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Reassessing the labor curve in nulliparous women

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OBJECTIVES: Our purpose was to examine the pattern of labor progression in nulliparous parturients in contemporary obstetric practice.

STUDY DESIGN: We extracted detailed labor data from 1329 nulliparous parturients with a term, singleton, vertex fetus of normal birth weight after spontaneous onset of labor. Cesarean deliveries were excluded. We used a repeated-measures regression with a 10th-order polynomial function to discover the average labor curve under contemporary practice. With use of an interval-censored regression with a log normal distribution, we also computed the expected time interval of the cervix to reach the next centimeter, the expected rate of cervical dilation at each phase of labor, and the duration of labor for fetal descent at various stations.

RESULTS: Our average labor curve differs markedly from the Friedman curve. The cervix dilated substantially slower in the active phase. It took approximately 5.5 hours from 4 cm to 10 cm, compared with 2.5 hours under the Friedman curve. We observed no deceleration phase. Before 7 cm, no perceivable change in cervical dilation for more than 2 hour was not uncommon. The 5th percentiles of rate of cervical dilation were all below 1 cm per hour. The 95th percentile of time interval for fetal descent from station +1/3 to +2/3 was 3 hours at the second stage.

CONCLUSION: Our results suggest that the pattern of labor progression in contemporary practice differs significantly from the Friedman curve. The diagnostic criteria for protraction and arrest disorders of labor may be too stringent in nulliparous women. (Am J Obstet Gynecol 2002;187:824-8.)

Key words: Arrest, labor curve, nullipara, protraction, cesarean

In 1955, Friedman[1] published a landmark study on a graphicostatistical analysis of primigravid labor based on his observation of 500 parturients at term. He depicted the relationship between duration of labor and cervical dilation as a sigmoid curve, which consisted of latent and active phases, followed by the second stage of labor (Fig 1). The active phase was further divided into acceleration phase, phase of maximal slope, and deceleration phase. This curve has been known as the Friedman curve. He also established a series of definitions of labor protraction and arrest.[2] These definitions have been widely adopted and applied in practice in the past half century.[3]

However, labor management has changed substantially since then. Induction of labor, oxytocin use, epidural analgesia, and fetal heart rate monitoring are very common in contemporary practice whereas breech vaginal delivery and mid forceps are rarely performed. The mean body mass of women is significantly higher than it was 50 years ago,[4] which may contribute to the increased fetal size. Some studies suggested that the Friedman curve was no longer appropriate for induced or actively managed labor.[5,6] In addition, the debate whether the deceleration phase described by Friedman exists remains unsettled.[7] We decided to re-examine the pattern of labor progression among nulliparous women in contemporary practice by use of more advanced statistical methods.

Material and methods

We used data from a previous study in which detailed labor and delivery information was collected.[8] In brief,

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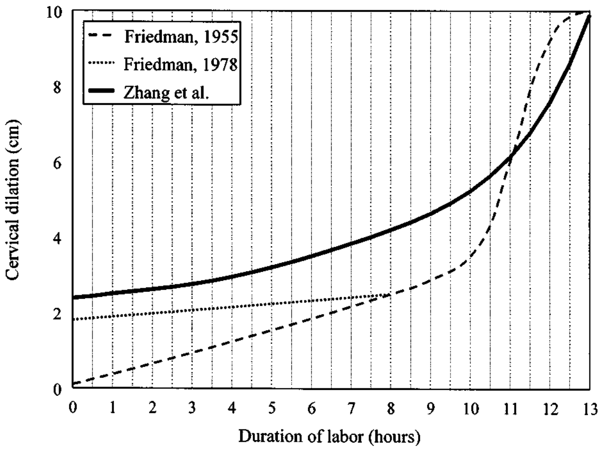

Fig 1. Comparison between the Friedman curve and the pattern of cervical dilation based on the current data.

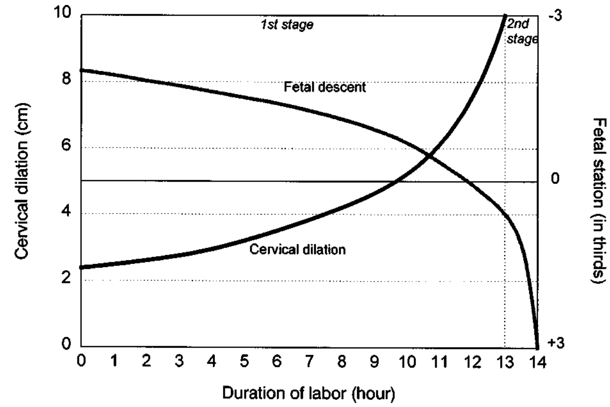

Fig 2. Patterns of cervical dilation *(left)* and fetal descent *(right)* in nulliparous women.

Table I. Comparison of study populations between Friedman's study and the current study

	Friedman study (n = 500)	*Current study (n = 1162)*
Year of data collection	Early 1950s	1992-1996
Birth weight between 2500-4000 g (%)	85	100
Labor induction (%)	4	0
Caudal/epidural anesthesia (%)	8	48
Oxytocin augmentation (%)	9	50
Breech delivery and twin gestation(%)	4	0
Low forceps/vacuum (%)	51	13
Mid forceps or cesarean delivery (%)	6	0

Table II. Expected time interval and rate of change at each stage of cervical dilation

Cervical dilation (cm) *From*	*To*	*Time interval (h)**	*Rate of cervical dilation (cm/h)**
2	3	3.2 (0.6, 15.0)	0.3 (0.1, 1.8)
3	4	2.7 (0.6, 10.1)	0.4 (0.1, 1.8)
4	5	1.7 (0.4, 6.6)	0.6 (0.2, 2.8)
5	6	0.8 (0.2, 3.1)	1.2 (0.3, 5.0)
6	7	0.6 (0.2, 2.2)	1.7 (0.5, 6.3)
7	8	0.5 (0.1, 1.5)	2.2 (0.7, 7.1)
8	9	0.4 (0.1, 1.3)	2.4 (0.8, 7.7)
9	10	0.4 (0.1, 1.4)	2.4 (0.7, 8.3)

*Median (5th and 95th percentiles).

we systematically selected 1329 subjects from 1992 to 1996 on the basis of the following inclusion criteria: nulliparous, singleton pregnancy, maternal age between 18 and 34 years, gestational age between 37 weeks 0 days and 41 weeks 6 days, birth weight between 2500 and 4000 g, spontaneous onset of labor, vertex presentation at admission, cervical dilation <7 cm at admission, and duration of labor from admission to delivery >3 hours. Because the purpose of our study was to demonstrate that a substantial proportion of labor ended in vaginal delivery may progress slower than the current cutoff points for labor arrest, we excluded the cesarean deliveries (n = 167), leaving 1162 subjects for analysis.

Resident physicians provided the majority of labor and delivery services under supervision of attending physicians. Forceps and vacuum were primarily used as low and outlet procedures with fewer than 1% of procedures done at the midpelvic level. The choice of delivering instruments was made by the delivering physician. All low operative procedures required a maternal or fetal indication, whereas outlet procedures were occasionally done electively at the discretion of the supervising physician. There was no active management of labor or other special protocols.

In addition to demographic characteristics, admission assessment and summary of labor and delivery, time at each vaginal examination, cervical dilation and station at each examination were extracted from the labor charts. Cervical dilation was measured in centimeters (from 0 to 10 cm), whereas the station of fetal presenting part was recorded in thirds (from –3 to +3 above or below the ischial spines).

Two major statistical analyses were conducted. First, we examined the pattern of labor progression by looking at the relationship between duration of labor and cervical dilation. A repeated-measures regression with a polynomial function was used to model the curve of cervical dilation.[9] Because patients were admitted at various points of cervical dilation but all ended at 10 cm, the regression was carried out in a reverse approach, with the 10 cm as the starting point and going backward. A 10th-order polynomial in time fitted the dilation values the best. PROC MIXED of SAS was used (SAS Institute, Cary, NC).

Second, we examined the time interval of cervical dilation from 1 centimeter to the next (eg, from 4 cm to 5

Table III. Expected time interval and rate of descent at each stage of station

Station (in thirds)		*First and second stages*		*Second stage only*	
From	*To*	*Time interval (h)**	*Rate (cm/h)*†*	*Time interval (h)**	*Rate (cm/h)*†*
–2	–1	7.9 (0.9, 65)	0.2 (0.03, 1.8)	—	—
–1	0	1.8 (0.1, 23)	0.9 (0.07, 12)	—	—
0	+1	1.4 (0.1, 13)	1.2 (0.12, 12)	—	—
+1	+2	0.4 (0.04, 3.8)	4.4 (0.44, 42)	0.27 (0.02, 2.93)	6.2 (0.57, 83)
+2	+3	0.1 (0.02, 0.9)	12.8 (1.9, 83)	0.11 (0.02, 0.63)	15.2 (2.6, 83)

*Median (5th and 95th percentiles).
†Measurement has been converted from thirds to fifths.

cm). Because continuous monitoring of the cervical dilation was not done, it is impossible to know exactly when an individual first reaches a given level of dilation (eg, 4 cm and/or 5 cm). To estimate the time interval requires a modeling assumption. It is well established that the duration of labor has a skewed distribution leaning toward the left (ie, some long labors produce a long right tail of the distribution). This distribution generally fits a log normal distribution. Thus, a natural assumption for the time interval is that they are log normally distributed, which was consistent with our data. For each individual, we calculated a series of time intervals between two consecutive measures of the cervical dilation. Each individual therefore contributes an interval censored value at a given level of dilation. We used PROC LIFEREG of SAS to fit a log normal distribution to the time interval.[10] The percentiles of the fitted distribution are the estimated population percentiles.

One possible bias of the above analysis of the time intervals comes from the possibility that the faster-progressing individuals were not seen before they had dilated more than the starting point of the given time interval. If this is true, then women with a faster labor may have contributed less information than those with a lengthy labor. To correct for this potential problem, we calculated a covariate representing the relative speed of progression for each individual. The covariate was computed on the basis of the entire observed progression (ie, overall rate of dilation) relative to the expected progression. The latter was derived from a model of rate of dilation change as a function of current dilation. This covariate was then added to the regression model for the time interval, and the percentiles of the time interval in the population were estimated from the average probability of the conditional (fitted) distribution over all individuals. We applied the same statistical methods to discover the pattern and time intervals of fetal descent.

Results

Our study population consisted of women with a mixed race/ethnicity: 65% non-Hispanic white, 12% non-Hispanic black, 7% Hispanic, 11% Asian, and 5% other. Mean maternal age was 23 years; mean maternal height and weight at delivery were 64 inches and 169 pounds, respectively; mean gestational age was 39.3 weeks. At admission, the median cervical dilation was 3.5 cm (10th and 90th percentiles: 1.5 and 5.0 cm, respectively). Thirty-eight percent had complete effacement and 35% had ruptured membranes. The median duration of labor from admission to 10 cm of cervical dilation was 7.3 hours (10th and 90th percentiles: 3.3 and 13.7 hours, respectively), and the median duration from complete cervical dilation to delivery was 53 minutes (10th and 90th percentiles: 18 and 138 minutes, respectively). The median number of vaginal examinations in labor was six times (10th and 90th percentiles: 4 and 10 times, respectively).

Table I compares our population with the Friedman data. Epidural analgesia and oxytocin augmentation were much more common now than 50 years ago. Yet, low forceps use was much less frequent in our population.

Fig 1 illustrates the average pattern of labor progression in nulliparous women. The transition from the latent to the active phase appears more gradual than the Friedman curve. From 4 cm to 10 cm, it takes approximately 5.5 hours, on average, instead of 2.5 hours under the Friedman curve. No deceleration phase was observed. Fig 2 depicts the average curves for both cervical dilation and descent of presenting fetal part.

Table II presents the expected time interval and rate of change at each stage of cervical dilation. As expected, the cervical dilation accelerates. The fastest change occurs between 4 and 5 cm, after which the rate of dilation doubles. The 95th percentiles of the time intervals suggest that labor lasting for more than 2 hours without perceivable change is not uncommon before 7 cm of dilation. The 5th percentile of the rates of dilation indicates that in many patients the rate of change never exceeds 1 cm per hour. However, all of them were delivered vaginally.

Table III shows the expected time interval and the rate of descent at each stage of station. At the second stage of labor, it may take up to 3 hours to descend from station +1/3 to +2/3 and an additional 30 minutes to delivery. We also found that the larger the fetal size the longer the active phase of labor and the second stage of labor (not shown).

Comment

Our study indicates that the pattern of labor progression in contemporary practice is markedly different from what was observed in the 1950s. Labor appears to progress more slowly now than the Friedman curve indicates. This finding is consistent with previous studies. For example, Friedman[2] showed that his study population who were delivered in the 1950s had a mean duration of active phase of 4.6 hours, which was similar to the observation by Hendricks et al[11] in the 1960s. However, data from the 1980s and 1990s demonstrated that the active phase of labor was significantly longer, with a median duration of 8 hours.[12-15] Several factors may be attributable to the difference.

First, evidence has suggested that maternal body mass has increased significantly in the past 50 years.[4] Along with reduction in smoking during pregnancy, the average fetal size has increased.[16] This might also in part explain why the station of fetal head appears higher in the first stage of labor in our data than in Friedman's series.[2] Second, obstetric management has also changed substantially, as illustrated in Table I.

The discrepancy between the Friedman curve and ours may also reflect methodologic differences in constructing these curves. Friedman plotted 500 individual charts and synthesized them into a curve, although the method of synthesis was not explicitly described.[1] Our data showed that women may enter the active phase at different stages, mostly between 3 and 5 cm of dilation. Even in active phase, the speed of progression varies from person to person. Because of the variation, the average labor curve tends to be flatter. However, the Friedman curve has a sharp upturn at 4 to 5 cm. It seems that the Friedman curve is more likely to represent an individual patient with an "ideal" labor instead of an average labor curve. Conversely, it should be borne in mind that the average labor curve may not necessarily be representative of individual curves.

The difference between the Friedman curve and ours was also noticeable in the "deceleration phase." We did not observe the deceleration phase, nor have other authors to date.[7,17] As Friedman acknowledged, "Often this terminal phase of the first stage is short or absent, probably because it is merely not being observed"[2] (page 34). The majority of women in our data did not have a deceleration phase. Therefore, the average labor curve shows no deceleration at the end of the first stage. However, we found that patients who had a cesarean delivery for dystocia at the second stage of labor often had a pattern similar to deceleration (not shown), suggesting that if a patient has a deceleration in late active phase, she may be at risk for dystocia at the second stage. Without the "deceleration phase," the slope of the active phase in our curve is less steep than the Friedman curve. Thus, the labor progression in the active phase appears not as fast as the Friedman curve. This will have a significant impact on the definitions of active phase protraction and arrest.

The definitions of labor protraction and arrest were established based on the 95th percentile of various parameters in the Friedman cohort in the 1950s.[1] Given the changes in population and management, the validity of these definitions warrants a reevaluation for contemporary practice. Our results indicate that these definitions are too stringent for the current population. Recent studies have also challenged the prevailing concept of labor protraction and arrest.[6,18-20] For instance, Rouse et al[18] demonstrated that extending the minimum period of oxytocin augmentation for active-phase labor arrest from 2 to at least 4 hours was effective and safe. Menticoglou et al[20] showed that the second stage of labor could be allowed up to 5 hours without compromising maternal or fetal safety. These findings strongly indicate that new evidence-based definitions of labor protraction and arrest are needed.

The limitations of our study should also be noted. First, measurement of cervical dilation and station was subjective. We did not perform prospective, hourly vaginal examinations. Second, our data reflect the current obstetric practice. The decision on cesarean delivery may have been influenced by the prevailing concept of labor protraction and arrest. Exclusions of cesarean deliveries (for reasons mentioned above), macrosomia, patients with labor less than 3 hours from admission or with a low-birth-weight infant may have underestimated the 5th and 95th percentiles of various measurements in our study (ie, the ranges are narrower than otherwise). But it is unlikely to have a large effect on the average labor curves. Finally, our findings may not be applicable to induced labor.

In summary, the labor curve has a profound impact on the diagnosis of protraction and arrest disorders and the decision on cesarean delivery. Our results suggest that the pattern of labor progression in contemporary obstetrics differs significantly from the Friedman curve. The diagnostic criteria for protraction and arrest disorders may be too stringent in nulliparous women.

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