OBSTETRICS

The transition from latent to active labor and adverse obstetrical outcomes

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BACKGROUND: Recommendations on preventing primary cesarean delivery removed the previously defined time limits for latent labor (defined as ending at 6 cm) and urged clinicians to avoid cesarean delivery for labor abnormalities in the latent phase. However, relatively little is known about the implications of labor curve abnormalities from 4 to 6 cm and subsequent outcomes.

OBJECTIVE: To examine the association between length of time for dilation from 4 to 6 cm, delivery outcomes, and maternal and neonatal morbidity.

STUDY DESIGN: This is a secondary analysis of a prospective cohort study of patients at ≥37 weeks presenting in spontaneous or induced labor with a nonanomalous living singleton in vertex presentation. Patients with a history of cesarean delivery or who did not achieve 6-cm dilation were excluded. We used interval censored regression to determine the 90th percentile for dilation time from 4 to 6 cm and used logistic regression to estimate the odds ratios and 95% confidence intervals for adverse outcomes for patients above this cutoff percentile compared with those at or below. Analyses were adjusted for obesity, nulliparity, race, hypertension, diabetes, and type of labor (induced vs spontaneous/augmented). Outcomes included cesarean delivery, maternal morbidity (composite of postpartum fever, wound infection, hemorrhage), and neonatal morbidity (composite of neonatal death, hypothermic therapy, mechanical ventilation, respiratory distress, meconium aspiration syndrome, seizure, or treatment of sepsis). In addition, we created receiver operator characteristic curves to predict cesarean delivery, and maternal and neonatal morbidity based on time to dilate from 4 to 6 cm. The cutoff for time for each outcome was identified using the Youden index to maximize sensitivity and specificity, and test characteristics were computed.

RESULTS: There were 7355 patients eligible for analysis, 728 (10%) had dilation times from 4 to 6 cm >10.3 hours, which was the 90th percentile, and 6627 (90%) had dilation times ≤10.3 hours. Having dilation time from 4 to 6 cm above the 90th percentile (10.3 hours) was associated with cesarean delivery (adjusted odds ratio, 2.05; 95% confidence interval, 1.67—2.52), composite maternal morbidity (adjusted odds ratio, 1.48; 95% confidence interval, 1.10—2.00), and composite neonatal morbidity (adjusted odds ratio 1.92; 95% confidence interval 1.52—2.4). The area under the receiver operator characteristic curve for predicting cesarean delivery was 0.73 (95% confidence interval, 0.71—0.75). The test characteristics for the cutoff of 9.75 hours were sensitivity 68.3% (95% confidence interval, 64.8%—71.7%), specificity 66.2% (95% confidence interval, 55.0%—67.3%), positive predictive value 18.5% (95% confidence interval, 17.1%—20.0%), and negative predictive value 94.9% (95% confidence interval, 94.2%—95.5%). For composite maternal morbidity, the cutoff was 6.98 hours and the area under the curve was 0.62 (95% confidence interval, 0.59—0.65), whereas for composite neonatal morbidity it was 5.5 hours (area under the curve 0.69; 95% confidence interval, 0.67—0.71).

CONCLUSIONS: Patients whose dilation time from 4 to 6 cm exceeds the 90th percentile have increased odds of cesarean delivery and postpartum complications. Prolonged dilation time has moderate predictive ability for adverse outcomes. Future studies should investigate at what point, if any, intervention is warranted during this period to reduce these risks.

Recommendations on preventing primary cesarean delivery removed the previously defined time limits for latent labor and urged clinicians to avoid cesarean delivery for labor abnormalities in the latent phase.[1] However, these recommendations have met with much controversy, in particular the redefinition of the active phase as starting at 6 cm instead of 4 cm as in previous guidlines.[1-6] We recently demonstrated that despite changes in labor management in our institution in accordance with the new guidelines, there was no change in the primary cesarean delivery rate, and there was an increase in maternal and neonatal morbidity, although these findings have not been replicated in all studies.[7-9] Although some studies have demonstrated that an increased time of latent labor in both induced and spontaneous labor is associated with worse neonatal and maternal outcomes, less is known specifically about the period of time from 4 to 6 cm.[10-14] A better understanding of normal labor progress and consequences of abnormal progress during this time period is essential for determining the risks and benefits of the new labor guidelines. Therefore, as a next step in understanding differences between previous and current guidelines, the objectives of this study were to examine the associations between length of time to dilate from 4 to 6 cm and delivery outcomes and maternal and neonatal morbidity.

Materials and Methods

This is a secondary analysis of a prospective cohort study of all patients at ≥37 weeks presenting for delivery from 2010 to 2015, either by spontaneous or induced labor, with a nonanomalous living singleton in vertex presentation.[15] The objective of the parent study was to determine associations between

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AJOG at a Glance

Why was this study conducted?
Although new labor guidelines redefined the start of active labor as 6 cm, little is known about the time to dilate from 4 cm to 6 cm and pregnancy outcomes.

Key findings
Patients whose dilation time from 4 cm to 6 cm exceeds the 90th percentile have increased risks of cesarean delivery and maternal and neonatal complications. However, the use of dilation time alone poorly predicts these outcomes.

What does this add to what is known?
The time to dilate from 4 cm to 6 cm has implications for delivery outcomes but should not be used in isolation of guide clinical care.

characteristics of electronic fetal monitoring and neonatal acidemia, and the full details of the methods have been published elsewhere.[15] For purposes of this analysis, all patients with a history of previous cesarean delivery or who did not reach 6-cm dilation were excluded. Demographic and clinical data including all cervical examinations during the labor course were extracted from the medical record by trained research personnel. Notably, the intrapartum record contains all medications, labor type (spontaneous, augmented, or induced), every cervical examination as well as time of examination, mode of delivery, and postpartum events and neonatal outcomes. Advanced maternal age was defined as maternal age ≥35 years, and

obesity was defined as body mass index ≥30 kg/m^2.

We analyzed dilation times from 4 to 6 cm using interval censored regression. The upper and lower 1% of dilation times were trimmed and then the 90th percentile cutoff for time for dilation from 4 to 6 cm was determined. Patients whose dilation times fell beyond the upper and lower 1% of dilation times were assigned the upper or lower 1% time, respectively, and included in further analyses. To summarize, a time interval was calculated between each centimeter from 4 to 6 cm cervical dilation, which gives a maximum and minimum possible time at which that next centimeter was reached. Interval-censored regression was used to

estimate median duration of labor from 4 to 6 cm. Because cervical dilation is not continuously measured, labor progression data are interval-censored. The time interval between each consecutive cervical dilation for each person gave an interval-censored value.[16,17] The distribution of the time intervals was right-skewed as a result of long labors, which created a long right tail of the distribution. To account for this, the time intervals were fitted to a log-normal distribution.

Baseline demographic and clinical characteristics were compared between the patients with dilation time from 4 to 6 cm ≤90th percentile with those >90th percentile using the χ^2 test. We then used logistic regression to estimate the adjusted odds ratios (aOR) and 95% confidence intervals (CIs) for adverse outcomes for patients above the 90th percentile compared with those at or below, adjusting for nulliparity, race, obesity, hypertension (both preexisting and pregnancy-related), diabetes (both pregestational and gestational), and type of labor (induced vs spontaneous/augmented). Outcomes included cesarean delivery, cesarean delivery for arrest disorders as reported on the operative record, composite and individual maternal morbidity (postpartum fever, wound infection, postpartum hemorrhage), neonatal intensive care unit admission, and composite neonatal morbidity (neonatal death, hypothermic therapy, mechanical ventilation, respiratory distress, meconium aspiration syndrome, seizure, or treatment of sepsis). Postpartum hemorrhage was defined by clinically estimated blood loss of >500 mL after a vaginal delivery or >1000 mL after cesarean delivery. Postpartum fever was defined as at least one recorded maternal temperature of >100.5°F or >38.1°C. We repeated this analysis stratified by labor type (induced vs spontaneous/augmented) and also by parity (nulliparous vs multiparous).

We conducted 2 sensitivity analyses. First, we repeated the primary analysis including the starting dilation at presentation to labor and delivery in the model. Second, we repeated the primary

FIGURE 1
Study flow diagram
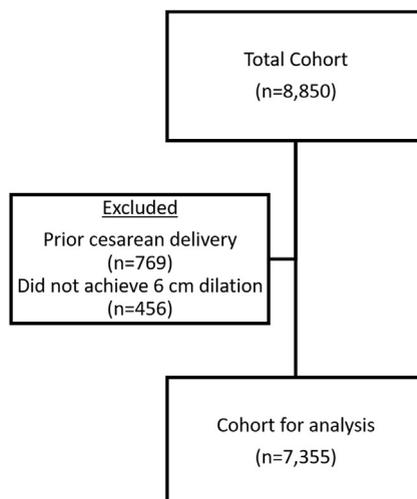
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TABLE 1
Patient characteristics

	>90%ile (10.3 h) (n=728)	≤90%ile (10.3 h) (n=6627)	P value
Maternal age ≥35 y	65 (8.9)	561 (8.5)	.67
Body mass index ≥30 kg/m^2	485 (66.8)	3446 (52.7)	<.01
Race/ethnicity			.04
African-American	487 (66.9)	4253 (64.2)	
White	174 (23.9)	1512 (22.8)	
Latina	38 (5.2)	485 (7.3)	
Other	29 (4.0)	377 (5.7)	
Nulliparity	463 (63.6)	2845 (42.9)	<.01
Hypertension	200 (27.5)	1015 (15.3)	<.01
Diabetes	51 (7.0)	255 (3.9)	<.01
Starting dilation (cm) at admission	2 (1, 3)	3 (2, 5)	<.01
Labor type			<.01
Spontaneous/augmented	193 (26.5)	3944 (59.5)	
Induced	535 (73.5)	2683 (40.5)	
Use of induction agents[a]	695 (95.5)	4400 (66.4)	<.01

Numbers are n (%). *P*-value from χ^2 test.

[a] Use of induction agents: use of oxytocin, prostaglandins, or Foley bulb.

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cesarean delivery, maternal morbidity, and neonatal morbidity, based on time to dilate from 4 cm to 6 cm. The cut point (time) was identified using the Youden index (*J*). Test characteristics including sensitivity, specificity, positive predictive value, and negative predictive value were determined.[18] Notably, the cut point determined by maximizing the Youden index is the point at which sensitivity and specificity are greatest, and both sensitivity and specificity are given equal weight.[19] We calculated the area under the curve (AUC) and 95% CIs for the ROC curves.

Approval for the study was obtained from the Human Research Protection Office at Washington University in St Louis. All tests were 2-sided, and a *P*<.05 was considered significant. No a priori sample size calculation was carried out because all patients from the parent study meeting inclusion criteria were included in the study.

Results

There were 8580 patients in the parent study, of whom 769 were excluded due to a history of cesarean delivery in a previous pregnancy and 456 were excluded due to not achieving 6 cm dilation (Figure 1). Of the patients who did not achieve 6 cm dilation, 189 were delivered at <4 cm and 267 were

analysis excluding patients with cesarean delivery for an arrest disorder as documented in the operative report. This analysis was done to explore whether the relationship between dilation time from

4 to 6 cm and outcomes differed when patients with later abnormal labor were excluded.

Finally, we created receiver operator characteristic curves (ROC) to predict

TABLE 2
Outcomes for patients with time for dilation from 4 to 6 cm at >90th percentile or ≤90th percentile

Outcome	>90%ile (10.3 h) (n=728)	≤90%ile (10.3 h) (n=6627)	P value	OR (95% CI)	aOR[a] (95% CI)
Cesarean delivery	168 (23.08)	573 (8.65)	<.01	3.17 (2.62−3.84)	2.05 (1.67−2.52)
Cesarean delivery for arrest disorder	125 (17.17)	340 (5.32)	<.01	3.83 (3.07−4.78)	2.38 (1.87−3.03)
Composite maternal morbidity[b]	60 (8.24)	313 (4.72)	<.01	1.81 (1.36−2.42)	1.48 (1.10−2.00)
Postpartum fever	41 (5.63)	209 (3.15)	<.01	1.83 (1.30−2.59)	1.44 (1.01−2.07)
Wound infection	2 (0.27)	5 (0.08)	.15	3.65 (0.71−18.84)	5.00 (0.86−29.06)
Postpartum hemorrhage	26 (3.57)	114 (1.72)	<.01	2.12 (1.37−3.26)	1.81 (1.15−2.85)
Transfusion	27 (3.71)	87 (1.31)	<.01	2.90 (1.87−4.49)	2.25 (1.41−3.58)
NICU admission	27 (3.71)	72 (1.09)	<.01	3.51 (2.24−5.50)	2.46 (1.53−3.96)
Composite neonatal morbidity[c]	117 (16.07)	469 (7.08)	<.01	2.52 (2.02−3.13)	1.92 (1.52−2.43)

aOR, adjusted odds ratio; *CI*, confidence interval; *NICU*, neonatal intensive care unit; *OR*, odds ratio.

[a] Adjusted for obesity, labor type, nulliparity, race, hypertension, diabetes; [b] Composite maternal morbidity: postpartum fever, wound infection, postpartum hemorrhage; [c] Composite neonatal morbidity: neonatal death, hypothermic therapy, mechanical ventilation, respiratory distress, meconium aspiration syndrome, seizure, or treatment of sepsis.

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TABLE 3
Indications for cesarean delivery in patients delivered by cesarean delivery at ≥6 cm (n=741)

Indication	N (%)
Arrest disorder	465 (62.8)
Nonreassuring fetal heart tracing	390 (52.6)
Failed operative vaginal delivery	22 (3.0)
Other	91 (12.3)

Patients may have had more than 1 indication for cesarean delivery; therefore, numbers add to more than total number of patients with cesarean delivery and percentages add to more than 100%.

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Characteristics of the participants are shown in Table 1. Patients with longer dilation times were more likely to be obese, nulliparous, and have comorbidities including hypertension and diabetes. Dilation time from 4 to 6 cm >90th percentile was significantly associated with an increased odds of cesarean delivery (aOR, 2.05; 95% CI, 1.67–2.52), cesarean delivery for arrest disorders (aOR, 2.38; 95% CI, 1.87–3.03), maternal morbidity (aOR, 1.48; 95% CI, 1.10–2.00), and neonatal morbidity (aOR, 1.92; 95% CI, 1.52–2.43) (Table 2). Indications for cesarean delivery are in Table 3. The most common indications were arrest disorders and nonreassuring fetal heart tracing.

delivered at 4 or 5 cm. Of the remaining 7355 patients eligible for analysis, 728 (10%) had dilation times from 4 to 6 cm >10.3 hours, which was the 90th percentile, and 6627 (90%) had dilation times ≤10.3 hours.

TABLE 4
Outcomes for patients with time for dilation from 4 to 6 cm at >90th percentile or ≤90th percentile, stratified by labor type

Outcome	>90%ile (10.3 h) (n=193)	≤90%ile (10.3 h) (n=3944)	P value	OR (95% CI)	aOR[a] (95% CI)
Spontaneous/augmented					
Cesarean delivery	31 (16.06)	272 (6.90)	<.01	2.58 (1.73–3.87)	2.01 (1.33–3.05)
Cesarean delivery for arrest disorder	22 (11.40)	157 (3.98)	<.01	3.10 (1.94–4.97)	2.34 (1.43–3.80)
Composite maternal morbidity[b]	13 (6.74)	176 (4.46)	.14	1.55 (0.86–2.77)	1.31 (0.73–2.36)
Postpartum fever	8 (4.15)	123 (3.12)	.43	1.34 (0.65–2.79)	1.08 (0.51–2.25)
Wound infection	0 (0)	5 (0.13)	1.00	—	—
Postpartum hemorrhage	5 (2.59)	58 (1.47)	.22	1.78 (0.71–4.50)	1.68 (0.66–4.27)
Transfusion	6 (3.11)	38 (0.96)	.01	3.30 (1.38–7.90)	3.24 (1.33–7.88)
NICU admission	7 (3.63)	34 (0.86)	<.01	4.33 (1.89–9.89)	3.45 (1.49–7.99)
Composite neonatal morbidity[c]	34 (17.62)	263 (6.67)	<.01	2.99 (2.03–4.42)	2.32 (1.54–3.47)
Outcome	**>90%ile (10.3 h) (n=535)**	**≤90%ile (10.3 h) (n=2683)**	**P value**	**OR (95% CI)**	**aOR[a] (95% CI)**
Induced					
Cesarean delivery	137 (25.61)	301 (11.22)	<.01	2.72 (2.17–3.42)	2.04 (1.60–2.60)
Cesarean delivery for arrest disorder	103 (19.25)	183 (6.82)	<.01	3.26 (2.51–4.23)	2.37 (1.79–3.12)
Composite maternal morbidity[b]	47 (8.79)	137 (5.11)	<.01	1.79 (1.27–2.53)	1.57 (1.10–2.23)
Postpartum fever	33 (6.17)	86 (3.21)	<.01	1.99 (1.31–3.00)	1.60 (1.05–2.45)
Wound infection	2 (0.37)	0 (0.00)	.03	—	—
Postpartum hemorrhage	21 (3.93)	56 (2.09)	.01	1.92 (1.15–3.19)	1.88 (1.12–3.18)
Transfusion	21 (3.93)	49 (1.83)	<.01	2.20 (1.31–3.69)	2.00 (1.17–3.42)
NICU admission	20 (3.74)	38 (1.42)	<.01	2.70 (1.56–4.68)	2.15 (1.22–3.79)
Composite neonatal morbidity[c]	83 (15.51)	206 (7.68)	<.01	2.21 (1.68–2.90)	1.80 (1.36–2.39)

aOR, adjusted odds ratio; *CI*, confidence interval; *NICU*, neonatal intensive care unit; *OR*, odds ratio.

[a] Adjusted for obesity, labor type, nulliparity, race, hypertension, diabetes; [b] Composite maternal morbidity: postpartum fever, wound infection, postpartum hemorrhage; [c] Composite neonatal morbidity: neonatal death, hypothermic therapy, mechanical ventilation, respiratory distress, meconium aspiration syndrome, seizure, or treatment of sepsis.

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TABLE 5
Outcomes for patients with time for dilation from 4 to 6 cm at >90th percentile or ≤90th percentile, stratified by parity

Outcome	>90%ile (10.3 h) (n=463)	≤90%ile (10.3 h) (n=2845)	P value	OR (95% CI)	aOR[a] (95% CI)
Nulliparous					
Cesarean delivery	149 (32.18)	408 (14.34)	<.01	2.83 (2.27−3.54)	2.23 (1.77−2.82)
Cesarean delivery for arrest disorder	11 (23.97)	269 (9.46)	<.01	3.02 (2.36−3.87)	2.37 (1.83−3.09)
Composite maternal morbidity[b]	47 (10.15)	187 (6.57)	.01	1.61 (1.15−2.25)	1.49 (1.05−2.11)
Postpartum fever	34 (7.34)	140 (4.92)	.03	1.53 (1.04−2.26)	1.38 (0.92−2.08)
Wound infection	2 (0.43)	2 (0.07)	.10	6.17 (0.87−43.89)	5.85 (0.70−49.21)
Postpartum hemorrhage	20 (4.32)	52 (1.83)	<.01	2.43 (1.43−4.10)	2.26 (1.30−3.94)
Transfusion	20 (4.32)	44 (1.55)	<.01	2.87 (1.68−4.92)	2.22 (1.26−3.92)
NICU admission	22 (4.75)	45 (1.58)	<.01	3.10 (1.85−5.22)	2.53 (1.46−4.38)
Composite neonatal morbidity[c]	93 (20.09)	339 (11.92)	<01	1.86 (1.44−2.40)	1.82 (1.39−2.38)

Outcome	>90%ile (10.3 h) (n=265)	≤90%ile (10.3 h) (n=3782)	P value	OR (95% CI)	aOR[a] (95% CI)
Multiparous					
Cesarean delivery	19 (7.17)	165 (4.36)	.03	1.69 (1.04−2.78)	1.41 (0.85−2.33)
Cesarean delivery for arrest disorder	14 (5.28)	71 (1.88)	<.01	2.92 (1.62−5.25)	2.41 (1.31−4.42)
Composite maternal morbidity[b]	13 (4.91)	126 (3.33)	.17	1.50 (0.83−2.69)	1.38 (0.76−2.51)
Postpartum fever	7 (2.64)	69 (1.82)	.34	1.46 (0.66−3.21)	1.50 (0.67−3.36)
Wound infection	0 (0.00)	3 (0.08)	1.00	—	—
Postpartum hemorrhage	6 (2.26)	62 (1.64)	.44	1.39 (0.60−3.24)	1.15 (0.48−2.73)
Transfusion	7 (2.64)	43 (1.14)	.03	2.36 (1.05−5.30)	2.04 (0.89−4.71)
NICU admission	5 (1.89)	27 (0.71)	.05	2.68 (1.02−7.00)	2.21 (0.82−5.95)
Composite neonatal morbidity[c]	24 (9.06)	130 (3.44)	<.01	2.80 (1.78−4.41)	2.37 (1.48−3.79)

aOR, adjusted odds ratio; *CI*, confidence interval; *NICU*, neonatal intensive care unit; *OR*, odds ratio.

[a] Adjusted for obesity, labor type, nulliparity, race, hypertension, diabetes; [b] Composite maternal morbidity: postpartum fever, wound infection, postpartum hemorrhage; [c] Composite neonatal morbidity: neonatal death, hypothermic therapy, mechanical ventilation, respiratory distress, meconium aspiration syndrome, seizure, or treatment of sepsis.

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In patients undergoing spontaneous or augmented labor, there was an increased odds of cesarean delivery, cesarean delivery for arrest of dilation, and neonatal morbidity but not for maternal morbidity in patients with dilation time >90th percentile (Table 4). In patients undergoing induced labor, there was an increased odds of cesarean delivery, cesarean delivery for arrest of dilation, maternal morbidity, and neonatal morbidity for patients with dilation time >90th percentile (Table 4). When considering parity, for nulliparous patients there was an increased odds of all of the aforementioned outcomes for patients with dilation time from 4 to 6 cm >90th percentile, whereas for multiparous patients, there was an increased odds of cesarean delivery for arrest of dilation and neonatal morbidity, but not for overall cesarean delivery or maternal morbidity in patients with prolonged dilation times from 4 to 6 cm (Table 5).

The addition of the starting cervical dilation to the model did not significantly change the results of the primary analysis. Similarly, excluding patients with arrest of dilation at or after 6 cm dilation (n=465) also did not meaningfully change results.

The ROC curves for predicting the outcomes are shown in Figure 2, A−C. ROC analysis demonstrated that sensitivity and specificity for predicting cesarean delivery were maximized with a cutoff of 9.75 hours (AUC, 0.73; 95% CI, 0.71−0.75) (Table 6). At this cutoff, the sensitivity was 68.3% (95% CI, 64.8−71.7), whereas specificity was 66.2% (95% CI, 65.0−67.3). For predicting composite maternal morbidity, the cutoff that maximized sensitivity and specificity was 6.98 hours (AUC, 0.62; 95% CI, 0.59−0.65), whereas for predicting composite neonatal morbidity, it was 5.50 hours (AUC, 0.69; 95% CI, 0.67−0.71). For neonatal morbidity the sensitivity was 76.9% (95% CI, 73.3−80.3), whereas the specificity was 54.7% (95% CI, 53.5−55.9).

FIGURE 2
Receiver-operative characteristic curves for outcomes
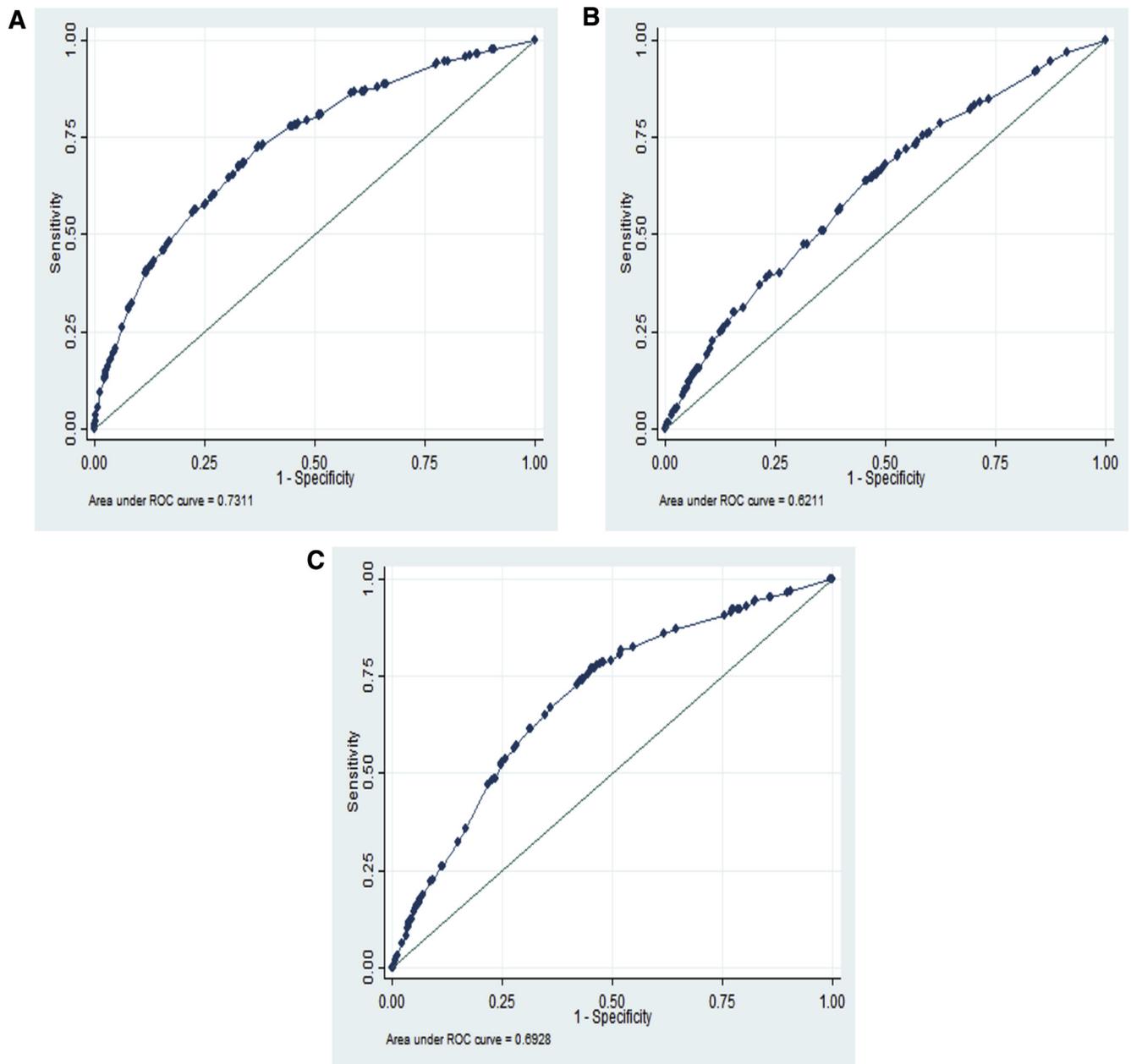
Receiver-operator characteristic curves for outcomes based on time to dilated from 4-6 cm. **A**, Prediction of cesarean delivery. **B**, Prediction of composite maternal morbidity. **C**, Prediction of composite neonatal morbidity.

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Discussion
Principal findings

We found that a prolonged time spent from 4 to 6 cm was associated with an increased risk of cesarean delivery and maternal and neonatal morbidity. However, although dilation time from 4 to 6 cm had moderate predictive ability for cesarean delivery, it was a poor predictor of maternal or neonatal morbidities.

Results in context

Our findings complement a previous analysis that defined a normal first stage of labor based on neonatal and maternal outcomes.[20] In that study, there was an association between prolonged first stage and increased risk of maternal fever, neonatal morbidity, and shoulder dystocia.[20] However, in that study, labor curves were constructed only for patients who achieved 10 cm dilation

TABLE 6
Test characteristics of time to dilate from 4 to 6 cm and outcomes

Outcome	AUC	Time cut off, h	Sensitivity	Specificity	PPV	NPV
Cesarean delivery	0.73 (0.71—0.75)	9.75	68.3% (64.8—71.7)	66.2% (65.0—67.3)	18.5% (17.1—20.0)	94.9% (94.2—95.5)
Composite maternal morbidity[a]	0.62 (0.59—0.65)	6.98	56.8% (51.5—61.9)	60.4% (59.2—61.5)	7.1% (6.2—8.1)	96.3% (95.7—96.8)
Composite neonatal morbidity[b]	0.69 (0.67—0.71)	5.50	76.9% (73.3—80.3)	54.7% (53.5—55.9)	12.9% (11.8—14.0)	96.5% (95.8—97.0)

AUC, area under the receiver-operator characteristic curve; *NPV*, negative predictive value; *PPV*, positive predictive value. Numbers in parenthesis are the 95% confidence intervals. Time cutoff determined from maximizing sensitivity and specificity.

[a] Composite maternal morbidity: postpartum fever, wound infection, postpartum hemorrhage; [b] Composite neonatal morbidity: neonatal death, hypothermic therapy, mechanical ventilation, respiratory distress, meconium aspiration syndrome, seizure, or treatment of sepsis.

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(regardless of eventual birth outcome). Our study differs in that we including all patients who achieved at least 6-cm dilation, regardless of whether they continued to dilate to 10 cm. In a large study of 10,677 patients undergoing induction of labor, Grobman et al[10] found that maternal morbidity increased with an increasing duration of the latent phase, whereas there was no increase in major neonatal morbidity. Importantly, in that study the latent phase was defined as ending at 5 cm dilation, limiting applicability to our findings.[10] Finally, in a study of 10,979 deliveries, Chelmow et al[11] found that increasing length of the latent phase was associated with a greater risk of cesarean delivery and neonatal morbidity. However, our study differs in that it specifically examines outcomes with time spent from 4 to 6 cm.

Clinical and research implications
Although the active phase of labor is now defined by the American College of Obstetricians and Gynecologists and the Society for Maternal—Fetal Medicine as beginning at 6 cm, our analyses demonstrate that prolonged dilation in the late latent phase from 4 to 6 cm is associated with adverse outcomes.[1,21] An accurate definition of arrest of dilation is essential to preventing unnecessary cesarean deliveries, especially given that that 34% of primary cesarean

deliveries are for labor arrest.[22] Indeed, our findings demonstrate that the labor course from 4 to 6 cm should not be ignored. Prolonged dilation time during this critical period is associated with increased maternal and neonatal morbidity. Although we do not suggest that arrest or protraction disorders should necessarily be diagnosed starting at 4 cm, our findings serve as a caution and call for closer observation and possibly more active management of patients who have prolonged labor in the last part of the latent phase. Clearly, there is a point at which intervention may be warranted even in the late latent phase, and it may be beneficial to account for this in future guidelines. However, this determination of normal and abnormal would best be determined based on morbidity and increasing risk and not based on a specific percentile of time.

One alternative to strictly defining active labor as starting at 4 or as 6 cm is to customize the start of active labor for each patient based on her individual labor curve. Some patients in our study undoubtedly were in the active phase as early as 4 cm, whereas others may not have entered the active phase until 6 cm. Applying one-time criteria or category to all patients may either apply overly stringent active phase standards to patients still in the latent phase or ignore true active-phase dysfunction by assuming patients are still in the latent

phase. One potential avenue for further research is customized predictive labor curves based on a patient's history and other factors. Such individualized curves could address the inherent uncertainty in applying standard curves universally.

Strengths and limitations
Our study has multiple strengths. First, the data are from a large prospectively collected laboring cohort with detailed clinical and demographic information including cervical examinations. Second, we used interval censored regression in our analyses, which is a more flexible and statistically rigorous method compared with other analytic tools for labor curve analysis.[23]

In contrast, there are potential limitations to consider. First, although we did adjust or stratify for multiple confounders, the possibility of unmeasured confounding still exists. Second, by focusing specifically on the time from 4 to 6 cm we may not have accounted for coexisting labor abnormalities earlier in the labor course. Third, the use of the Youden index to identify a cut point for time has certain disadvantages. Although this method maximizes sensitivity and specificity, in clinical medicine there may be a preference for prioritizing sensitivity over specificity or vice versa.[19] In the present case, using the Youden index to identify a cut point of 9.75 hours for

predicting cesarean delivery later in labor had a relatively high sensitivity but a lower specificity. In fact, 77% of patients with a time to dilate from 4 to 6 cm >90th percentile still had a vaginal delivery.

Conclusions

Obstetric providers should be attuned to their patients' progress during the end of the latent phase into the beginning of the active phase. Increasing dilation time during this period is associated with an increased risk of cesarean delivery as well as neonatal and maternal morbidity. Future studies should investigate at what point, if any, intervention is warranted during this period to reduce these risks. ∎

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