OBSTETRICS

A validated calculator to estimate risk of cesarean after an induction of labor with an unfavorable cervix

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BACKGROUND: Induction of labor occurs in >20% of pregnancies, which equates to approximately 1 million women undergoing an induction in the United States annually. Regardless of how common inductions are, our ability to predict induction success is limited. Although multiple risk factors for a failed induction have been identified, risk factors alone are not enough to quantify an actual risk of cesarean for an individual woman undergoing a cesarean.

OBJECTIVE: The objective of this study was to derive and validate a prediction model for cesarean after induction with an unfavorable cervix and to create a Web-based calculator to assist in patient counseling.

STUDY DESIGN: Derivation and validation of a prediction model for cesarean delivery after induction was performed as part of a planned secondary analysis of a large randomized trial. A predictive model for cesarean delivery was derived using multivariable logistic regression from a large randomized trial on induction methods (n = 491) that took place from 2013 through 2015 at an academic institution. Full-term (≥37 weeks) women carrying a singleton gestation with intact membranes and an unfavorable cervix (Bishop score ≤6 and dilation ≤2 cm) undergoing an induction were included in this trial. Both nulliparous and multiparous women were included. Women with a prior cesarean were excluded. Refinement of the prediction model was performed using an observational cohort of women from the same institution who underwent an induction (n = 364) during the trial period. An external validation was performed utilizing a publicly available database (Consortium for Safe Labor) that includes information for >200,000 deliveries from 19 hospitals across the United States from 2002 through 2008. After applying the same inclusion and exclusion criteria utilized in the derivation cohort, a total of 8466 women remained for analysis. The discriminative power of each model was assessed using a bootstrap, bias-corrected area under the curve.

RESULTS: The cesarean delivery rates in the derivation and external validation groups were: 27.7% (n = 136/491) and 26.4% (n = 2235/8466). In multivariable modeling, nulliparity, gestation age ≥40 weeks, body mass index at delivery, modified Bishop score, and height were significantly associated with cesarean. A nomogram and calculator were created and found to have an area under the curve in the external validation cohort of 0.73 (95% confidence interval, 0.72–0.74).

CONCLUSION: A nomogram and user-friendly Web-based calculator that incorporates 5 variables known at the start of induction has been developed and validated. It can be found at: http://www.uphs.upenn.edu/obgyn/labor-induction-calculator/. This calculator can be used to augment patient counseling for women undergoing an induction with an unfavorable cervix.

Key words: Bishop score, calculator, cesarean, failed induction, induction of labor, unfavorable cervix

Introduction

In 2012, 23% of pregnant women (almost 1 million women) underwent an induction of labor.[1] While it is one of the most common obstetrical procedures, our ability to predict success of induction is limited, despite the fact that approximately one third of inductions will end in a cesarean delivery.[2-5]

Although multiple risk factors for a failed induction have been identified,[2-8] risk factors alone are not enough to quantify an actual risk of cesarean for an individual woman undergoing a cesarean. Prediction models for induction success have been limited to nulliparous women and have generally found a favorable starting cervical exam to be the largest driver of success.[3-5,9,10] Prediction of delivery outcomes for both nulliparous and multiparous women who are starting their induction with an unfavorable cervical exam (Bishop score ≤6) remains understudied. With the known associated risks of prolonged labor and failed induction,[11-13] it is clinically useful to be able to accurately predict the likelihood of cesarean after an induction of labor.

Therefore, our objective was to develop and validate a prediction model of cesarean delivery for both nulliparous and multiparous women undergoing an induction of labor with an unfavorable cervix. The goal of this model was to create a calculator that could be used to supplement counseling for women undergoing an induction with an unfavorable cervix.

Materials and Methods

The current study was a derivation and validation of a prediction model for cesarean delivery after induction of labor. This study was a planned secondary analysis of a large randomized trial (Foley or Misoprostol for the Management of Induction [FOR MOMI])[14] that compared time to delivery among 4 induction methods (misoprostol alone, cervical Foley alone, misoprostol/cervical Foley concurrently, cervical Foley/oxytocin concurrently). The randomized trial was conducted from May 2013 through June 2015 at the Hospital of the University of Pennsylvania. The study was approved by the institutional review board at the

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TABLE 1
Characteristics of women from derivation group by mode of delivery

Characteristic	Vaginal delivery	Cesarean delivery	*P* value[a]
Maternal age, y[b]	28 (22–32)	25 (22–32)	.26
Height, in			
<62	44 (12.4)	23 (16.9)	.05
62–63.9	68 (19.2)	38 (27.9)	
64–65.9	108 (30.5)	31 (22.8)	
≥66	134 (37.8)	44 (32.3)	
BMI at delivery, kg/m^2			
<25.0, normal weight	23 (6.9)	6 (4.7)	.005
25.0–29.9, overweight	97 (29.3)	26 (20.5)	
30.0–34.9, obese class 1	87 (26.3)	23 (18.1)	
35.0–39.9, obese class 2	63 (19.0)	42 (33.1)	
≥40.0, obese class 3	61 (18.4)	30 (23.6)	
Race			
White	50 (14.1)	26 (19.1)	.18
Black	283 (79.7)	98 (72.1)	
Other	22 (6.2)	12 (8.8)	
Nulliparity	174 (49.0)	116 (85.3)	<.001
Gestational age at delivery			
37 wk 0 d–37 wk 6 d	83 (23.4)	22 (16.2)	<.001
38 wk 0 d–38 wk 6 d	64 (18.0)	13 (9.6)	
39 wk 0 d–39 wk 6 d	98 (27.6)	24 (17.6)	
40 wk 0 d–40 wk 6 d	71 (20)	34 (25)	
≥41 wk	39 (11)	43 (31.6)	
Indication for induction			
Postdate	26 (7.3)	38 (27.9)	<.001
Maternal[c]	114 (32.1)	34 (25)	
Fetal[d]	170 (47.9)	55 (40.4)	
Elective	45 (12.7)	9 (6.6)	
Preexisting or gestational diabetes	28 (7.9)	16 (11.8)	.22
Chronic hypertension	34 (9.6)	6 (4.4)	.07
Hypertensive disease of pregnancy	111 (31.3)	53 (39.0)	.11
Cervical dilation at induction, cm[b]	1 (1–2)	1 (0.5–1.5)	<.001
Effacement at induction, cm[b]	2 (2–3)	2 (2–3)	.45
Station at induction, cm[b]	−3 (−3 to −3)	−3 (−3 to −3)	.44
Modified Bishop score at induction[b]	3 (2–4)	2 (2–3)	.006

Levine et al. Risk calculator for cesarean after induction. Am J Obstet Gynecol 2017. *(continued)*

University of Pennsylvania. Women with a prior cesarean and contraindication to misoprostol or a vaginal delivery were excluded from the study.[14] Both nulliparous and multiparous women were included. Full-term (≥37 weeks) women carrying a singleton gestation with intact membranes and an unfavorable cervix (Bishop score ≤6 and dilation ≤2 cm) undergoing an induction of labor were included. The components of the modified Bishop score were cervical dilation, station, and effacement.[15-17] Full details regarding the induction and labor protocols utilized for the trial can be found in the original article.[14]

The primary outcome for the prediction model was cesarean delivery for any indication. The proposed guidelines for model building, refinement, and validation for prediction models were utilized.[18] First, a model was derived using data from a large randomized trial (FOR MOMI,[14] n = 491; derivation data set). This data set was chosen for derivation since it was a contemporary data set (performed from 2013 through 2015), had an extensive amount of detailed demographic and clinical data available for evaluation, and was collected prospectively from a randomized trial. Prediction models are created by identifying a set of risk factors/variables that are predictors of the outcome based on multivariable logistic regression modeling. Risk factor selection used stepwise methods considering all variables with at least 5% prevalence and an association with the outcome (cesarean) of $P < .20$ from bivariate tests. Continuous variables were assessed for linearity prior to being entered into models. The following variables were considered for predictive modeling: maternal age, maternal height, maternal weight change over pregnancy, maternal weight change rate, body mass index (BMI) at first prenatal visit, BMI at last prenatal visit, change in BMI over pregnancy, BMI change rate, race, parity, gestational age in weeks at time of induction, postdate gestational age, indication for induction, pregestational diabetes, chronic hypertension, presence of oligohydramnios, cervical dilation, station, Bishop score at start of induction, and method of induction. BMI at delivery was defined as the BMI at the time of delivery or at the most recent prenatal visit if delivery BMI was unavailable (for 98% of women, this was within 1.5 weeks of delivery). Neonatal sex and postnatal weight were also related to delivery outcome, but since they are not always routinely established prior to the start of the induction, they were not included in our