratio (OR) from the multivariable logistic regression for the entire cohort by converting the adjusted OR to a RR using the formula $RR=OR/[(1-p)+(OR\times p)]$, where p is the incidence in unexposed population as has been previously described.[14] Each population attributable fraction (PAF) was then calculated using Levin's formula: $PAF=[Pe(RR-1)]/[1+Pe(RR-1]$, where Pe is the prevalence of the risk factor in the population.[15] Before the initiation of the study, approval was obtained from the Christiana Care Institutional Review Board. Analysis was performed using SPSS 16 software (SPSS Inc., Chicago, IL) and SAS 9.1 software (SAS Institute Inc., Cary, NC).

RESULTS

We identified 24,679 women who delivered a live neonate; 70 women were excluded because 60 neonates had birth weight less than 350 g, seven neonates had birth weight that fell outside the standard range, and three women had missing data on method of delivery.[16] Among these, 10,355 women were nulliparous; 600 had a multiple-gestation pregnancy, 1,092 had gestational age less than 37 or more than 42 weeks, 349 had breech presentation, and 510 had missing data for labor induction. As a result, the sample for analysis included 7,804 nulliparous women with singleton vertex birth and gestation between 37 and 42 weeks, meeting the criteria for inclusion in the cohort.

Table 1 shows the characteristics of the study sample and the percentage undergoing labor induction or cesarean delivery for each. Indications for labor induction as identified by the medical provider were fetal indications in 13.6% of cases, fetal macrosomia in 3.3%, maternal indications in 24.9%, postterm pregnancy less than 41 weeks of completed gestational age in 14.3%, postterm pregnancy 41 or more weeks of gestational age in 18.3%, and 25.6% elective. The overall percentage of elective inductions, if postterm inductions less than 41 weeks were included, was 39.9%. Among women undergoing labor induction, 40.7% underwent preinduction cervical ripening indicating a Bishop Score less than 6; among women with an elective indication, the proportion was 37%. Indications for cesarean delivery were labor dystocia in 75.1% of cases, fetal distress in 28.2%, maternal medical indications in 1.6%, and "other" indications in 2.9%. This sums to more than 100% because more than one indication could be chosen; for example, 8.5% of women indicated both labor dystocia and fetal distress. Labor dystocia was significantly more common among women undergoing labor induction (79.0% compared with 68.9%, $P<.001$).

The association of each exposure variable with odds of a cesarean delivery is shown in Table 2. The use of labor induction was associated with a more than twofold increase in the odds of cesarean delivery. Other factors associated with greater odds of cesarean delivery included sociodemographic characteristics including black race, marital status, patient type, insurance type, and age older than 35 years; prepregnancy health risks including diabetes, chronic hypertension, and prepregnancy obesity; and pregnancy complications including gestational diabetes,

Table 1. Characteristics of the Study Cohort, Percentage of Deliveries Induced, and Percentage of Cesarean Delivery

Characteristics	Total Sample	Labor Induction	Cesarean Delivery
Sociodemographic characteristics			
Patient type			
Private patient	6,322 (81.0)	44.4	26.0
Service patient	1,482 (19.0)	40.4	23.5
Insurance type			
Medicaid or uninsured	2,311 (29.6)	38.6	22.2
Private insurance	5,490 (70.4)	45.7	26.9
Marital status			
Unmarried	3,52 (39.1)	40.3	22.9
Married	4,752 (60.9)	45.7	27.2
Race/ethnicity			
Other race/ethnicity	6,173 (79.7)	44.4	24.8
Black race	1,569 (20.2)	40.7	28.4
Age group (y)			
Younger than 20	1,296 (16.6)	36.4	17.8
20–34	5,842 (74.9)	44.1	25.7
35 or older	666 (8.5)	53.5	38.7
Prepregnancy risk factors			
Diabetes			
No prepregnancy diabetes	7,759 (99.4)	43.4	25.4
Prepregnancy diabetes	45 (0.6)	80.0	37.8
Hypertension			
No chronic hypertension	7,667 (98.2)	43.0	25.3
Chronic hypertension	137 (1.8)	75.9	40.2
BMI (kg/m^2)			
Less than 18.5	357 (4.6)	31.1	14.0
18.5–24.9	4,435 (56.8)	39.1	20.4
25–29.9	1,767 (22.6)	47.7	28.7
30–39.9	1,055 (13.5)	56.6	41.2
40 or above	190 (2.4)	63.7	50.5
Pregnancy complications			
Weight gain			
Less than 18.14 kg (40 lb)	4,939 (63.3)	40.8	23.2
18.14 kg (40 lb) or more	2,865 (36.7)	48.4	29.4
Gestational diabetes			
No gestational diabetes	7,392 (94.7)	42.6	24.9
Gestational diabetes	412 (5.3)	61.7	37.1
Gestational hypertension			
No gestational hypertension	7,118 (91.2)	39.4	24.2
Gestational hypertension	686 (8.8)	87.8	38.8
Birth weight			
Less than 4,000 g	7,137 (91.4)	42.2	23.5
4,000 g or more	667 (8.6)	58.6	47.1
Gestational age (wk)			
37	611 (7.8)	42.7	20.0
38	1,379 (17.7)	38.1	20.7
39	2,281 (29.2)	35.4	22.5
40	2,513 (32.2)	42.3	26.9
41 or more	1,020 (13.1)	73.3	38.5
Labor type			
Not induced	4,400 (56.4)	—	—
Induced	3,404 (43.6)		
Delivery method			
Vaginal	5,813 (74.5)	—	—
Cesarean	1,991 (25.5)		

BMI, body mass index.
Data are n (%) or %.
A dash indicates not determined.

Table 2. Association of Risk Factors With Odds of Cesarean Delivery for the Entire Cohort

Factor	Crude		Multivariable	
	OR	95% CI	Adjusted OR	95% CI
Sociodemographic characteristics				
Patient type				
Private	1.00	Referent	1.00	Referent
Service	0.87*	0.77–1.00	0.95	0.81–1.12
Insurance type				
Medicaid or uninsured	1.00	Referent	1.00	Referent
Private	1.28†	1.15–1.44	1.05	0.89–1.23
Marital status				
Unmarried	1.00	Referent	1.00	Referent
Married	1.25†	1.13–1.39	1.14	0.99–1.33
Race/ethnicity				
Other	1.00	Referent	1.00	Referent
Black	1.21‡	1.07–1.37	1.41†	1.22–1.64
Age group (y)				
Younger than 35	1.00	Referent	1.00	Referent
35 or older	1.97†	1.67–2.33	1.71†	1.43–2.05
20 or older	1.00	Referent	1.00	Referent
Younger than 20	0.58†	0.50–0.68	0.71†	0.59–0.85
Prepregnancy risk factors				
Diabetes				
None	1.00	Referent	1.00	Referent
Prepregnancy diabetes	1.78	0.97–3.26	0.91	0.478–1.72
Hypertension				
None	1.00	Referent	1.00	Referent
Chronic hypertension	1.99†	1.41–2.81	0.99	0.68–1.43
BMI (kg/m²)				
Less than 18.5	1.0	Referent	1.0	Referent
18.5–24.9	1.56‡	1.15–2.12	1.36	0.99–1.87
25–29.9	2.48†	1.81–3.40	1.96†	1.41–2.71
30–39.9	4.31†	3.12–5.95	3.24†	2.32–4.53
40 or above	6.27†	4.15–9.97	4.51†	2.92–6.96
Pregnancy complications				
Weight gain				
Less than 18.14 kg (40 lb)	1.00	Referent	1.00	Referent
18.14 kg (40 lb) or more	1.38†	1.24–1.53	1.37†	1.29–1.53
Gestational diabetes				
None	1.00	Referent	1.00	Referent
Gestational diabetes	1.79†	1.45–2.19	1.38‡	1.10–1.72
Gestational hypertension				
None	1.00	Referent	1.00	Referent
Gestational hypertension	1.98†	1.68–2.33	1.38†	1.15–1.66
Birth weight				
Less than 4,000 g	1.00	Referent	1.00	Referent
4,000 g or more	2.89†	2.46–3.40	2.28†	1.91–2.72
Gestational age				
37–40 wk	1.00	Referent	1.00	Referent
41 wk or more	2.03†	1.77–2.34	1.58†	1.35–1.85
Labor type				
Spontaneous labor	1.00	Referent	1.00	Referent
Induced labor	2.67†	2.40–2.96	1.93†	1.71–2.17

OR, odds ratio; CI, confidence interval; BMI, body mass index.
* *P*<.05.
† *P*<.001.
‡ *P*<.01.

gestational hypertension, weight gain more than 18.14 kg (40 lb), gestational age of 41 weeks or more, and birth weight of 4,000 g or more. Tobacco use was not significantly associated with cesarean delivery and was not included in further analyses.

Table 2 shows the results of the multivariable logistic regression. The odds of cesarean delivery associated with the use of labor induction was only somewhat attenuated after adjustment for confounders (adjusted OR 1.93, 1.75–2.2). Black race, maternal age 35 and older, gestational age of 41 weeks or more, prepregnancy overweight and obesity, the presence of gestational diabetes, gestational hypertension, excess weight gain, and labor induction were all significantly associated with an increased odds of cesarean delivery. Patient provider type, insurance, and marital status, however, were not independently associated with cesarean delivery in this multivariable model, nor were prepregnancy diabetes, chronic hypertension, or a BMI in the normal range.

Hierarchical models, adjusting first for sociodemographic factors, then for medical risks, and finally for pregnancy complications, indicated that little confounding was related to sociodemographic factors, and the majority of confounding associated with labor induction was due to medical risks and pregnancy complications (data not shown but available on request).

The analysis restricted to the 4,623 women (59% of the nulliparous term singleton vertex cohort) without maternal comorbidities or pregnancy complications and who delivered at up to 41 weeks of gestational age is shown in Table 3. Labor induction in this group was used in 29.2% of cases, and 17.1% underwent a cesarean delivery. The cesarean delivery percentage was 25.5% for women who were induced and 13.6% for those not induced, giving an unadjusted RR of 1.87 (1.65–2.12). Within this low-risk cohort, the risk of cesarean delivery for women with indicated inductions was RR 1.92 (1.61–2.29) and elective inductions was RR 1.84 (1.59–2.12) when compared with women with spontaneous labor. The odds of cesarean delivery associated with induction for this low-risk group were estimated using logistic regres-

Table 3. Association of Labor Induction With Odds of Cesarean Delivery Among 4,623 Women Without Medical Risks, Pregnancy Complications, or a Birth Weight 4,000 g or More Delivering at 37 to 41 Weeks Gestational Age

	Crude		Multivariable	
Factors	OR	95% CI	Adjusted OR	95% CI
Sociodemographic characteristics				
Patient type				
Private	1.00	Referent	1.00	Referent
Service	0.85	0.70–1.03	1.10	0.86–1.39
Insurance type				
Medicaid or uninsured	1.00	Referent	1.00	Referent
Private	1.49*	1.27–1.76	1.18	0.94–1.49
Marital status				
Unmarried	1.00	Referent	1.00	Referent
Married	1.46*	1.26–1.69	1.22	0.99–1.51
Race/ethnicity				
Other	1.00	Referent	1.00	Referent
Black	0.98	0.82–1.17	1.35*	1.09–1.68
Age group (y)				
Younger than 35	1.00	Referent	1.00	Referent
35 or older	2.47*	1.98–3.08	1.83*	1.41–2.36
20 or older	1.00	Referent	1.00	Referent
Younger than 20	0.55*	0.44–0.67	0.74†	0.57–0.96
Pregnancy weight gain				
Less than 18.14 kg (40 lb)	1.00	Referent	1.00	Referent
18.14 kg (40 lb) or more	1.25‡	1.08–1.44	1.28‡	1.09–1.50
Labor type				
Spontaneous labor	1.00	Referent	1.00	Referent
Induced labor	2.17*	1.86–2.55	2.03*	1.73–2.38

OR, odds ratio; CI, confidence interval.
* *P*<.001.
† *P*<.05.
‡ *P*<.01.

sion, and after adjustment for the other risk factors, was adjusted OR 2.03 (1.7–2.4). Black race, maternal age 35 years and older, and weight gain of 18.14 kg (40 lb) or more remained significant risk factors for cesarean delivery in this group after adjustment; maternal age younger than 20 years was protective.

The population attributable fraction for low-risk women, for whom the rate of induction was 29.2% and the RR was 1.87, is 20.3%. The adjusted OR from the multivariable logistic regression for the entire cohort was 2.03 (1.73–2.38), converted to RR 1.72 (1.54–1.92). Using an induction rate of 43.6%, this resulted in a population attributable fraction of 23.6%. Using these two approaches and given the tendency for population attributable fraction to overestimate contribution to outcomes, we estimate the population attributable fraction to fall at approximately 20%. This suggests that 20% of cesarean deliveries among the low-risk women as well as all women in the nulliparous term singleton vertex cohort could be attributed to the use of labor induction.

DISCUSSION

We studied cesarean delivery for a cohort of nearly 8,000 nulliparous women presenting with a vertex singleton pregnancy at term using data derived from hospital obstetric records. Women in the cohort represented 85% of the births in the region and received obstetric care provided by a mix of both hospital staff and community providers. Consistent with earlier studies, the odds of a cesarean delivery was influenced by obstetric management, sociodemographic factors, maternal comorbidities, pregnancy complications, and neonatal factors.[6,17–21] The risk factors with the greatest contribution to cesarean delivery in this population, based on the strength of their association and their prevalence, were the use of labor induction and the presence of maternal prepregnancy obesity. Neither of these factors is reliably reported in vital statistics data and neither has been included in explorations of temporal changes in cesarean delivery.[7]

Labor induction was associated with a twofold increase in the odds of a cesarean delivery after adjustment for confounders. The effect was somewhat larger among a low-risk group of women without major complications that might lead to the indication for labor induction or cesarean delivery. The population attributable fraction reflecting the contribution of labor induction to the rate of cesarean delivery in this population was estimated to be 20%. We also found that the obesity-related risk remained independently associated with odds of cesarean delivery after adjusting for maternal demographic factors as well as obesity-related complications including gestational diabetes, gestational hypertension, excess maternal weight gain, or neonatal birth weight of 4,000 g or more. The odds of cesarean delivery increased with increasing maternal BMI in the overweight range and continued to rise with each BMI category.

The findings of increased risk related to labor induction are consistent with those from other studies and consistent with findings that labor progression for electively induced labors differs from spontaneous labors, and women with an unfavorable cervix receiving preinduction cervical ripening are those at greatest risk.[18] Multiple studies have found labor induction to be associated with an increased risk among nulliparous, and to a lesser extent multiparous, women.[5,6,19,20,22] One small study suggested that labor induction may not be associated with an increased risk for women without an indication for induction.[21]

Several prospective studies have shown that induction of women at gestational age of 41 weeks or more decreases the risk of cesarean delivery, and there is promising evidence that labor induction, when used discriminately by protocol, may reduce the odds of a cesarean delivery.[23,24] The results of these interventions are not inconsistent with our findings. By using labor induction based on an algorithm accounting for individual risk factors for cephalopelvic disproportion and uteropelvic insufficiency, these interventions may serve to avoid failure of labor induction in the population of women who our results show to be at greatest risk: women with prepregnancy obesity, gestational diabetes, excess weight gain, and a macrosomic neonate, as well as women with gestational hypertension.

The major strengths of this study include the large and diverse population and the use of clinical data with reliable capture of maternal health risks and pregnancy complications. Moreover, the use of labor induction was more common than in earlier studies and applied to a large number of low-risk women, providing the power to make meaningful estimates of risk in that population. Finally, the study of outcomes for women cared for in a community setting by multiple providers adds to the potential generalizability of our findings.

As with all retrospective analyses, this study is limited in its ability to conclusively measure the effect of an intervention when it is applied in a nonrandom fashion, and it may be limited in generalizability because it includes women in a single center. In addition, the use of population attributable fraction has been known to overestimate the contribution of a risk to outcomes. Moreover, these findings may have limited applicability to multiparous women.

This study has taken a unique population-based approach to explore the effect of labor induction on outcomes at an institution with frequent use of elective labor induction. Using clinical data, we explored the association between induction and cesarean delivery in the context of maternal medical risks and pregnancy complications, and used these measures to estimate the potential effect of induction on cesarean delivery rates. Our findings demonstrate that nulliparous women, with and without medical risks or pregnancy complications, who deliver after labor induction have a twofold increase in the odds of a cesarean delivery. Our findings also suggest that a portion of the rise in rates of cesarean delivery among women without medical indication may be the result of the increasing use of elective labor induction in addition to a growing prevalence of obesity in the U.S. population. This study has important implications for providers and their patients and emphasizes the need for women to be counseled about the potential risk of cesarean delivery associated with labor induction. It also predicts that efforts to reduce the use of elective labor induction might lead to a 20% decrease in the rates of cesarean delivery for a community-based population of nulliparous women.

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