# Quantitative analysis for grading uterine electromyography activities during labor

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**BACKGROUND:** The strength of uterine contraction is one of the decisive factors for labor progression and parturition. Clinicians usually encounter difficulties in early identification of inadequate contractions and in oxytocin treatment. Electromyography—an emerging technology for uterine contraction monitoring—can quantify the intensity of myoelectric activity of uterine contraction. Therefore, grading patients with different uterine contraction intensities by electromyography is of great significance to the clinical intensive management of uterine contraction and labor process.

**OBJECTIVE:** This study aimed to quantify and grade electromyography activity during the latent phase of the first stage of labor and explore its relationship with oxytocin treatment and length of labor.

**STUDY DESIGN:** We performed a retrospective cohort study to identify electromyography parameters as a predictor for oxytocin treatment and length of labor among a cohort of term singleton primipara (n=508) during the latent phase who delivered in Guangzhou between August 2018 and December 2021. The electromyography parameters were graded according to the quartile method, and the significance of grading and delivery outcome was explored. Univariate and multivariate logistic regression were used to determine the predictors of oxytocin treatment.

**RESULTS:** Maternal gestational age (adjusted risk ratio, 1.2; 95% confidence interval, 1.0−1.5), root mean square (adjusted risk ratio, 0.01; 95% confidence interval, 0.004−0.03), and power (adjusted risk ratio, 0.02; 95% confidence interval, 0.01−0.05) were significant predictors of oxytocin argumentation. The low electromyography activity group had a longer first stage labor and total labor time and were more likely to use oxytocin.

**CONCLUSION:** Electromyography parameters root mean square and power had high predictive values for later oxytocin treatment among patients with spontaneous labor. Patients with low-grade electromyography were more likely need oxytocin treatment. Electromyography grading is very important for its clinical promotion and use, and it could lead to more reliable analyses of oxytocin treatments and eventually to more effective interventions to prevent prolonged labor.

**Key words:** electrohysterogram (EHG), electromyography, myometrium, oxytocin treatment, parturition, uterine electromyography activity

## Introduction

Numerous studies have confirmed that electromyography (EMG) signals are able to reflect the original process of muscle fiber excitation, and the electrical signals recorded through skin are consistent with those recorded through mucosal and serosal electrodes.[1,2] In comparison with the gold-standard intrauterine pressure catheter,[3] EMG showed high consistency with uterine contraction and better accuracy and sensitivity than tocodynamometry (TOCO).[4] EMG activity was also reflective of the frequency and intensity of uterine contraction. Recent advances in EMG have therefore been applied in both clinical practice and research, including the prediction of preterm birth,[5,6] parturition,[7,8] and labor arrest[9,10] and the evaluation of the effects of tocolysis,[11−14] oxytocin,[10] and patient-controlled epidural analgesia (PCEA)[15−17] on EMG activities and outcomes in labor.

EMG is recognized as an effective means of pregnancy and delivery monitoring, but it is still not widely used in the clinical setting. The use of EMG quantification was limited in clinical practice owing to both technical difficulties and the lack of reference values. At present, no technology is able to automatically calculate EMG intensity in a direct and prompt manner. More importantly, well-defined reference values and appropriate classifications of EMG activities, which can be regarded as treatment reference, are yet to be established. Traditionally, normative reference values have been established in multicenter studies. Unfortunately, EMG data are collected only by specified equipment, and the process and results are inconsistent among different EMG teams.[7,18,19] Our team is devoted to the study of uterine EMG during labor, and our previous studies have confirmed that EMG intensity and activity are characterized by considerable variability at different and stages of labor and among individuals.[20] Therefore, to achieve better clinical practicability of EMG, this study attempted to quantify and grade EMG activity during the latent phase of the first stage of labor and explore its relationship with oxytocin treatment and length of labor.

## Materials and Methods

### Patients

A retrospective observational cohort study was conducted in a single institution (Guangzhou Women and Children's Medical Center, Guangdong, China) from August 2018 to December 2021; it included 508 primiparas with spontaneous labor and intact membranes at term during the first stage of labor with cervical dilation from 0 to 6 cm. The inclusion criteria were as follows: (1) a singleton pregnancy with a gestational age of 37 to 42 weeks, (2) fetus with occipital presentation, (3) patients received PCEA before receiving

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## AJOG MFM at a Glance

### Why was this study conducted?

This study was conducted to quantify uterine electromyography (EMG) activities during the latent phase of labor and explore the electrical events' relationship with oxytocin treatment and length of labor.

### Key findings

Through grading analysis of uterine EMG activities, patients were categorized into low, median, and strong grade EMG activities. Low-grade EMG indicated high possibility of oxytocin treatment in the follow-up labor process and also longer first stage and total labor time.

### What does this add to what is known?

Other current studies only show uterine EMG characteristics under different conditions of labor. Lack of a clinical reference range or grading of uterine EMG parameters limit the clinical and research application value of the studies. Grading EMG activities during normal labor in our study provides a reference threshold for treatment. It may serve as a foundation for future EMG research on labor management and lead to new strategies for monitoring labor and guiding clinical intervention during labor.

EMG monitoring and had regular uterine contractions on TOCO, and (4) patients had not received oxytocin infusion before EMG. The completed gestational weeks were determined by the date of the first day of the last menstrual period and confirmed by ultrasound scan. Patients with medical complications of pregnancy or fetal abnormalities confirmed during pregnancy that would be expected to affect delivery mode were excluded (refer to Table S1). The study protocol was in accordance with the ethical guidelines and approval of Guangzhou Women and Children's Medical Center (protocol number 2018040301). Informed consent was obtained from all patients.

Patients were asked to remain still while in the supine position without disturbing the electrodes and TOCO used for the recordings. EMG data were not available to the treating physician. Participation in the study did not affect the treatment of patients by any means. All clinical decisions were solely based on the routinely used TOCO and other clinical signs and symptoms. Indications for oxytocin treatment were hypotonic uterine atony that leads to prolonged or arrested labor and delayed fetal head descent.

Maternal age (years), body mass index (BMI), gestational age, duration of labor, and delivery outcome were recorded.

### Electromyography recording and analysis

Uterine EMG activities were recorded noninvasively from the abdominal surface by using 2 sets of silver−silver chloride (Ag−AgCl) Beckman differential bipolar electrodes (Shanghai Jun Kang Medical Supplies Co, Ltd, Shanghai, China). Electrodes were placed around the patients' navel, and each electrode was separated from its respective partner by approximately 3 cm. A reference electrode was placed laterally on the patient's hip. Using PowerLab hardware (ADInstruments, CastleHill, Australia), uterine EMG signals were digitally filtered to yield a final band pass of 0.34 to 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 was found.[15]

All patients were monitored for at least 30 minutes and also followed with external TOCO using a standard maternal−fetal monitor (Avalon FM20; Philips, Best, the Netherlands). EMG and TOCO recordings were obtained during the latent phase of the first stage of labor for 30 minutes immediately following the definition of cervical dilation by attendants in the delivery room.

The determination criteria of EMG burst and parameters were obtained from previous publications,[20−22] including number of bursts/10 minutes and burst duration, which represent the frequency and duration of uterine contraction, respectively. Root mean square (RMS) and power were used to assess the energy of the electrical activity of bursts. Frequency-related parameters including media frequency and peak frequency of the power density spectrum were used for characterizing the uterine electrical signals. All the EMG recording and analysis were done by trained and experienced investigators.

### Outcomes

The primary outcome was subsequent oxytocin treatment. The secondary outcome was length of labor.

### Statistical analysis

The statistical significance of intergroup differences was evaluated by 1-way analysis of variance or Kruskal−Wallis test when appropriate for pairwise comparisons according to the distribution of variables. Spearman's correlation was used to determine the relationship between EMG activity and length of labor. Multivariate linear regression analysis was used to estimate the association between the duration of the length of labor and clinic data (gestational age, BMI, etc) and EMG parameters. Logistic analysis was used to identify the correlation of clinic data and EMG parameters with oxytocin treatment.

All statistical tests were 2-sided, and the level of significance was recognized as $P<.05$. All statistical analyses were performed by using the IBM SPSS 23.0 software (SPSS Inc, Chicago, IL). and the statistical software R 3.6.1 (R Core Team 2019). A $P$ value.05 for a 2-sided test was considered as statistically significant.

## Results

### General characteristics of the patients

Table 1 presents the general characteristics of this cohort. Among 508 patients, 227 received oxytocin treatment (oxytocin group) and 281 did not (without oxytocin group) during the next period of labor. The RMS

TABLE 1
**General characteristics of the patients**

| Category | n (%)/mean (standard deviation)/median (ranges) |
|---|---|
| Maternal characteristics | |
| Age, y | 28.5 (3.3) |
| Body mass index, kg/m$^2$ | 25.2 (23.6–27.24) |
| Gestational age, wk | 39.6 (38.8–40.3) |
| Oxytocin treatment | |
| With oxytocin | 227 (44.69%) |
| Without oxytocin | 281 (55.32%) |
| Fetal characteristics | |
| Neonatal birthweight, g | 3220.0 (3002.5–2450.0) |
| 1-min Apgar | 9 (8–9) |
| 5-min Apgar | 9 (9–10) |
| Delivery mode | |
| Spontaneous vaginal delivery | 420 (82.68%) |
| Operative vaginal birth (forceps) | 52 (10.24%) |
| Cesarean delivery | 36 (7.09%) |
| Labor characteristics | |
| First stage of labor, min | 620 (450–763.8) |
| Second stage of labor, min | 40 (27–70) |
| Third stage of labor, min | 5 (4–6) |
| Postpartum hemorrhage, mL | 250 (200–300) |

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values were divided into 3 groups (low, median, and strong EMG activity groups) by the quartiles (refer to Table 2), so were the power values (refer to table S2). Baseline characteristcs including age, BMI, neonatal weight, and delivery mode were not statistically different among groups. Lower EMG activity was observed in patients at greater gestational age. The low EMG activity group had a longer first stage and total length of labor and was more likely to use oxytocin (refer to Table 2).

### Electromyography activity classification and its clinical predictive value

We included the variables that were statistically different between the patients with or without oxytocin treatment in the univariate and multivariate logistic regression models to explore potential differential contributions. RMS and power showed independently high performance for the prediction of oxytocin treatment (refer to Table 3), both of which had good diagnostic accuracy as indicated by a receiver operating characteristic area under the curve value of 0.96 and 0.95 (Figure 1).

### Relationship between electromyography parameters and length of labor

We conducted correlation analysis and regression analysis on 472 patients with spontaneous vaginal delivery. In correlation analysis, both peak frequency (Spearman correlation=−0.21) and power (Spearman correlation=−0.20) showed a negative correlation with the length of the first stage of labor ($P$<.001). The same correlation was observed between peak frequency (Spearman correlation=−0.23) and power (Spearman correlation=−0.22) with the total length of labor ($P$<.01). Through multivariate linear regression, it was found that gestational age ($P$=.007, 0.12; 95% confidence interval [CI], 0.01−0.09), BMI ($P$=.02, 0.11; 95% CI, 0.01−0.07) and peak frequency ($P$=.02, −0.22; 95% CI, −6.98 to −0.54) were correlated with the length of total stage of labor, though the R-Squared was only 0.1 (refer to table S3).

## Comment

### Principal findings

In this study, we analyzed and described the characteristics of EMG activities during the first stage of labor in 508 patients. We found that RMS and power were able to independently yield excellent prediction of subsequent oxytocin treatment. Through grading analysis of EMG activities, we found that a low grade of EMG activities indicated high possibility of oxytocin treatment in the follow-up labor process, whereas high-grade EMG activity is associated with lower oxytocin use.

### Results in the context of what is known

EMG provides valuable data concerning contraction intensity, duration, and interval. However, there is much ambiguity and inadequacy in current studies on the quantification of EMG characteristics that were only presented under different conditions, such as EMG activity being intense in preterm[5] or term labor[7,23] and while it was inhibited after the use of epidural analgesia[15,16] or tocolysis.[24] The lack of an established clinical reference range or grading of parameters limited the application of EMG in clinical practice and research. Therefore, we aimed to grade uterine contractility by EMG activity in this more detailed study.

### Clinical implications

Intrapartum assessment of uterine activity is routinely employed to guide active management of labor and delivery. Accordingly, the initial objective of our study was to explore the relationship between EMG parameters and oxytocin treatment. The results indicated that there were significant

TABLE 2
**Clinical data and EMG characteristics of 3 grades of RMS**

| Factor | RMS | | | F/H/$X^2$ | *P* value |
|---|---|---|---|---|---|
| | <25%<br>0.01–0.02 mV | 25%–75%<br>0.02–0.07 mV | >75%<br>0.07–0.42 mV | | |
| Maternal characteristics | | | | | |
| Age, y | 28.7±3.4 | 28.5±3.0 | 28.3±3.6 | 0.3 | .7 |
| Body mass index, kg/$m^2$ | 25.4 (23.6–27.0) | 24.9 (23.6–27.2) | 25.4 (23.5–27.4) | 0.02 | .9 |
| Gestational age, wk | 39.7 (38.9–40.4) | 39.5 (38.4–40.1)[a] | 39.7 (39.0–40.5)[a] | 5.2 | .006 |
| Labor characteristics | | | | | |
| Neonatal birthweight, g | 3210.0 (3000.0–3440.0) | 3240.0 (3060.0–3492.5) | 3160.0 (2980.0–3400.0) | 3.1 | .2 |
| First stage of labor, min | 693.0 (512.5–823.8) | 620.0 (450.0–780.0)[a] | 552.5(397.5–720.0)[a,b] | 21.5 | <.01 |
| Second stage of labor, min | 47.5 (31.3–84.0) | 40.0 (27.0–69.8) | 34.0 (20.0–60.0)[a] | 13.5 | .001 |
| Third stage of labor, min | 5.0 (4.0–6.0) | 5.0 (3.0–6.0) | 5.0 (4.0–7.0) | 1.8 | .4 |
| Total labor, min | 757.5 (570.0–898.8) | 660.0 (506.3–828.8)[a] | 575.0 (445.0–768.8)[a,b] | 24.7 | <.01 |
| Postpartum hemorrhage, mL | 230.0 (200.0–330.0) | 250 (200–300) | 230 (200–300) | 2.1 | .4 |
| Oxytocin treatment | | | | | |
| With oxytocin | 159 (100%) | 56 (24.8%) | 12 (9.8%) | 293.8 | <.01 |
| Without oxytocin | 0 | 170 (75.2%) | 111 (90.2%) | | |
| Delivery mode | | | | | |
| Spontaneous vaginal delivery | 128 (80.5%) | 192 (85.0%) | 100 (81.3%) | 3.4 | .5 |
| Operative vaginal birth (forceps) | 16 (10.1%) | 20 (8.8%) | 16 (13.0%) | | |
| Cesarean delivery | 15 (9.4%) | 14 (6.2%) | 7 (5.7%) | | |
| Uterine EMG parameters | | | | | |
| Number of bursts/10 min | 4 (3–4) | 4 (3–4) | 4 (3–5) | 3.9 | .2 |
| Duration, s | 44.3 (38.8–51.0) | 43.2 (33.8–52.9) | 43.8 (35.0–56.8) | 2.9 | .2 |
| Median frequency, Hz | 0.52 (0.49–0.55) | 0.49 (0.46–0.53)[a] | 0.47 (0.45–0.50)[a,b] | 41.0 | <.01 |
| Peak frequency, Hz | 0.43 (0.41–0.49) | 0.42 (0.37–0.49) | 0.40 (0.37–0.43)[a,b] | 24.1 | <.01 |
| Power, nV2 | 0.25 (0.14–0.41) | 2.5 (1.4–3.6) | 12.4 (7.5–24.0)[a,b] | 416.9 | <.01 |

Data are expressed as mean±standard deviation, median (ranges), and N (%).

*EMG*, electromyography; *RMS*, root mean square.

[a] Compared *P* values with <25% group; [b] Compared with 25%–75% group.

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differences in the uterine EMG parameters in patients with and without subsequent oxytocin use. This was in accordance with the study by Vasak et al [10], which found that the frequency of EMG bursts was higher in patients with augmentation of labor. Our results showed that lower RMS and power of EMG burst was more likely to be associated with oxytocin use. We therefore categorized patients into 3 groups according to uterine contractions indicated by EMG activity as follows: hypotonic, normal, and hypertonic uterine contractions.

The secondary objective of our study was to determine the EMG parameters and their association with length of labor. Our study showed that patients with lower RMS and power and higher median and peak frequency were more likely to have longer lengths of first stage and total labor. However, the correlations of these were relatively weak. In linear regression, we did not find that any individual parameter or combination of the 5 uterine EMG parameters had a significant correlation with the length of labor. One possible explanation was that there were a number of confounding factors affecting the length of labor, such as maternal BMI, gestational weeks, incoordinate uterine action, and human interventions such as oxytocin treatment, etc.

## Research implications

Hypocontractile uterine activity is the most common risk factor for

TABLE 3
**Factors related to oxytocin treatment using univariate and multivariate logistic regression analysis**

| Variable | *P* value | Univariate RR | *P* value | Multivariate RR[a] | *P* value | Multivariate RR[b] | *P* value |
|---|---|---|---|---|---|---|---|
| Age, y | .8 | 1.0 (0.95–1.1) | .8 | 1.0 (0.9–1.1) | .8 | 1.0 (0.9–1.1) | .7 |
| BMI, kg/m$^2$ | .6 | 1.0 (0.9–1.0) | .5 | 1.0 (0.9–1.1) | .8 | 1.0 (0.9–1.1) | .6 |
| Gestational age, wk | .003 | 1.2 (1.1–1.4) | <.01 | 1.2 (1.0–1.5) | .02 | 1.2 (1.0–1.5) | .02 |
| Neonatal birthweight, g | .4 | 1.0 (1.0–1.001) | .5 | 1.0 (0.99–1.0) | .9 | 1.0 (0.99–1.0) | .7 |
| Duration, s | .9 | 0.99 (0.98–1.0) | .2 | 1.0 (0.98–1.02) | .9 | 1.0 (0.98–1.02) | 1.0 |
| Number of bursts/10 min | .3 | | .9 | | .9 | | .8 |
| RMS, mV[c] | <.01 | 0.01 (0.004–0.02) | <.01 | 0.01 (0.004–0.03) | <.01 | | |
| Power, nV$^2$[c] | <.01 | 0.02 (0.01–0.05) | <.01 | | | 0.02 (0.01–0.05) | <.01 |
| Median frequency, Hz[c] | <.01 | 1.9 (1.5–2.3) | <.01 | 1.4 (0.9–2.4) | .5 | 1.5 (0.9–2.4) | .1 |
| Peak frequency, Hz[c] | <.01 | 1.6 (1.3–1.9) | <.01 | 0.9 (0.5–1.4) | .08 | 0.8 (0.5–1.3) | .4 |

EMG parameters (RMS, power, median frequency, and peak frequency) were transferred by normal scores of SPSS to realize the normal transformation of data. The normality of the scores was evaluated using the Kolmogorov–Smirnov and Shapiro–Wilk tests of normality.

*EMG*, electromyography; *RMS*, root-mean-square; *RR*, relative risk.

[a] Regression model included all variables presented in the table except power, because RMS and power are colinear; [b] Regression model included all variables presented in the table except RMS; [c] EMG parameters (RMS, Power, Median frequency and Peak frequency) were transferred by normal scores of SPSS to realize the normal transformation of data. The normality of the scores was evaluated using the Kolmogorov-Smirnov and Shapiro-Wilk tests of normality.

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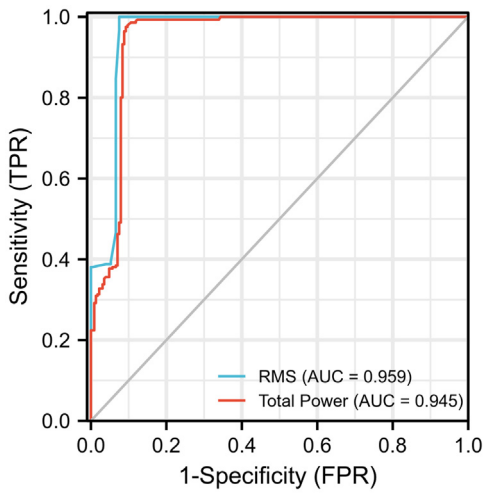
FIGURE
**The ROC curves for EMG parameters to predict oxytocin treatment**

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protraction and/or arrest disorders in the first stage of labor. Presently, it is widely monitored qualitatively by palpation or with TOCO. However, these methods are not accurate enough and are easily affected by factors such as patient position and obesity. Patients are prone to unnecessary medical interventions such as amniotomy and oxytocin treatment owing to inaccurate evaluation. To avoid the risk of unnecessary adverse reactions to patients and fetuses caused by excessive application of oxytocin,[25] accurate identification of hypotonic uterine contraction is essential. We believe that low-grade EMG may be an EMG characteristic of patients with primary hypotonic uterine contraction. The cesarean delivery rate was higher in the low-grade RMS and power groups. Although there are many reasons for cesarean delivery, arrested labor owing to uterine atony during labor is also one of the indications. Physicians should be alerted when encountering patients with low-grade EMG, and oxytocin should be used timely to reduce the occurrence of prolonged or arrested labor process and to promote smooth labor process progression.

## Strengths and limitations

A strength of this study is that it is to date one of the largest retrospective control studies on EMG solely involving primiparas in the first stage of labor. We initially explored the uterine EMG grading and found its correlation with oxytocin treatment, laying a foundation for the follow-up use of uterine EMG in labor management. However, the EMG grading extrapolated study still requires further verification. The main limitations of the trial are as follows: First, this study did not include patients who needed induction of labor, patients with prelabor rupture of the membranes, and patients with complications, and this is

a single center, retrospective cohort study. All the above affected the generalizability of this study. Second, we did not pay attention to the dosage of oxytocin and the interval between EMG collection and later oxytocin treatment, which may also affect the study conclusion. Nevertheless, this is the first attempt to grade EMG activities. We hope that our research can lead other experts to explore the range of EMG in normal uterine contractions. Future well- designed cohort studies that can effectively reduce bias are needed to confirm the effectiveness of this grading method in assessing the clinical outcome, including the use of oxytocin, length of labor, mode of delivery, etc. To establish better extrapolation of the clinical scope of uterine EMG, a multicenter study of unified EMG monitoring methods is still needed.

## Conclusions

We evaluated 5 EMG-measured parameters and their predictive values for later oxytocin treatment among patients with spontaneous labor. By grading the EMG parameters, we identified that low-grade EMG patients were more likely to need oxytocin treatment. EMG grading is crucial for the clinical promotion and utilization of EMG, and it could lead to more reliable analyses of oxytocin treatments and eventually to more effective interventions to prevent prolonged labor. ■

## Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.ajogmf.2022.100798.

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