Uterine Electrical Signals and Cervical Dilation During the First Stage of Labor

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Citation: Li P, Huang Q, Wang L, Garfield RE, Liu H. Uterine Electrical Signals and Cervical Dilation During the First Stage of Labor. Arch Obstet Gynecol. 2022;3(1):47-52.

Abstract

Objective: The purpose of this study was to explore the changes in uterine electrical signals recorded by electromyography in relationship with the progression of cervical dilation during the first stage of labor. **Methods:** Uterine electromyography was recorded from the abdominal surface for 30 min in 200 nulliparous women presenting at ≥ 370/7 weeks of gestation. Eight groups were defined as follows: Group 1 (n=10), non-laboring patients with no cervical effacement; Group 2 (n=15), patients with cervical effacement; Groups 3 to 7, patients in the first stage of labor with cervical dilation at 1–2 cm (n=10), 2–3 cm (n=50), 3–5 cm (n=45), 5–7 cm (n=30), and 7–9 cm (n=25), respectively; and Group 8 (n=15), patients in the second stage of labor with the cervix at 10 cm dilation. Uterine electromyography bursts were characterized by the analysis of various burst characteristics, including number of bursts, total power, and peak frequency of power density spectrum. Intergroup differences were assessed using one-way analysis of variance, and linear relationships between data were determined using Pearson's correlation coefficient. **Results:** The burst frequency (number/30 minutes) and power density spectrum peak frequency increased steeply to peak levels at a cervical dilation of about 3 cm. However, the electromyography burst power reached peak levels at a cervical dilation of 5–7 cm. The correlations of the frequency of bursts (R=0.934, P<0.001), power (R=0.890, P<0.001), and power density spectrum peak frequency (R=0.972, P<0.001) with cervical changes were significant. **Conclusions:** Uterine electromyography effectively quantifies the contribution of uterine muscle electrical activity to the advancement of cervical dilation with the progression of labor. This study suggests that the dilation of the cervix is related to uterine electricity activity, helping to clarify the labor process.

Keywords: Cervical dilation, Labor, Uterine contractility, Uterine electromyography

Introduction

Regular uterine contractions and cervical dilation are essential for the onset and progression of delivery or parturition and are the most common clinical indicators of labor. During the first stage of labor, the cervix gradually dilates to 10 cm in preparation for delivery. This cervical transformation determines how much resistance must be overcome to open the uterus, and uterine contractile activity determines how much muscular force must be exerted for birth [1]. For over 60 years, the basic phenomena of efficient contractions, cervical effacement, and cervical dilation have been formulated to provide definitions for the stages of labor [2-4]. These definitions and their relationship with clinical events, including the onset of labor, normal progression, latent labor, and active phases of labor, are critical for expert birth care.

The progress of labor from the latent to the active phase occurs when the rate of dilation accelerates. The terms 'dilation' and 'accelerates' connote an evolving, dynamic situation resulting from active uterine force. The various phases of labor are derived from studies based on the use of digital examination for cervical dilation and the use of the tocodynamometer (TOCO) or intrauterine pressure catheter for the estimation of uterine contractions [2-4]. Proper evaluation of the normality of labor requires accurate and quantitative assessment of both cervical dilation and the activity of uterine muscle contractions. The labor process should be evaluated with quantitative values of uterine activity rather than the qualitative and subjective expression of contraction, including strong vs. weak contractions assessed using

imprecise and inaccurate instrumentation. Uterine electrical activity organized into bursts is the basis for contractions, the mechanism underlying cervical effacement and dilation [5,6]. Electrical activity of the uterus can be objectively measured using electromyography (EMG) [7]. The previous studies also used EMG to examine the effect of analgesic on myoelectric activity of uterus during the first and second stages of labor, and to distinguish patients progressing with spontaneous labor from patients that develop uterine inertia [8-10]. However, to our knowledge, no prior study has examined the relationship of uterine EMG activity with cervical dilation. EMG technology should not only benefit the diagnosis of term labor, but it should also improve the accuracy of diagnosing the onset of active preterm labor [11-15]. The aim of this study was to clarify the relationship between uterine EMG, which monitors contractions, and cervical dilation, and to assess whether uterine EMG can distinguish the various phases of labor.

Materials and Methods

A prospective observational study of women undergoing labor and delivery were recruited from the delivery ward and the emergency department at a single medical center. The study protocol complied with the ethical guidelines and approval of the Guangzhou Women and Children's Medical Center (Protocol number 2014110533), and involved 200 nulliparous women of gestational age 37 to 41 weeks. Gestational age was calculated from the date of the first day of the last menstrual period and was confirmed using early ultrasound scans. Informed consent was obtained from all study participants. All the women had singleton pregnancies. Women with any of the following were excluded: (1) medical complications of pregnancy including hypertension, cholestasis, gestational diabetes; (2) multiple gestations; (3) oligohydramnios; (4) malpresentation; (5) antepartum hemorrhage; and (6) fetal distress.

Women were enrolled into eight groups. Group 1 included 10 non-laboring patients with no cervical effacement. Group 2 (n=15) comprised patients with cervical effacement. Groups 3 to 7 consisted of patients in the first stage of labor with cervical dilation at 1–2 cm (n=10), 2–3 cm (n=50), 3–5 cm (n=45), 5–7 cm (n=30), and 7–9 cm (n=25), respectively, while Group 8 (n=15) included patients in the second stage of labor, with the cervix at 10 cm dilation. Cervical examinations were performed by various clinicians who were blinded to the results of the former examinations. Cervical dilation and effacement were assessed in the intervals between uterine contractions. The patients were not followed longitudinally with series of cervical dilation measurements conducted on the same patient at various times, but rather were randomly selected and underwent cervical dilation measurement and EMG. Maternal age, body mass index, gestational age, and birth weight, 1st stage of labor, 2nd stage of labor were also recorded. Data from patients treated with oxytocin were not used for the analysis.

Uterine EMG activity was recorded for 30 min from the abdominal surface using a PowerLab electromyograph (AD Instruments, Castle Hill, NSW, Australia) and 4 Ag-AgCl differential bipolar electrodes (Shanghai Jun Kang Medical Supplies Co. Ltd., Shanghai, China) placed around the navel. Each electrode was separated from the others by approximately 3 cm. A reference electrode was placed laterally on the patient's hip. EMG signals were amplified deferentially with respect to the reference electrode. All data were sampled at 1000 samples/second. Uterine EMG signals were digitally filtered to yield a final bandpass of 0.34–1.00 Hz to exclude most components of motion, respiration, and cardiac signals, while preserving the main contraction signals where 98% of uterine electrical activity is found [11]. All patients were also monitored with a standard TOCO using a standard maternal-fetal monitor (Philips, Avalon FM20, Best, Netherlands).

The following criteria were used to identify EMG bursts (Chart 8.0 software, AD Instruments): (1) continuous group of positive and negative signals of at least twice the baseline amplitude; (2) group of signals not returning to baseline for longer than 10 seconds; and (3) bursts usually accompanied by contractions shown on the TOCO. Parameters analyzed for EMG burst characteristics included burst frequency (number bursts/30 minutes), total EMG power (pV^2), and peak frequency of the power density spectrum (PDS, in Hz). EMG total power was used to assess energy and amplitude of the EMG burst activity.

Intergroup differences were assessed using one-way analysis of variance and statistical significance for all tests was set at P<0.05. Power analysis was performed using a power of 0.80 and an alpha of 0.05, to yield a desired minimum sample size of 7 per group based on uterine EMG data from our previous studies. Linear relationships between data were determined using Pearson's correlation coefficient (R). Statistical analyses were performed using SPSS 25.0 (SPSS statistics by IBM, Armonk, NY, USA).

Results

There were no statistically significant differences in terms of demographic or obstetric characteristics between the groups (Table 1).

The relationships between the various components of bursts of uterine electrical activity that produce uterine contractions, including the frequency of bursts, power, and PDS peak frequency, are demonstrated in Figures 1- 3, respectively. With the progression of labor, the interval of each uterine contraction shortened and the PDS frequency obtained from the uterine EMG increased, particularly during the cervical dilations of 3 cm (the traditional active phase of labor). Most importantly, with the progression of cervical dilation, the

Table 1: Demographic and obstetric variables.

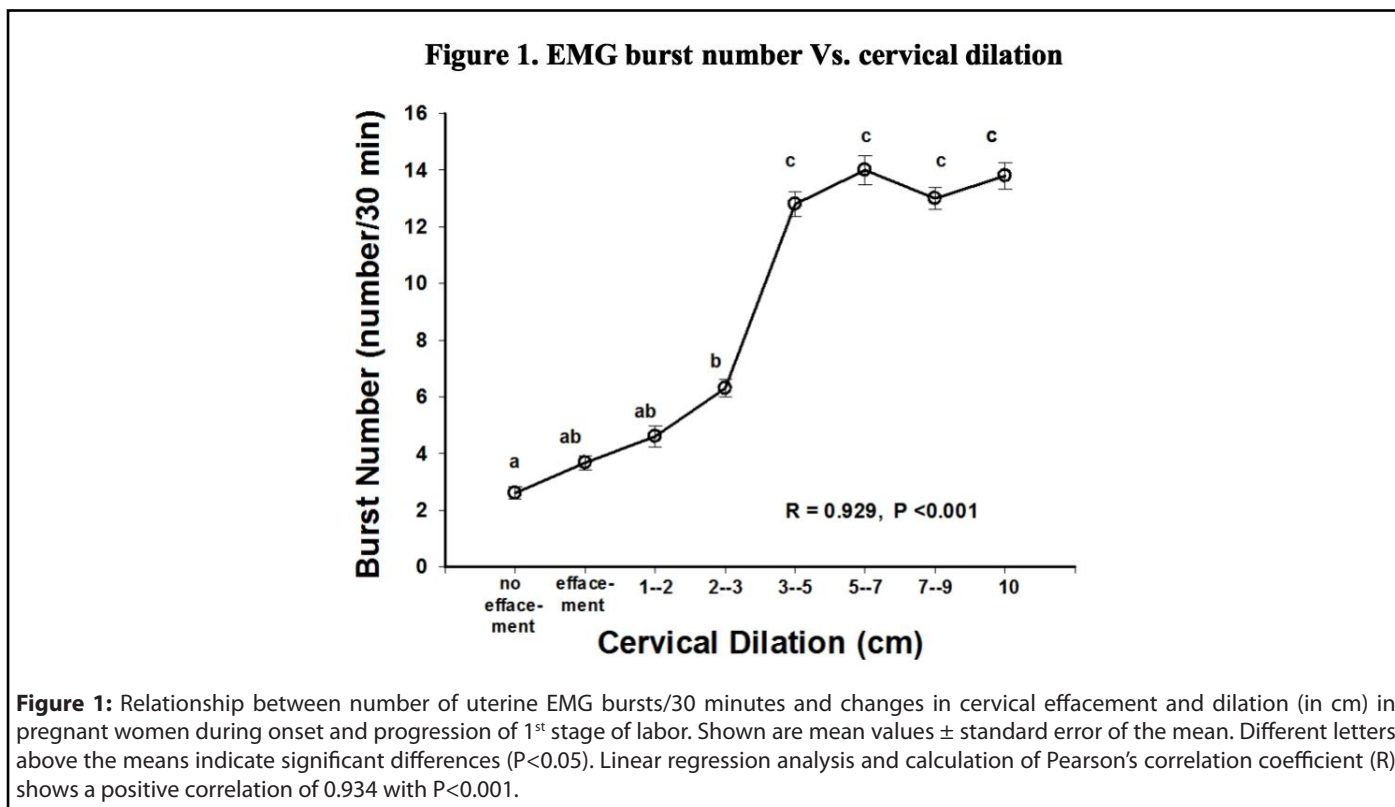| Groups	Age (y)	BMI (kg/m²)	Gestational age (week)	Birth weight (g)	1st stage of labor (min)	2nd stage of labor (min)
Group 1 (N=10)	30.30 ± 1.03	25.24 ± 0.98	39.49 ± 0.37	3168 ± 98	630.00 ± 93.00	51.00 ± 8.60
Group 2 (N=15)	29.73 ± 0.81	26.15 ± 0.73	40.11 ± 0.23	3128 ± 90	492.73 ± 35.92	63.27 ± 7.77
Group 3 (N=10)	26.90 ± 0.59	27.06 ± 1.21	39.94 ± 0.29	3212 ± 78	661.00 ± 102.44	46.40 ± 9.88
Group 4 (N=50)	28.20 ± 0.44	24.93 ± 0.32	39.62 ± 0.14	3177 ± 52	596.11 ± 39.46	53.24 ± 5.45
Group 5 (N=45)	27.98 ± 0.56	24.71 ± 0.42	39.90 ± 0.12	3273 ± 52	631.17 ± 36.95	48.89 ± 5.35
Group 6 (N=30)	28.07 ± 0.63	25.98 ± 0.58	39.77 ± 0.18	3288 ± 50	587.60 ± 47.76	59.30 ± 8.24
Group 7 (N=25)	27.80 ± 0.43	24.34 ± 0.48	39.34 ± 0.19	3228 ± 70	484.00 ± 47.42	72.87 ± 9.93
Group 8 (N=15)	28.13 ± 0.76	25.41 ± 0.65	39.29 ± 0.30	3084 ± 103	599.73 ± 16.88	56.40 ± 2.69
P	0.17	0.07	0.1	0.47	0.23	0.36

Patient demographics and characteristics in this study. Group 1, non-laboring patients with no cervical effacement; Group 2, comprised patients with cervical effacement; Groups 3 to 7 consisted of patients in the first stage of labor with cervical dilation at 1–2 cm, 2–3 cm, 3–5 cm, 5–7 cm, and 7–9 cm; Group 8, patients with the cervix at 10-cm dilation. All values are means ± standard error of the mean. There were no significant differences (P>.05) between the groups.

power of each uterine contraction increased, when comparing early cervical dilation to cervical dilation of 5–7 cm (the new definition of active phase of labor).
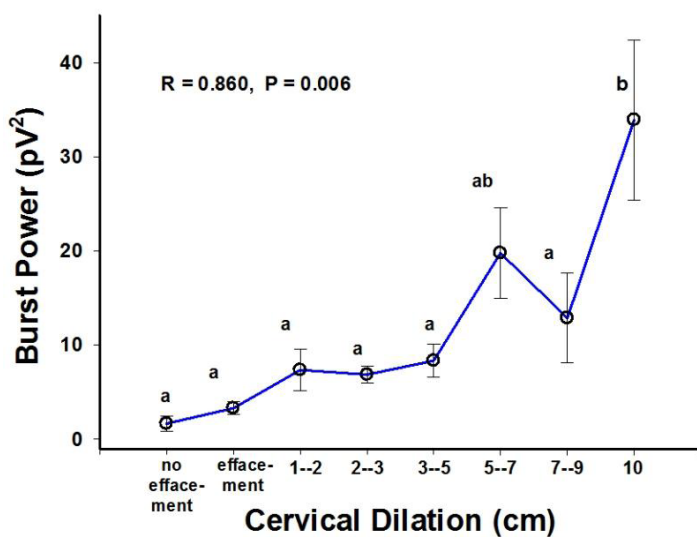
As shown in Figure 1, the correlation of the frequency of the bursts with cervical changes was significant (R=0.934, P<0.001). The burst frequency (number/30 minutes) was significantly greater after entering labor (Group 5, 12.10 ± 0.37) than before labor (Group 1, 2.60 ± 0.22) (P<0.05). The burst frequency increased progressively from no effacement to 2–3 cm of cervical dilation (P<0.05), and subsequently more steeply to a peak level at about 3 to 5 cm of cervical dilation (P<0.05), but levelled off thereafter.

The relationship between EMG burst power and changes in cervical effacement and dilation is shown in Figure 2. Linear

Figure 1: Relationship between number of uterine EMG bursts/30 minutes and changes in cervical effacement and dilation (in cm) in pregnant women during onset and progression of 1st stage of labor. Shown are mean values ± standard error of the mean. Different letters above the means indicate significant differences (P<0.05). Linear regression analysis and calculation of Pearson's correlation coefficient (R) shows a positive correlation of 0.934 with P<0.001.
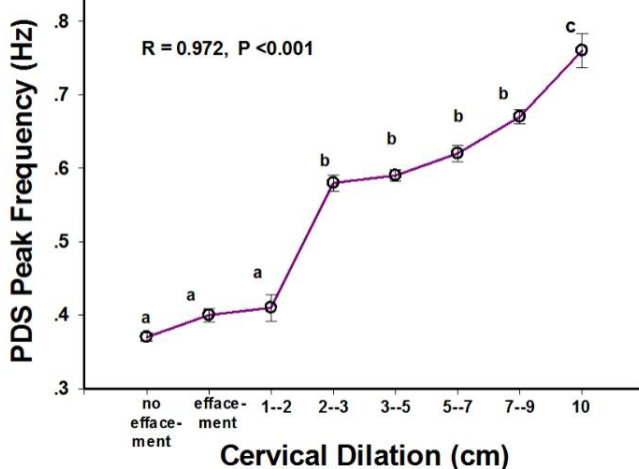
Figure 2: Data as shown in Figure 1. Relationship between EMG burst power and changes in cervical effacement and dilation. Linear regression analysis (R=0.860, P=0.006) and Pearson's correlation coefficient (R=0.860, P<0.001) reveal a significant relationship.

regression (R=0.860, P=0.006) and Pearson's correlation (R=0.860, P<0.001) analyses revealed significant relationships between EMG burst power and changes in cervical effacement and dilation. The total power values in Group 5 (20.08±1.29 pV^2), and Group 8 (33.93±8.51 pV^2) were significantly higher than that of Group 1 (1.65±0.80 pV^2, P < 0.05), suggesting that the total power of EMG burst increased with the progression of labor, and when the cervical dilation exceeded 5 cm, the total burst power attained peak values (Group 6, 18.16 ± 1.65 pV^2).

We also studied the relationship between EMG PDS peak frequency and changes in cervical dilation. As shown in Figure 3, positive and significant relationships were noted with linear regression analysis (R=0.972, P<0.001) and Pearson's correlation coefficient (R=0.972, P<0.001). With the progression of labor, the PDS peak frequency of Group 4 (0.58 ± 0.01 Hz, cervical dilation of 2-3 cm) was markedly greater than those of groups with cervical dilation less than 2 cm (Group 1, 0.37 ± 0.01 Hz, P<0.05; Group 2, 0.40 ± 0.01 Hz, P<0.05; Group 3, 0.41 ± 0.02 Hz, P<0.05).

Figure 3: Data as shown in Figure 1. Relationship between EMG power density spectrum (PDS) peak frequency and changes in cervical effacement and dilation. Linear regression analysis (R=0.972, P<0.001) and Pearson's correlation coefficient (R=0.972, P<0.001) demonstrate a positive and significant relationship.

Discussion

This study systematically analyzed several important burst characteristics of uterine electrical activity during the early to the advanced first stage of labor, demonstrating the relationship between the cause of uterine contractility and cervical dilation. The study clearly demonstrated that: 1) frequency-related characteristics (frequency of burst, PDS peak frequency) of uterine electrical activity accompanied cervical dilation because both increased simultaneously with a very positive and significant correlation, and reached the inflection point while the cervical dilation was 2–3 cm (the old definition of the active phase of labor); and 2) the power-related parameter (total power) of each uterine contraction obtained from the uterine EMG increased, when considering the early cervical dilation and attained the inflection point when the cervical dilation reached 5–7 cm (the new definition of the active phase of labor).

There remain disputes regarding the starting point of the active period. However, the factors influencing the progression of labor have been largely neglected. Parturition is composed of two major steps: a relatively long conditioning (preparatory) phase, followed by a short secondary phase (active labor) [2,17]. These two might also be separated by a critical "interim phase", after which treatments for the prevention of labor may become ineffective. Cohen suggested that clinical parameters are the major factors influencing labor, and that both uterine contractions and the dilation of the cervix are important, indicating that uterine EMG activity with contraction force should also be a clinical parameter [17,18]. The findings of the current study indicate that the forceful contractions of the uterus should be strong enough during the later stages to overcome any passive (or active) resistance to dilation and delivery that the cervix may offer. These have significant implications for the management of labor and delivery.

Conventional teaching and the theoretical understanding of normal dilation rates have been dominated by the sigmoid curve of Friedman [2,3,19,20]. The perception of the latent phase and active phase was defined while the cervical dilation was 3 cm, and this affected the conduct of labor, as well as many routine measures and interventions that interrupt the natural course of labor in modern maternity units, including treatments for preterm labor, sedation, and epidural analgesia [21-25]. Our results showed, regarding the frequency-related parameters of uterine EMG, that while the cervical dilation was 2–3 cm, the frequency of myometrial electrical activity increased, corresponding to the physical condition of the women, particularly, the degree of pain, frequency, and tone of the increased contractions.

Zhang and colleagues reported that the acceleration of cervical dilation occurs after 6 cm, contrary to Friedman's results [4,26-28]. The use of 6 cm as the starting point of active labor has also led to the redefinition of problems with the diagnosis of labor and the elimination of some terms such as dystocia and arrest of labor. Our results also suggested that, with labor progression, the power-related parameter of uterine EMG increased and the inflection point was reached at the point where cervical dilation was 5–7 cm. This suggests that the dynamic increase in uterine contractions leads to increased cervical dilation rates, the objective characteristic of myometrial activity, suggesting that the starting point of activity may be between 5 and 7 cm dilation.

The overall effectiveness of labor depends on both the efficiency of contractions and cervical resistance [1]. However, effective contractions require optimally transformed myometrium electrical activity in which the uterus first stiffens and then shortens so that uterine force is effectively directed towards the cervix [1,6]. This important indicator of the progression of labor has been variably characterized as coinciding with regular contractions and increased contraction power. The various EMG patterns for women in labor suggest that electromyographic activity should be present in all women in active labor. Irregular weaker contractions may reflect the need for oxytocin augmentation or may even require delivery by Cesarean section according to the clinical diagnoses. Therefore, labor should be assessed using quantitative parameters of uterine activity rather than subjective parameters, based on contractility vis-a-vis strong vs. weak contractions measured inaccurately or only according to cervical dilation.

This study provided a new way of thinking about labor processes. Because of individual differences, we were unable to capture the EMG signals of different cervical dilations in each patient. Considering the findings of this study, we recommend further studies focusing on the routine use of the definition of the active phase of labor, to generate a component of standard labor management and may contribute further to satisfactory perinatal results and improved maternal outcomes.

Our studies showed that EMG activity is involved in the transition of uterine activity in term pregnancy during the first stage of labor when the cervix is dilating. The diagnosis of the onset of labor and the active phase of labor, which are important in obstetrics, could also benefit greatly from the use of uterine EMG. Uterine EMG is a useful tool for appropriate labor management and can be used as a guide when interventions are undertaken during labor.

Funding

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