Normal Progress of Induced Labor

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OBJECTIVE: To compare the normal labor progress of women whose labor was induced with that of women who labored spontaneously.

METHODS: A retrospective cohort study of all consecutive women admitted for labor at 37 weeks or more of gestation from 2004–2008 who reached the second stage of labor. Women whose labor was induced and women whose labor was augmented were compared with women who labored spontaneously without augmentation. Results were stratified by parity. Univariable and multivariable analyses were performed; interval censored regression was used to estimate the median time spent to progress 1 cm in dilation and the total time from 4–10 cm dilation by parity.

RESULTS: Of 5,388 women in the cohort, 2,021 spontaneously labored, 1,720 were augmented, and 1,647 were induced. After adjusting for race, obesity, macrosomia, and Bishop score, women who were induced had a significantly longer total time in labor than women who labored spontaneously (median [95th percentile] in hours for nulliparous women: 5.5 [16.8] induced compared with 3.8 [11.8] spontaneous; for multiparous women 4.4 [16.2] induced compared with 2.4 [8.8] spontaneous). However, median time to progress 1 cm dilation in active labor (6 cm or greater) was similar in induced and spontaneous labor. The time to progress 1 cm dilation in latent labor (less than 6 cm) was significantly longer in women who were induced compared with women who experienced spontaneous labor.

CONCLUSION: The latent phase of labor is significantly longer in induced labor compared with spontaneous labor, although the active phase of labor (greater than 6 cm) is similar between the two groups. Arrest diagnoses before 6 cm in women undergoing induction should be made cautiously.

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LEVEL OF EVIDENCE: II

Over 20% of pregnancies resulted in an induction of labor in 2007, representing a 140% increase since 1990.[1] Unfortunately, women, particularly nulliparous women, who are induced are more likely to require cesarean delivery than those with spontaneous labor.[2–8] The reason for the increased risk of cesarean delivery in women who are induced is unclear, but it may be attributable in part to the way physicians manage labor that is induced.

In the Consortium for Safe Labor, women who underwent cesarean delivery for arrest or failed induction spent similar amounts of time in labor before the cesarean delivery whether or not they were induced or in spontaneous labor.[9] However, the course of labor in women undergoing induction may be slower than in spontaneous labor, suggesting that perhaps women whose labor is induced might be diagnosed with arrest of dilation prematurely.[10] Given the number of women undergoing an induction of labor, it is imperative to characterize the course of induced labor to prevent unnecessary cesarean delivery for arrest disorders in this population. Therefore, our objective was to compare the normal labor progress of women whose labor was induced with that of women who labored spontaneously.

PATIENTS AND METHODS

This was a 4-year retrospective cohort study of all consecutive term (37 weeks or greater of gestation) deliveries at Washington University Medical Center in St. Louis, Missouri, from July 2004 to June 2008 who reached 10 cm of dilation. Institutional board

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Women were included if their gestational age was at least 37 0/7 weeks at admission to labor and delivery, carried a singleton pregnancy in vertex presentation, and had an umbilical cord gas obtained at delivery. We excluded women who delivered preterm, had fetuses with congenital anomalies, or delivered by cesarean before complete dilation. We extracted detailed information on maternal sociodemographic, obstetric and gynecologic history, medical and surgical history, prenatal history, antepartum records, and labor and delivery records. The labor and delivery records included medications, labor type, cervical examination times, dilation and station, length of labor stages, mode of delivery, and postpartum record. Cervical dilation was documented in centimeters ranging from 0 to 10 cm. All data were extracted using close-ended forms by trained research assistants who underwent regularly scheduled training.

For this study, we compared the duration and curves of the first stage of labor by whether labor was induced, spontaneous, or augmented as determined by chart review. Augmentation was defined as women having a diagnosis of spontaneous labor at admission who subsequently received oxytocin augmentation. Women in the spontaneous labor group received no augmentation with oxytocin but may have undergone artificial rupture of membranes; however, because artificial rupture of membranes may be considered an augmentation method, we performed a secondary analysis excluding these women from the spontaneous labor group. To model the curvilinear trend of cervical dilation over time, we used a repeated-measures regression with a polynomial function. Because the known fact was achievement of complete dilation, the regression model was executed in a reverse approach by starting at 10 cm and working backward to the first cervical examination. Polynomial equations are formed by taking the independent variable to sequential powers. A ninth-order polynomial in time was the best fit for the dilation values in our data[11]; XTMIXED of STATA 11.1 was used for the analysis.

Study groups were compared using analysis of variance or the Mann-Whitney *U* test for continuous variables and χ^2 or Fisher's exact test for categorical variables, as appropriate. The main analysis investigated the time it took for cervical dilation to increase from 4 cm to 10 cm in aggregate as well as by increments of 1 cm (eg, from 4 cm to 5 cm) using interval-censored regression. As a result of the variability of cervical dilation at first examination and subsequent examination timing, it is not possible to know exactly when a level of cervical dilation is reached. This required us to calculate a time interval between every centimeter of cervical dilation giving a possible minimum and maximum time that the cervical dilation was reached. The time interval assumption fits a log normal distribution, and previous publications have demonstrated that the duration of labor often has a right-skewed pattern.[11] We calculated the time interval between each consecutive cervical dilation for all individuals giving them an interval-censored value for each level of dilation.[11–17] We used PROC LIFEREG of SAS 9.2 to fit a log normal distribution to the time interval and estimated median, fifth, and 95th percentiles. Multivariable models were built to adjust for relevant confounding factors. Both variables demonstrated to be historically relevant as well as those identified in bivariable analyses were considered, including maternal age, race, prior cesarean delivery, tobacco use, fetal birth weight, diabetes, hypertension, body mass index (calculated as weight (kg)/[height (m)]^2), and Bishop score. Final models to estimate the relationship between type of labor and labor curve adjusted for only statistically significant factors: race, macrosomia (birth weight greater than 4,000 g), obesity (maternal body mass index greater than 30.0), and admission Bishop score greater than 5. These analyses were repeated to stratify by parity.

RESULTS

Of 5,388 women in the cohort, 2,021 (37.5%) presented in spontaneous labor, 1,720 (31.9%) were augmented, and 1,647 (30.6%) were induced. Women who were induced were more likely to be white, older, aged 35 years or older, nulliparous, diabetic, hypertensive, obese, have a macrosomic neonate, and have a Bishop score less than 5 (Table 1). Women who were induced or presented in spontaneous labor were similar with regard to prior cesarean delivery and smoking.

Nulliparous women who were induced had a significantly longer labor than those who were admitted in spontaneous labor (Table 2). The time to progress from 4 cm to 10 cm was longer in induced labor compared with spontaneous labor (median 5.5 compared with 3.8 hours, 95th percentile 16.8 compared with 11.8 hours). Nulliparous women who were induced required longer to achieve each 1-cm increment of cervical dilation until 6 cm with 95th percentiles ranging between 2 and 5.5 hours longer in the induced group compared with the spontaneous group. After 6 cm, women in induced and spontaneous labor spent similar amounts of time advancing 1

Table 1. Patient Characteristics

	Induction of Labor (n=1,647)	Augmentation of Labor (n=1,720)	Spontaneous Labor (n=2,021)	*P*
Maternal age (y)	25.5±6.2	24.6±5.7	24.6±5.7	<.01
Maternal age older than 35 y	143 (8.7)	103 (6.0)	133 (6.6)	<.01
Race				<.01
White	386 (23.4)	269 (15.6)	266 (13.2)	
African American	1,102 (66.9)	1,273 (74.0)	1,549 (76.7)	
Hispanic	91 (5.5)	120 (7.0)	134 (6.6)	
Other	68 (4.2)	56 (3.3)	72 (3.5)	
Nulliparous	734 (44.6)	689 (40.1)	573 (28.4)	<.01
Multiparous	913 (55.4)	1,031 (59.9)	1,448 (71.7)	<.01
Prior cesarean delivery	92 (5.6)	115 (6.7)	140 (6.9)	.23
Diabetes	111 (6.7)	38 (2.2)	37 (1.8)	<.01
Hypertension	313 (19.0)	186 (10.8)	121 (6.0)	<.01
Smoking	296 (18.0)	296 (17.2)	388 (19.2)	.28
BMI (kg/m^2)	33.1±7.4	31.6±6.8	30.4±6.2	.03
BMI greater than 30.0	1,020 (63.6)	891 (53.1)	880 (45.8)	<.01
Bishop score at admission	2 (1–4)	5 (3–6)	6 (5–8)	<.01
Bishop score less than 5	1,548 (94.7)	1,150 (67.4)	622 (31.2)	<.01
Macrosomia	121 (7.4)	96 (5.6)	79 (3.9)	<.01
Mode of delivery				<.01
Spontaneous vaginal	1,363 (82.8)	1,454 (84.5)	1,801 (89.1)	
Operative vaginal	245 (14.9)	236 (13.7)	201 (9.9)	
Cesarean	39 (2.4)	30 (1.7)	19 (0.9)	
Type of induction				
Prostaglandins	526 (31.9)	—	—	—
Foley balloon and oxytocin	71 (4.3)	—	—	—
Oxytocin	854 (51.9)	—	—	—
Artificial rupture of membranes	33 (2.0)	—	—	—
Combination	163 (9.9)	—	—	—

BMI, body mass index.
Data are mean±standard deviation, n (%), or median (interquartile range) unless otherwise specified.

cm in dilation. Women who were augmented had statistically significantly longer labors for each 1 cm of dilation compared with the spontaneous labor group throughout labor. Before 6 cm, the median and 95th percentiles for the time to progress each 1 cm in the augmented group closely resemble the time required to progress in the induction group.

A similar pattern was seen in multiparous women (Table 3). The time for multiparous women who were induced to progress from 4 cm to 10 cm was longer compared with multiparous women in spontaneous labor (median 4.4 compared with 2.4 hours, 95th percentile 16.2 compared with 8.8 hours). The time to progress each 1-cm increment until 6 cm was longer

Table 2. Time in Hours for Each Centimeter of Cervical Dilation in Nulliparous Women

Cervical Dilation (cm)	Induction of Labor (n=732)	*P**	Augmented Labor (n=688)	*P**	Spontaneous Labor (n=572)
4–10	5.5 (1.8, 16.8)	<.01	5.4 (1.8, 16.8)	<.01	3.8 (1.2, 11.8)
3–4	1.4 (0.2, 8.1)	<.01	1.2 (0.2, 6.8)	<.01	0.4 (0.1, 2.3)
4–5	1.3 (0.2, 6.8)	<.01	1.4 (0.3, 7.6)	<.01	0.5 (0.1, 2.7)
5–6	0.6 (0.1, 4.3)	.02	0.7 (0.1, 4.9)	<.01	0.4 (0.06, 2.7)
6–7	0.4 (0.05, 2.8)	.05	0.5 (0.06, 3.9)	<.01	0.3 (0.03, 2.1)
7–8	0.2 (0.03, 1.5)	.93	0.3 (0.05, 2.2)	.01	0.3 (0.04, 1.7)
8–9	0.2 (0.03, 1.3)	.80	0.3 (0.05, 2.0)	<.01	0.2 (0.03, 1.3)
9–10	0.3 (0.04, 1.9)	.13	0.3 (0.05, 2.4)	<.01	0.3 (0.04, 1.8)

Data presented in hours as median (5th percentile, 95th percentile) unless otherwise specified. The reference group was spontaneous labor.
* Adjusted for race, body mass index greater than 30 kg/m^2, birth weight greater than 4,000 g, and Bishop score higher than 5 at admission.

Table 3. Time in Hours for Each Centimeter of Cervical Dilation in Multiparous Women

Cervical Dilation (cm)	Induction of Labor (n=915)	P*	Augmentation of Labor (n=1,032)	P*	Spontaneous Labor (n=1,449)
4–10	4.4 (1.2, 16.2)	<.01	4.7 (1.3, 17.5)	<.01	2.4 (0.6, 8.8)
3–4	1.5 (0.2, 10.2)	<.01	1.1 (0.2, 7.5)	<.01	0.3 (0.05, 2.3)
4–5	1.2 (0.2, 7.9)	<.01	1.3 (0.2, 8.2)	<.01	0.3 (0.04, 1.9)
5–6	0.5 (0.1, 4.2)	<.01	0.8 (0.1, 6.0)	<.01	0.2 (0.03, 1.7)
6–7	0.3 (0.03, 1.8)	.03	0.4 (0.06, 3.2)	<.01	0.2 (0.03, 1.6)
7–8	0.1 (0.02, 1.0)	.72	0.3 (0.04, 1.7)	<.01	0.2 (0.03, 1.3)
8–9	0.1 (0.02, 0.8)	.50	0.2 (0.03, 1.3)	<.01	0.2 (0.02, 1.0)
9–10	0.1 (0.02, 0.8)	.50	0.2 (0.03, 1.1)	<.01	0.1 (0.02, 0.8)

Data presented in hours as median (5th percentile, 95th percentile) unless otherwise specified. The reference group was spontaneous labor.

* Adjusted for race, body mass index greater than 30 kg/m^2, birth weight greater than 4,000 g, and Bishop score higher than 5 at admission.

in induced labor compared with spontaneous labor; after 6 cm, the time to progress each 1-cm increment was similar between the two groups. Although the difference in time to progress from 6 to 7 cm was statistically significant (P=.03), these differences are clinically not distinguishable (12-minute difference between the 95th percentiles). The multiparous augmented labor group required longer times to progress through labor than the spontaneous labor group, although after 7 cm, these differences are likely not clinically distinguishable (18- to 24-minute differences between the 95th percentiles). Figure 1 graphically demonstrates the labor curves for spontaneous and induced labor stratified by parity. The spontaneously laboring multiparous and nulliparous women progressed more rapidly through labor compared with the induced multiparous and nulliparous women, respectively. Excluding women with artificial rupture of membranes from the spontaneous labor group did not change the results in primiparous or multiparous women (data available on request).

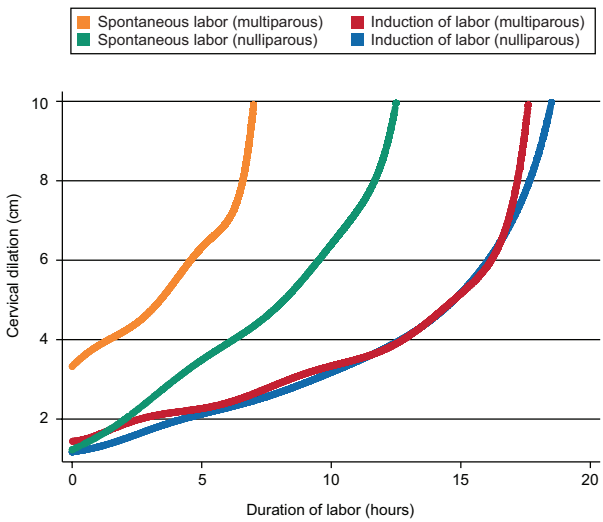

Fig. 1. Average labor curves stratified by parity and type of labor onset.

Harper. Normal Labor in Induction. Obstet Gynecol 2012.

DISCUSSION

Nulliparous and multiparous women who undergo induction of labor and reach complete dilation are in labor for a longer period of time than women in spontaneous labor as a result of a slower rate of cervical dilation between 4 and 6 cm. However, after 6 cm, women who are induced and in spontaneous labor have similar rates of cervical dilation. Both nulliparous and multiparous women who are induced can spend over 17 hours (95th percentile) in labor after 4 cm while still reaching 10 cm dilation. Cervical dilation before 4 cm may be even slower in women who are induced, requiring over 8 hours to progress from 3 to 4 cm. The labor progress for women who are augmented with oxytocin closely resembles the induction of labor group before 6 cm and progress more slowly through labor compared with the spontaneous labor group.

Our findings our consistent with a study by Cheng et al[18] that examined the effect of the length of the first stage in induction on the mode of delivery. In this study, over 50% of women who are induced who had a first stage of labor longer than 24 hours delivered vaginally. This increased to over 60% when only multiparous women are considered.

The progression of labor in our cohort of women undergoing labor induction is significantly slower than current accepted definitions of protraction (less than 1 cm/h dilation for 4 hours) and arrest disorders (no cervical dilation for 2 hours).[19] Additionally, the active phase of labor (defined as an increased rate of cervical dilation) begins after 6 cm, much later than

previously accepted definitions of 3–4 cm.[19,20] Consequently, if these traditional definitions of active phase arrest are applied to women whose labor is induced, a significant number of cesarean deliveries for arrest disorders may be performed prematurely. Prospective trials of labor management in induced labor are necessary to determine if application of these findings alters cesarean delivery rates in these women.

A prior study by Rinehart et al[10] suggested that women who are induced have slower labors than women who enter labor spontaneously. However, this study is hindered by lack of a contemporary control group of spontaneous labor. The cohort of labor induction was compared with the historical cohort from Friedman et al; unfortunately, a greater than 45-year difference between these cohorts makes them relatively incomparable as a result of differences in the patient populations and in the management of labor.

Vahratian et al[14] examined the progress of labor in nulliparous women undergoing induction stratified by whether or not they had a favorable cervix at the time of induction. They also were able to use an interval-censored regression analysis to estimate the time spent to achieve 1 cm of dilation. Women who required cervical ripening had a slower labor than women in spontaneous labor until 6 cm, at which point their labor patterns were similar. Interestingly, women induced from a favorable cervix had faster labors than women in spontaneous labor, largely as a result of shorter times to reach 6 cm. This study examined only nulliparous women, and no prostaglandins were used for cervical ripening, potentially limiting the generalizability of the study.

The progress of labor in women who receive oxytocin augmentation is very similar to women who are induced before 6 cm; both groups require much longer median times to progress 1 cm compared with the spontaneous labor group and both groups had 95th percentiles of greater than 4 hours for each 1 cm of dilation. These findings may reflect a misclassification of women being induced with oxytocin as having received oxytocin augmentation; it may also reflect that some women are admitted and misdiagnosed as being in labor and then subsequently receive oxytocin for protracted labor curves. Additionally, women who received oxytocin augmentation progressed more slowly in labor throughout labor, although the differences were not necessarily clinically distinguishable. It is possible that the longer time to progress was the reason for the use of oxytocin augmentation in this group.

We used a large cohort of consecutive term births who reached 10 cm of dilation to analyze the effect of labor induction on the course of the first stage of labor. Our control group consisted only of women who labored spontaneously without receiving oxytocin augmentation, thus preventing misclassification errors (ie, induction may be misinterpreted as augmentation) and allowing a comparison to a natural labor course. We had detailed patient-level data, including patient characteristics and medication details, enabling us to reconstruct labor curves while adjusting for relevant confounding factors. The use of an interval-censored regression analysis accounts for being unable to determine the precise time a cervical dilation is achieved. Finally, all methods of induction (prostaglandins, oxytocin, and Foley balloon) and indications for induction were included, making this study generalizable to a wide population.

One limitation of the study is that we excluded women who did not reach the second stage of labor because we were interested in the normal course of labor rather than women who required a cesarean delivery; their exclusion could result in selection bias. Women who were excluded may have had a protraction or arrest disorder, leading to longer labor curves in the women who were excluded. Because women who have a cesarean delivery are more likely to have been induced than to have entered labor spontaneously, this may have falsely shortened the length of labor in women who were induced and reached complete.

We also excluded women who received oxytocin augmentation from the spontaneous labor group. The reasons for this were twofold. First, it avoids misclassifying women who received oxytocin only for induction as being in spontaneous labor. Second, women typically receive oxytocin because of protracted or arrested labor; our goal was to compare women who are induced with "normal" labor. Consequently, the times reported for the spontaneous labor groups may be slightly shorter than for women who receive augmentation.

Of note, our analysis does not begin until 3 cm of dilation, largely because when women are admitted in spontaneous labor, their cervical examination is typically at least 3 cm or greater. Therefore, we are unable to comment on the length of labor before 3 cm in comparison to the spontaneous labor group and so we do not comment on the cervical ripening phase of labor induction in this study. At our institution, cervical ripening agents are typically stopped between 2 and 4 cm and induction is subsequently continued with oxytocin alone; we do not feel that the induction

agent before this point will have a significant effect on labor progression, particularly in the active phase of labor.

In conclusion, women whose labor was induced spent a longer total time in labor than women who presented in spontaneous labor; both primiparous and multiparous women spent long times (greater than 17 hours) in labor after reaching 4 cm and still reach 10 cm dilation. Before 6 cm, women may spend up to 10 hours to achieve each 1 cm of dilation. After 6 cm, women who are induced can spend 1–2 hours progressing 1 cm of dilation, similar to women entering labor spontaneously. This pattern of labor in women undergoing labor induction suggests that an arrest diagnosis before 6 cm needs to be carefully considered; before 6 cm, a slow rate of dilation in a woman being induced may be normal and may not indicate a need for cesarean delivery. In women undergoing induction of labor, an arrest of labor diagnosis before 6 cm needs to be considered carefully.

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