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Physiologic partograph to improve birth safety and outcomes among low-risk, nulliparous women with spontaneous labor onset

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ABSTRACT

Oxytocin augmentation and cesarean rates among low-risk, term, nulliparous women with a spontaneous onset of labor in the United States approximate 50% and 26.5%, respectively. This indicates that the quality of obstetrical care is less than optimal in this nation. Exorbitant oxytocin use, the intervention most commonly associated with preventable adverse perinatal outcomes, jeopardizes birth safety while the high cesarean rate in this high-volume group compromises population health and increases health care costs. Dystocia, characterized by the slow, abnormal progression of labor, is the most commonly reported indication for primary cesareans, accounting directly for approximately 50% of all nulliparous cesareans and indirectly for most repeat cesareans. Diagnoses of dystocia are most often based on ambiguously defined delays in cervical dilation beyond which labor augmentation is deemed justified. Dystocia is known to be over-diagnosed which undoubtedly contributes to contemporary oxytocin augmentation and primary cesarean rates. Labor attendants would benefit from an evidence-based framework for homogenous labor assessment. To this end, we present a physiologically-based partograph for '*in-hospital*' use in assessing the labors of low-risk, term, nulliparous women with spontaneous labor onset. This tool incorporates several evidence-based labor principles that combine to give needed clinical meaning to 'dystocia' as a diagnosis. It is hypothesized that our partograph will safely limit diagnoses of dystocia to only the slowest 10% of low-risk, nulliparous women. This should, in turn, safe-guard against unnecessary, injudicious, and potentially harmful use of oxytocin when labor is already adequately progressing while also indicating when its use may be justified. We further hypothesize that cesareans performed for dystocia in this population will decrease by ≥50%. No significant influence on other labor process or labor outcome variables is expected with partograph use. Widespread use of this physiologically-based partograph will be warranted if our hypotheses are supported.

Introduction

Within appropriately-defined boundaries of safety, birth outcomes for nulliparous women are best when labor begins and progresses spontaneously [1–12]. Because the cesarean rate for low-risk, term, nulliparous women is a reliable indicator of obstetrical care quality [6,13,14], the current U.S. cesarean rate of 26.5% [13] for this population raises significant concern about the quality and safety of labor care in the U.S. The total U.S. cesarean rate is 32.9% [15]. These rates are higher than ever before and exceed national [13,14] and international [16] objectives. This jeopardizes population health and safety because the best birth outcomes occur with cesarean rates <15% [16] while higher rates result in excessive morbidity and mortality [17–19]. Moreover, based on the most recent U.S. birth statistics, achieving a 15% total cesarean rate would decrease birth costs by $1.63 billion per year [15,20].

Dystocia is the most commonly reported indication for primary cesareans [21,22], accounting directly for approximately 50% of all nulliparous cesareans [14,23] and indirectly for most repeat cesareans. It is nebulously characterized by the American College of Obstetricians and Gynecologists as "the slow, abnormal progression of labor" [21] while, in practice, diagnoses of dystocia are most often based on ambiguously defined delays in cervical dilation beyond which labor augmentation is deemed justified. Dystocia is known to be "over-diagnosed" [22] indicating that existing definitions lack clinical meaning because they neither differentiate normal from abnormal labor progression nor discriminate labors that are more prone to adverse outcomes. Dystocia over-diagnosis does, however, largely explain why approximately 50% of nulliparous women with spontaneous labor onset receive oxytocin augmenta-

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tion during labor [24–27]. This is of concern because oxytocin, a "high-alert medication" [28], is the intervention most commonly associated with preventable adverse perinatal outcomes [29]. Any overuse of oxytocin imposes unnecessary risk on the mother and fetus during labor.

Partographs are tools that allow labor progress to be graphically recorded and visually assessed. They aid in the early detection of abnormal labor progress and are credited with decreasing rates of prolonged labor, oxytocin use, cesareans, and/or intrapartum morbidity/mortality as compared to 'usual' care. Still, partograph use is not nearly as widespread as their benefit deems appropriate and only rarely in the U.S. Our research team has developed a physiologically-based partograph for '*in-hospital*' use in assessing the labors of nulliparous women with spontaneous labor onset. We posit that our tool greatly improves on existing designs by incorporating several evidence-based principles that combine to give needed clinical meaning to 'dystocia' as a diagnosis. This should, in turn, optimize the safety of mother and fetus during labor.

The hypotheses

Our physiologically-based partograph was developed to improve '*in-hospital*' birth safety as compared to 'usual care' among low-risk, nulliparous women with spontaneous labor onset. We hypothesize that:

1. Partograph use will safely limit diagnoses of dystocia during the first stage of labor to only the slowest 10%.
2. Partograph use will decrease oxytocin augmentation rates by ≥50% while having no significant influence on most other labor process variables, e.g., amniotomy rates, analgesia use.
3. Partograph use will significantly decrease cesareans performed for dystocia by ≥50% while having no significant influence on other labor outcome variables, e.g., Apgar scores, postpartum hemorrhage rates.

The partograph

Our partograph is a simple-to-use, inexpensive, evidence-based tool designed to aid hospital-based labor care providers in the early detection of abnormal labor progress among low-risk, term (≥37 weeks gestation), nulliparous women carrying a singleton, cephalic presenting fetus who have a spontaneous onset of labor (Fig. 1). This tool is structured to allow sufficient time for the events of physiological labor to progress without unnecessary interventions while also indicating when interventions aimed at accelerating labor may be justified. It also allows the ongoing evaluation of the effect of interventions, when used. Our partograph design incorporates four evidence-based principles (see Table 1).

Principles of partograph with rationale

Principle 1

Active labor onset must be accurately diagnosed before the rate of cervical dilation (cm/h) is used to assess labor progression.

Correctly establishing that a parturient is in 'active' labor, i.e., when the rate of cervical dilation begins to become progressively more rapid [22,30,31], is of utmost importance because it serves as the basis for identifying slow cervical dilation that might require accelerative intervention. Unfortunately, truly active labor can never be diagnosed prospectively; rather, it can only be determined retrospectively based on an assessment of adequate cervical dilation over time (cm/h).

In 'usual' clinical practice, laboring women are typically admitted to labor units under criteria commonly *associated with* 'active' phase labor which is suggested to reliably begin between 3 cm and 5 cm, in the presence of uterine contractions [22]. However, these criteria do not validly describe active labor onset for many, if not a majority of, nulliparous women with spontaneous labor onset when traditional cervical dilation expectations are used to differentiate active from earlier labor [32,33]. The clinical dilemma is that many women are inadvertently admitted prior to progressive

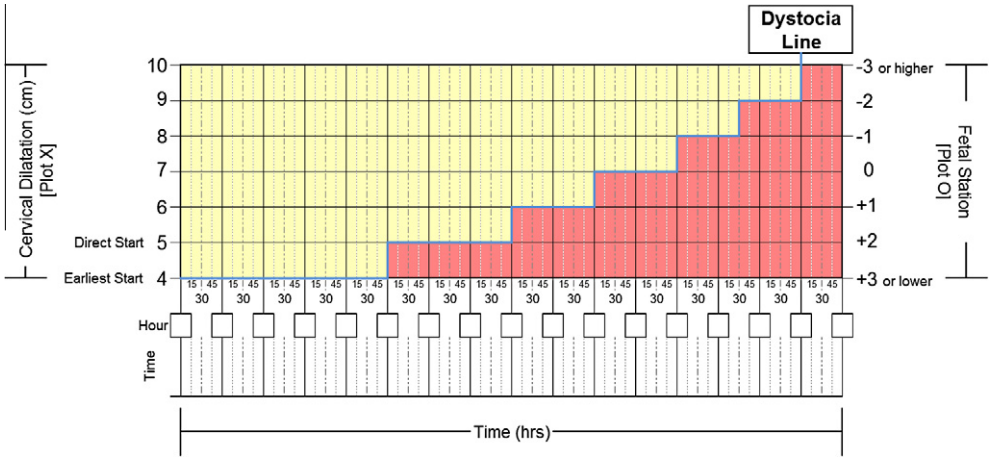

Fig. 1. Partograph for low-risk, nulliparous women with spontaneous labor onset.

Table 1
Principles of partograph.

Principle 1	Active labor onset must be accurately diagnosed before the rate of cervical dilation (cm/h) is used to assess labor progression.
Principle 2	Expectations of cervical dilation (cm/h) for the population must be appropriately-defined.
Principle 3	Cervical dilation rates progressively accelerate throughout the majority of active labor.
Principle 4	The time duration necessary to dilate from one centimeter to the next is more variable in earlier active labor than in more advanced active labor.

labor yet held to dilation rate expectations of active labor which undoubtedly contributes to overdiagnoses of dystocia.

The timing of labor admission among low-risk, nulliparous women with spontaneous labor onset influences the labor process and outcomes. Women admitted early (e.g., <4 cm dilatation) are approximately twice as likely to be augmented with oxytocin when compared to women admitted in more active labor [1,2,34]. Indeed, the rate of oxytocin use is inversely related to cervical dilatation at admission ($r = -0.79$, $p < 0.05$) [35]. Moreover, receiving oxytocin at an earlier stage of labor is associated with a higher cesarean risk [5]. The cesarean rate following early labor admission in this low-risk population is reported to be more than twice as high as the reference group rate in most studies [1–5] although an Italian team recently reported no difference in cesarean rates between women presenting at ≤4 cm or >4 cm [35]. Cesareans for dystocia were higher in the early admission groups in both identified studies reporting specific surgical indications ($p < 0.001$ in each study) [1,4]. These findings corroborate those from a study reporting that before 4 cm dilatation, the earlier a woman is admitted for labor is *linearly* related to her cesarean delivery risk [5]. Main et al., in their study of 41,416 nulliparous births, concluded that early admission alone explains 38% of the variation in cesarean rates among low-risk, nulliparous women with spontaneous labor onset ($r = 0.62$, $p < 0.0001$) [6].

Half of all cesareans performed in nulliparous women for dystocia occur at ≤5 cm dilatation [36]. This raises concern that many cesareans may be performed *prior to* active labor which is contrary to the guideline of the American College of Obstetricians and Gynecologists, that is, cesareans for slow progress should not be performed prior to active cervical dilation and then only after an adequate trial of labor [21].

Our physiologically-based partograph incorporates contemporary findings which indicate that progressive labor for nulliparous women can only be known to reliably begin at ≥5 cm cervical dilatation [24,25,37]. Before 5 cm dilatation, only adequate cervical change over time (e.g., ≥1 cm in ≤2 h time window) demonstrates progressive labor. Partograph initiation should not occur prior to 4 cm dilatation since such 'early' admissions are associated with more intervention and/or cesarean deliveries for low-risk, nulliparous women with spontaneous labor onset [1–6,34,35].

Principle 2

Expectations of cervical dilation (cm/h) for the population must be appropriately-defined.

The rate of cervical dilation (cm/h) in the first stage of labor is the backbone of decision making for clinicians providing care to laboring women. Early work regarding expectations of dilation for nulliparous women during the active phase was published by Friedman beginning in the 1950s. It is the mean – 2 SD cervical dilation rate of 1.2 cm/h that Friedman reported in his *phase of maximum slope* [30,31] that is often considered to be slowest acceptable rate of dilation during nulliparous active labor. The '1 cm/h rule' commonly applied in clinical settings was borne from Friedman's work representing the slowest yet normal dilation from approximately 4 cm through complete dilatation.

Common partograph designs display time (h) and cervical dilatation (cm) on the *x*-axis and *y*-axis, respectively. Most have incorporated Friedman's findings through use of a graphically straight 'alert' line that represents a dilation rate of 1 cm/h (Fig. 2). Alert line incorporation was meant to represent the cervical dilation rate of the slowest 10% of nulliparous women in active labor so that timely transfer from lower- to higher-resource settings could be accomplished [38]. An 'action' line is conventionally placed a number of hours to the right of the 'alert' line, most commonly 4 h. Only when the 'action' line is reached are more aggressive management

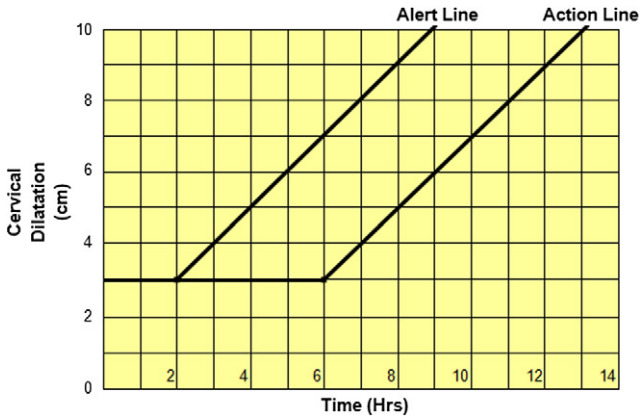

Fig. 2. Central component of common partographs. Reprinted with permission of John Wiley and Sons from Philpott RH, Castle WM. Cervicographs in the management of labour in primigravidae. I. The alert line for detecting abnormal labour. J Obstet Gynaecol Br Commonw 1972;79(7):592–598.

interventions such as oxytocin augmentation typically initiated in an attempt to accelerate labor progress.

Although the 'alert' line is purported to discriminate only the slowest 10% of nulliparous labors [38], studies spanning the past four decades have consistently reported that approximately 18–56% of nulliparous women cross the 'alert' line following partograph initiation (see Table 2) [38–48]. Indeed, *it is the 'action' line rather than the 'alert' line that better segregates the slowest 10% of nulliparous women* although even the 4-h 'action' line is crossed by 10–45% of nulliparous women. Of note, the 4-h action line can only be crossed when dilation averages <0.64 cm/h for partographs initiated at 3 cm, <0.60 cm/h for partographs initiated at 4 cm, and <0.56 cm/h for partographs initiated at 5 cm.

Contemporary, non-partograph studies of low-risk, nulliparous women also support that the slowest-yet-normal '*linear*' rate of cervical dilation for this population is much slower than 1 cm/h. When defining active labor as the time necessary for the cervix to dilate from 4 cm to 10 cm, low-risk nulliparous women achieving spontaneous labor and birth without adverse outcome have active labor dilation rates that range between 0.8 and 1.0 cm/h at the mean and between 0.3 and 0.5 cm/h at the mean – 2 SD [49–51]. These findings confirm those of Perl and Hunter [52] who purport that labors progressing at ≥0.5 cm/h, in the absence of other problems, be considered within normal limits. In their study, 10.3% of term, nulliparous women with a spontaneous labor onset progressed at <0.5 cm/h. When beginning with criteria commonly associated with the onset of active labor (i.e., dilatation of 3–5 cm + regular contractions), a recent systematic review of nulliparous women ($n = 7009$) concluded that mean dilation is 1.2 cm/h while mean – 2 SD dilation approximates 0.6 cm/h [33].

In sum, the extant literature indicates that a linear dilation rate approximating 0.5 cm/h should be achievable for approximately 90% of laboring nulliparous women. Our partograph incorporates this average threshold but in light of the progressive acceleration in cervical dilation that accompanies typical labors.

Principle 3

Cervical dilation rates progressively accelerate throughout the majority of active labor.

Cervical dilation during 'active labor' is not *linear*. Some investigators have concluded that a sigmoid pattern develops [30,31,35] while others report that a hyperbolic pattern lacking a deceleration phase predominates [24,25,37]. In either scenario, cervical dilation rates accelerate throughout the majority of active labor, if not all of

Table 2
Nulliparous women assessed via partographs with 'alert' and 4-h 'action' lines.

Study	Year	Country(ies)	Earliest partograph initiation	*n*	Alert line crossed (<1 cm/h)	Action line crossed (<0.64 cm/h)
Philpott et al. [38,39]	1972	Zimbabwe	3 cm	624	21.8% (*n* = 136)	10.9% (*n* = 68)
Drouin et al. [40]	1979	Cameroon	3.4 ± 0.6 cm[a]	480	56.3% (*n* = 270)	32.3% (*n* = 155)
World Health Organization [41]	1994	Indonesia, Thailand, & Malaysia	3 cm	2397	30.9% (*n* = 741)	11.7% (*n* = 281)
Lavender et al. [42]	1998	England	3 cm	311	Not reported	38.1% (*n* = 118)
Lavender et al. [43]	1999	England	3 cm	171	Not reported	37.4% (n = 64)
Pattinson et al. [44]	2003	South Africa	4 cm	350	49.7% (*n* = 174)	Not reported
Lavender et al. [45]	2006	England	3 cm	1485	Not reported	45.3% (*n* = 673)
Mathews et al. [46][b]	2007	India	3 cm	175	19.4% (*n* = 34)	10.9% (*n* = 19)
			4 cm	156	17.9% (*n* = 28)	1.3% (*n* = 3)
Orji [47]	2008	Nigeria	4 cm	259	34.8% (*n* = 90)	18.5% (*n* = 48)
van Bogaert [48]	2009	South Africa	3 cm	1595	34.4% (*n* = 548)	10.1% (*n* = 161)

[a] Mean dilatation at "active phase" onset.
[b] Two partographs with 4-h action lines were tested in this study.

it. Zhang et al. [25], for example, report that cervical dilation accelerates with each passing centimeter among low-risk, term, nulliparous women ($n = 1162$) with a spontaneous labor onset. Median rates of dilation between 3–4, 4–5, 5–6, 6–7, 7–8, 8–9, and 9–10 cm were 0.4, 0.6, 1.2, 1.7, 2.2, 2.4, and 2.4 cm/h, respectively. At the 5th percentile, these dilation rates were 0.1, 0.2, 0.3, 0.5, 0.7, 0.8, and 0.7 cm/h, respectively, never exceeding 1 cm/h despite half of the women in this study receiving oxytocin augmentation during labor.

Linear conceptualizations of cervical dilation, although common in contemporary practice, are fundamentally flawed leading to expectations that are likely unrealistically fast in earlier active labor for low risk, nulliparous women as described previously [53]. Zhang and et al. [25] findings can be used to illustrate the shortcomings of viewing cervical dilation linearly. From 3 cm forward, calculations based on their data demonstrate that dilation rates conceptualized as linear (Fig. 3, solid line) are faster than actual rates (Fig. 3, dashed line) until some point after 5 cm dilatation when the linear rates become slower than actual rates. Thus, diagnoses of dystocia and interventions aimed at correcting 'slow' labor are much more likely in earlier active labor when linear dilation expectations are less likely to be met [53]. Bearing this in mind, the expectation of cervical dilation in our partograph is based on hyperbolic progression.

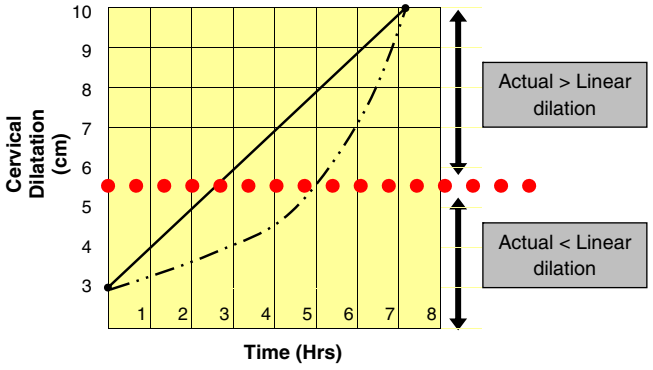

Fig. 3. Hyperbolic, median nulliparous labor curve with linear conceptualization. (– · · –) Hyperbolic labor curve (median) (derived from Zhang et al. [25]), (—) dilation conceptualized linearly (based on Zhang et al. [25]). Reprinted with permission of John Wiley and Sons from Neal JL, Lowe NK, Patrick TE, Cabbage LA, Corwin EJ. What is the slowest-yet-normal cervical dilation rate among nulliparous women with spontaneous labor onset? J Obstet Gynecol Neonatal Nurs 2010;39(4):361–369.

Principle 4

The time duration necessary to dilate from one centimeter to the next is more variable in earlier active labor than in more advanced active labor.

As rates of cervical dilation accelerate with advancing labor, the time necessary to dilate from one centimeter to the next is typically less variable [24,25,37]. Therefore, while it is appropriate for clinicians to wait several hours prior to intervening as the cervix changes in early active labor (e.g., from 4 cm to 5 cm), it may be inappropriate to wait as long later in labor (e.g., between 8 cm and 9 cm). Our partograph accommodates this through progressively shorter horizontal sections of the '*dystocia line*' with advancing dilatations which concomitantly sculpt the hyperbolic landscape of the partograph (see Fig. 1). In addition, at ≥5 cm dilatation, oxytocin augmentation may be considered any time there is a >4 h delay in cervical change *even if the dystocia line has not been crossed*. While it is hypothesized that our partograph will safely limit diagnoses of dystocia during the first stage of labor to only the slowest 10%, diagnoses of dystocia at each integer dilatation point should be equally dispersed. If this is not the case, modification of the dystocia line may be indicated.

Use of Partograph: Our new partograph for nulliparous women is designed for '*in-hospital*' use in settings staffed with trained labor care providers and with the maternal and fetal monitoring capabilities that are typical in the U.S. and other developed countries. It is composed of a '*dystocia line*' and displays time (h) on the *x*-axis and cervical dilatation (cm) and fetal station on the *y*-axis (see Fig. 1).

The spontaneous onset of labor is a prerequisite of partograph use. Labor is defined as regular, painful contractions (minimum 2 in 10 min, each lasting ≥40 s) and complete or near complete effacement (i.e., 80–100%). Membranes may be intact or ruptured and bloody show may be absent or present. The partograph is initiated in the presence of labor *and* a qualifying cervical exam, i.e., at 4 cm dilatation if being preceded by cervical change over time (i.e., ≥1 cm in ≤2 h window) or at ≥5 cm regardless of the rate of previous cervical change.

Cervical dilatation examinations are recognized to be crude assessments that rely solely on the clinical experience and proprioceptive skill of the examiner. Because labor care providers accurately determine actual cervical dilatation in only half of all cases [54–57] but are accurate to ±1 cm from actual dilatation in approximately 90% of cases [54,56,57], dilatations reported as a range are not recognized on the partograph. Instead, range dilatations are rounded *down* to the nearest integer dilatation, e.g., "4–5 cm" is rounded to 4 cm. The partograph should only be initiated and continued when there are no complications that require urgent attention through intervention. Admission for labor prior to partograph eligibility does not preclude use of this tool as long as interventions aimed at accelerating labor (i.e., oxytocin augmentation, amniot-

omy) are not initiated prior to the woman becoming partograph 'eligible' as previously described.

Only cervical dilatation (plotted as 'X'), descent of the fetal head (plotted as 'O'), and the time of the cervical examination are charted on the partograph. The first qualifying cervical exam is plotted directly *on the dystocia line* with an 'X' and fetal station is plotted with an 'O'. To minimize error and facilitate ease-of-use, the time of exam is rounded to *most recent* 15-min increment and entered on the appropriate 'Time' line, e.g., an exam performed at 3:21 pm is rounded to 3:15 pm for partograph purposes. This is documented as 'Hour' zero ('0') in the accompanying box. The time line and hour boxes are then completed in 1-h increments from the point of the first documented examination forward. Subsequent examinations are documented on the appropriate partograph 'time' line after rounding to the *most recent* 15-min increment. Labor progress is assessed on the partograph based on cervical change over time. Future computerization of this instrument should eliminate the need to round via automatic population of the time lines following exam entry.

For cervical dilation remaining *left of* or *on the dystocia line*, no interventions are indicated. For labor moving *to the right of the dystocia line*, thorough assessment is indicated with consideration of management options including supportive therapy only, oxytocin augmentation, or delivery. Additionally, at $\geq$5 cm dilatation, oxytocin augmentation may be considered any time there is a >4 h delay in cervical change (i.e., no change to the next integer dilatation) *even if the dystocia line has not been crossed*. The particular oxytocin regimen used and/or the decision to perform a cesarean for dystocia is not directed by the partograph. Ideally, any decision to proceed with cesarean delivery should require a mandatory,

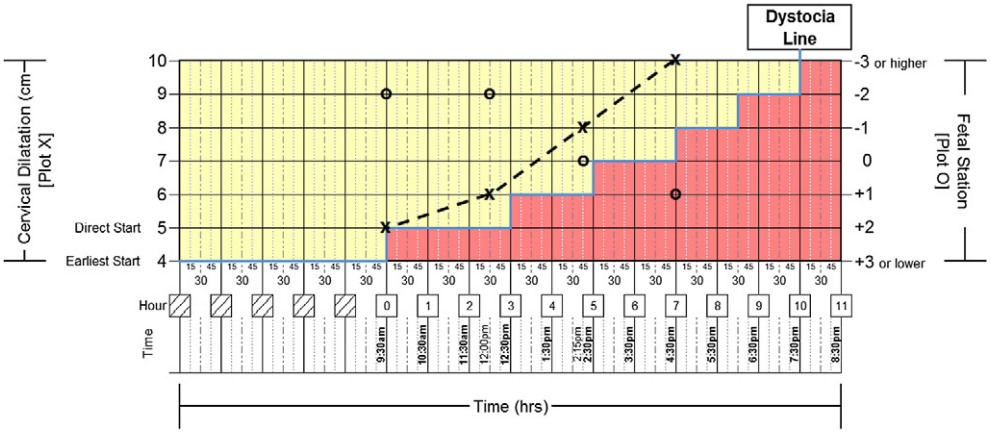

Fig. 4. Example 1: Labor remaining left of the dystocia line without delay. Scenario: (i) At 9:37 am, the cervix is dilated 5 cm and the fetal head is at −2 station. The partograph is initiated by plotting an 'X' at 5 cm on the dystocia line and an 'O' at −2 station. On the time line, 9:30 am is documented which becomes the start of hour zero ('0'). The time line is completed in 1-h increments from that point forward. (ii) At 12:03 pm, the cervix is dilated 6 cm and the fetal head is at −2 station. Labor progress is adequate, remaining left of the dystocia line and without delay. (iii) At 2:25 pm, the cervix is dilated 8 cm and the fetal head is at 0 station. Labor progress is adequate, remaining left of the dystocia line and without delay. (iv) At 4:40 pm, the cervix is completely dilated and the fetal head is at +1 station. Use of the partograph is complete. Second stage labor is managed in the 'usual care' pattern of the labor care provider.

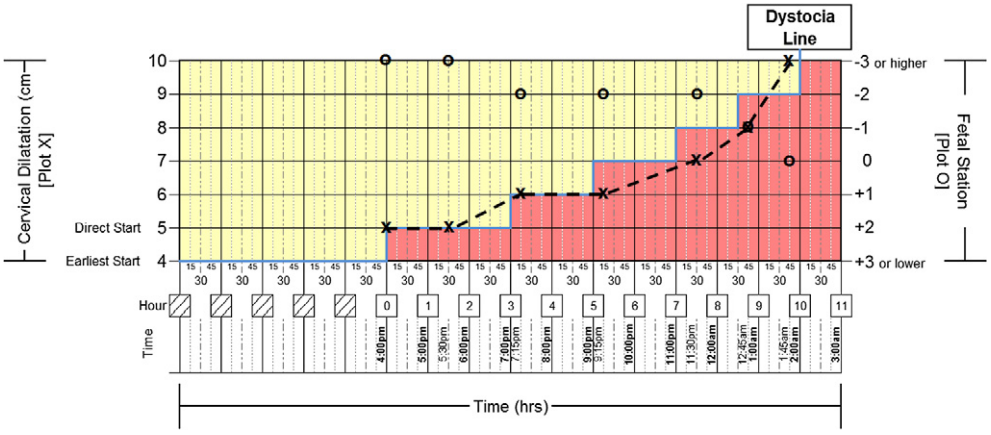

Fig. 5. Example 2: Labor moving right of the dystocia line. Scenario: (i) At 4:07 pm, the cervix is dilated 5 cm and the fetal head is at −3 station. The partograph is initiated by plotting an 'X' at 5 cm on the dystocia line and an 'O' at −3 station. On the time line, 4:00 pm is documented which becomes the start of hour zero ('0'). The time line is completed in 1-h increments from that point forward. (ii) At 5:41 pm, the cervix is dilated 5 cm and the fetus head is at −3 station. Labor remains left of the dystocia line without partograph-defined delay. (iii) At 7:15 pm, the cervix is dilated 6 cm and the fetal head is at −2 station. Labor progress is adequate, remaining left of the dystocia line and without delay. (iv) At 9:20 pm, the cervix is dilated 6 cm and the fetal head is at −2 station. Labor dystocia is diagnosed as progress moves right of the dystocia line. Thorough assessment is indicated with management option choices including supportive therapy only, oxytocin augmentation, or delivery. Oxytocin augmentation is chosen. (v) At 11:39 pm, the cervix is dilated 7 cm and the fetal head is at −2 station. Labor remains right of the dystocia line. (vi) At 12:52 am, the cervix is dilated 8 cm and the fetal head is at −1 station. Labor remains right of the dystocia line. (vii) At 1:50 am, the cervix is completely dilated and the fetus is at 0 station. Use of the partograph is complete. Second stage labor is managed in the 'usual care' pattern of the labor care provider.

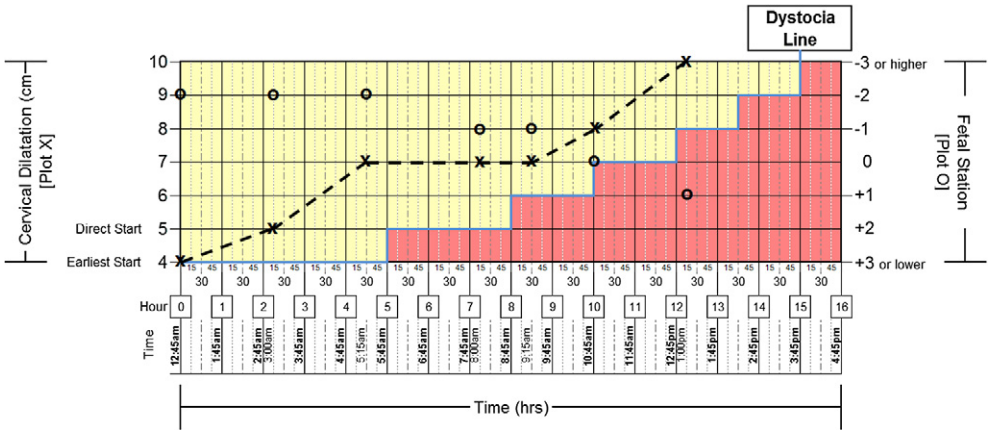

Fig. 6. Example 3: Labor remaining left of the dystocia line with delay. Scenario: (i) At 11:15 pm, the cervix is dilated 3 cm and the fetal head is at −2 station. The parturient does not yet meet criteria for partograph initiation. (ii) At 12:54 am, the cervix is dilated 4 cm and fetal head remains at −2 station. The partograph is initiated due to ≥1 cm change in dilation in ≤2 h window. An 'X' is plotted at 4 cm on the dystocia line and an 'O' is plotted at −2 station. On the time line, 12:45 am is documented which becomes the start of hour zero ('0'). The time line is completed in 1-h increments from that point forward. (iii) At 3:06 am, the cervix is dilated 5 cm and the fetal head is at −2 station. Labor progress is adequate, remaining left of the dystocia line and without delay. (iv) At 5:19 am, the cervix is dilated 7 cm and the fetal head is at −2 station. Labor progress is adequate, remaining left of the dystocia line and without delay. (v) At 8:10 am, the cervix is dilated 7 cm and the fetal head is at −1 station. Labor remains left of the dystocia line without partograph-defined delay. (vi) At 9:22 am, the cervix is dilated 7 cm and the fetal head is at −1 station. Labor progress is delayed due to the >4 h delay in cervical change. Thorough assessment is indicated with management option choices including supportive therapy only, oxytocin augmentation, or delivery. Oxytocin augmentation is chosen. (vii) At 10:52 am, the cervix is dilated 8 cm and the fetal head is at 0 station. Labor progress is again adequate, remaining left of the dystocia line. (viii) At 1:02 pm, the cervix is completely dilated and the fetal head is at +1 station. Use of the partograph is complete. Second stage labor is managed in the 'usual care' pattern of the labor care provider.

independent second provider opinion since this alone reportedly decreases unnecessary cesareans by approximately 2.2% [58]. Other labor management decisions are per provider 'usual care' patterns, e.g., pain management, timing of amniotomy, cervical examination frequency, and other labor interventions. Observations of fetal condition (e.g., heart rate, amniotic fluid appearance, molding), uterine activity (e.g., frequency, duration, strength), and maternal condition (e.g., vital signs, urine output) during labor will be assessed per the 'usual care' patterns dictated by institutional policy.

Figs. 4–6 display examples of correctly completed partographs with accompanying scenario data.

Testing the hypotheses

To test our hypotheses, we suggest a three-group comparative design. Specifically, we propose that labor process and labor outcome variables be compared between a *partograph-assessed* labor group and two 'usual' labor care groups, i.e., a *historical group* of patients attended in labor by the partograph providers but prior to partograph introduction and a *concurrent group* of patients attended in labor by different providers not trained on partograph use. A randomized controlled trial within a single institution is not feasible due to threats to internal validity. However, a trial involving randomization of sites to either partograph or usual care may be accomplished in a multicenter trial as long as inter-institutional practice patterns are comparable prior to the start of the study and there is no overlap of providers between institutions.

The sample should include nulliparous women of low obstetric risk who are carrying a singleton, cephalic presenting fetus at term gestation. Labor must have a spontaneous onset with an anticipated vaginal birth. We recommend that the labor process be evaluated, at minimum, with the following variable package: cervical dilatation at labor admission, amniotic membrane rupture timing and type (i.e., spontaneous or artificial), oxytocin use and timing, analgesia use and timing, epidural use and timing. The labor outcome variable package should include delivery mode, 'in-hospital' labor duration, Apgar scores, neonatal disposition (i.e., newborn nursery or special care nursery), postpartum hemorrhage, costs, and maternal satisfaction with her birth experience.

Consequences of the hypotheses

Our physiologically-based partograph is designed to safely limit diagnoses of dystocia to only the slowest 10% of low-risk, nulliparous women with spontaneous labor onset. If successful, this instrument will give needed clinical meaning to 'dystocia' as a diagnosis for this population. This should, in turn, safe-guard against unnecessary, injudicious, and potentially harmful use of oxytocin when labor is already adequately progressing while also indicating when its use may be justified. We hypothesize that approximately 10% of women whose labors are assessed by our partograph will receive oxytocin while cesareans performed for dystocia will decrease by ≥ 50%. No significant influence on other labor outcome variables is expected with partograph use.

The best perspective from which to view the potential impact of our partograph is in the light of contemporary maternity statistics. Presently, dystocia is known to be "over-diagnosed" [22] explaining why approximately 50% of nulliparous women with spontaneous labor onset receive oxytocin augmentation during labor [24–27]. This compromises birth safety since oxytocin is the intervention most commonly associated with preventable adverse perinatal outcomes [29]. The current U.S. cesarean rate for low-risk, term, nulliparous women is 26.5% [13] with dystocia being the most commonly reported indication for this population [21,22]. These statistics indicate that the quality of obstetrical care is currently less than optimal in this nation particularly because the cesarean rate for low-risk, term, nulliparous women is a reliable indicator of obstetrical care quality [6,13,14].

The purpose of the 'dystocia line' incorporated in our partograph should not be confused with that of the 'action' lines found in most existing partographs. Action lines are meant to differentiate labors at higher risk of adverse outcome from those of lower risk thereby indicating a potential need for labor accelerative intervention. Unfortunately, the action line has not proven to effectively differentiate lower from higher risk groups as there is no clear dilation rate on the partograph below which perinatal morbidities

sharply rise. Indeed, the extent to which the relationship between prolonged labor and labor morbidity is causal is by no means certain. In comparison, our 'dystocia line' is not necessarily meant to indicate increased risk of adverse birth outcomes for women who cross to the right of it. Instead, in the philosophical spirit of *primum non nocere*, it is designed to improve the safety of those who do not cross this line by decreasing unnecessary oxytocin use and primary cesareans.

More than four million U.S. births occur each year and, of these, 40% are to nulliparous women. Ninety-nine percent of U.S. births occur in hospitals. Our partograph is designed for the '*in-hospital*' labor assessment of low-risk, nulliparous women with spontaneous labor onset, a high-volume group. This instrument provides a long-needed, evidence-based framework for homogeneous labor assessment. Widespread use of this physiologically-based partograph will be warranted if our hypotheses are supported.

Conflict of interest

The authors have no conflicts of interest to disclose.

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