Original Research

Changes in uterine electromyography according to cervical dilatation in the first stage of labor

Neža Sofija Pristov[1,†], Ela Rednak[1,†], Ksenija Geršak[1,2], Andreja Trojner Bregar[1,2], Miha Lučovnik[1,2,*]

[1] *Department of Perinatology, Division of Obstetrics and Gynecology, University Medical Center Ljubljana, 1000 Ljubljana, Slovenia*

[2] *Medical Faculty, University of Ljubljana, 1000 Ljubljana, Slovenia*

*Correspondence: miha.lucovnik@kclj.si (Miha Lučovnik)
† These authors contributed equally.

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Background: Myometrial contractile activity can be evaluated by recording uterine electromyography (EMG) non-invasively from the abdominal surface. Uterine EMG has been shown to detect contractions during labor as reliably as tocography (TOCO) and intrauterine pressure catheters. To evaluate whether changes in uterine EMG throughout the first stage of labor correlate with advancing cervical dilatation. *Methods*: Uterine EMG was recorded from the abdominal surface for 30 minutes in 32 women during the first stage of labor at term. Women were divided in three groups according to cervical dilatation at the time of EMG recording: $<$3 cm (n = 4), 3–5 cm (n = 19), and 6–10 cm (n = 9). Power density spectrum (PDS) peak frequencies within EMG bursts were compared between groups using ANOVA ($p < 0.05$ significant). Bonferroni post-hoc test was used for pair-wise comparison among groups. *Results*: PDS peak frequencies were significantly different in the three groups ($p < 0.001$). PDS peak frequency in the $\geq$6 cm dilatation group (0.52 $\pm$ 0.06 Hz) was significantly higher than in the $<$3 cm group (0.41 $\pm$ 0.02 Hz; $p = 0.001$) and 3 to 5 cm group (0.44 $\pm$ 0.04 Hz, $p = 0.001$). Difference between $<$3 cm and 3 to 5 cm groups was not statistically significant ($p = 0.55$). *Discussion*: Uterine EMG PDS peak frequencies increase with increasing cervical dilatation during the first stage of labor.

Keywords

Uterine electromyography (uterine EMG); Electrohysterography (EHG); Cervical dilatation; Labor

1. Introduction

Myometrial contractile activity can be evaluated by recording uterine electromyography (EMG) non-invasively from the abdominal surface [1–3]. Uterine EMG has been shown to detect contractions during labor as reliably as tocography (TOCO) and intrauterine pressure catheters [4–6]. In addition, EMG yields important information on changes in electrical properties of the myometrium characteristic of labor [7, 8]. Several studies demonstrated that uterine EMG predicts onset of labor at term and preterm more accurately than other methods in clinical use today [9–13]. Uterine EMG properties have also been shown to differentiate active vs. latent labor in women presenting with regular contraction at term [7, 14].

No uterine studies to date evaluated uterine EMG as a means of assessing progress of labor in the first stage, i.e., from onset of regular painful contractions to full dilatation of uterine cervix. This assessment currently still mostly depends on vaginal examinations to estimate cervical change and TOCO to assure adequate frequency of contractions [15, 16]. Both methods have several drawbacks. TOCO became the standard of care more than 40 years ago without ever undergoing vigorous clinical trials [17]. It only measures change in shape of the abdominal wall as a function of uterine contractions and, as a result, is a qualitative rather than a quantitative method [17]. Monitoring uterine activity with TOCO alone has been proven not to be helpful in assessing progress of labor [17, 18]. On the other hand, estimating cervical dilatation by digital vaginal exam is very subjective and measurements vary significantly among caregivers [19, 20]. Moreover, vaginal exams may cause discomfort and pain, and can also be a source of infection [21, 22]. Therefore, a more objective and less invasive method to assess labor progress in the first stage of labor would be very helpful to clinicians and could increase satisfaction of laboring women with intrapartum care.

The objective of the study was to evaluate whether changes in uterine EMG throughout the first stage of labor correlate with advancing cervical dilatation.

2. Methods

Women at 37 0/7 to 41 6/7 weeks of gestation with singleton pregnancies and fetuses in cephalic presentations admitted with regular uterine contractions to labor ward of the Department of Perinatology, University Medical Center Ljubljana, Slovenia, were included in the study. All women included provided written informed consent for study participation. The National Medical Ethics Committee approved the study (reference number: 137/02/10).

Uterine EMG measurements were performed in labor ward. Four electrodes were arranged symmetrically around the navel. Uterine EMG was recorded for 30 min using the SureCall Monitor (Reproductive Research Technologies,

Table 1. Baseline characteristics of women in the three study groups.

Characteristic	Cervical dilatation <3 cm (N = 4)	Cervical dilatation 3–5 cm (N = 19)	Cervical dilatation 6–10 cm (N = 9)	p
BMI (kg/m^2)	28 ± 5	31 ± 5	27 ± 4	0.07
Nulliparity	4 (100%)	9 (47%)	5 (56%)	0.12
Maternal age (years)	32 ± 5	31 ± 5	29 ± 6	0.71
Gestational age (weeks)	39 ± 2	39 ± 2	39 ± 1	0.86
Labor augmentation with oxytocin	1 (25%)	9 (47%)	3 (33%)	0.62

Means with standard deviations or Number N (%) are shown; BMI, body mass index.

Houston, Texas, USA). Recordings were analyzed with Chart 5 software (ADInstruments, Castle Hill, Australia). In order to exclude most components of motion, respiration, and cardiac signals, and to more clearly discern "bursts" of uterine electrical activity, EMG signals were digitally filtered (bandpass 0.3 to 1.00 Hz). Data were sampled at 100 Hz. Fourier transform was used to obtain the power density spectrum (PDS) of each burst. The PDS curve is a function of frequency and represents the relative contribution of each frequency to the signal. Peak PDS frequencies of bursts analyzed in recording were averaged to obtain a mean peak PDS frequency for each patient.

Different clinicians blinded to the results of uterine EMG measurements performed cervical examinations. Women were classified into three groups according to cervical dilatation at the time of EMG recording: <3 cm, 3–5 cm, and 6–10 cm. Normality of distribution was assessed using Shapiro-Wilk test. Background clinical characteristics as well as EMG PDS peak frequencies in the three groups were compared using Chi square test (for categorical variables) and ANOVA (for continuous variables). Bonferroni post-hoc test was used for pair-wise comparisons of EMG PDS peak frequencies among groups. For all tests, a p value < 0.05 was considered statistically significant. The software used for statistical analysis was IBM SPSS Statistics for Windows Version 25.0 (IBM Corp., Armonk, NY, USA).

3. Results

Thirty-two women were included in the study: 4 (13%) were dilated <3 cm, 19 (59%) 3 to 5 cm, and 9 (28%) ≥6 cm at the time of uterine EMG recording. Table 1 presents comparison of baseline characteristics of women in the three groups. None of the women included had undergone a cesarean section in their previous pregnancy or had a uterine scar from prior myomectomy or other surgical procedures. All women had a spontaneous vaginal delivery, except one in the 3 to 5 cm cervical dilatation group who delivered by cesarean section due to fetal distress. All women in the 3–5 cm dilatation group have been classified by the attending clinicians as being in active labor.

Uterine EMG PDS peak frequencies differed significantly in the three groups ($p < 0.001$) (Fig. 1). Post-hoc analysis showed significant differences in PDS peak frequency in the ≥6 cm dilatation group vs. <3 cm ($p = 0.001$) and 3 to 5 cm ($p = 0.001$), but not between <3 cm and 3 to 5 cm groups ($p = 0.55$).

4. Discussion

The main finding of the study is that uterine EMG PDS peak frequencies increase with increasing cervical dilatation. This indicates potential effectiveness of uterine EMG as a means for assessment of labor during the first stage.

Continuing trend towards higher EMG activity as labor progresses is in line with earlier findings with intrauterine pressure measurements [23]. However, increase in uterine EMG PDS peak frequency with increasing cervical dilatation does not merely reflect stronger contractions late in the first stage, but suggests changes in electrical properties of the myometrium (e.g., increase in cell coupling through gap junctions, increased frequency of electrical signals etc.) throughout the first stage of labor. These changes can be detected non-invasively by recording uterine EMG from the abdominal surface. Our results are in accordance with previously published studies on accuracy of uterine EMG in predicting labor at term and preterm [9, 12, 13]. Maner *et al.* [9, 24, 25] showed high sensitivity and specificity of EMG for predicting onset of labor at term. Similarly, Lucovnik *et al.* [12] found high diagnostic values of uterine EMG for identifying women with preterm contractions at <34 weeks' that are going to deliver within seven days from EMG measurements. Our results are also in line with those of Trojner Bregar *et al.* [7], who showed gradual changes in uterine EMG characteristics as latent labor progresses into the active phase of the first stage of labor. Our study confirms shifts in uterine EMG activity towards higher signal frequencies as labor progresses during the first stage.

Relatively high rates of labor augmentation with oxytocin should be taken into account when interpreting our results. Active management of labor with high-dose oxytocin regimen (initial oxytocin infusion of 2 to 5mU/min with increments every 20–30 min until a maximum dose of 40 mU/min is reached) is common obstetric practice at our institution [26, 27]. Although there are no direct data on effects of oxytocin on uterine EMG PDS peak frequencies, it stands to reason then these could be affected by oxytocin administration. Pajntar *et al.* [28–30] showed an increase in uterine cervi-

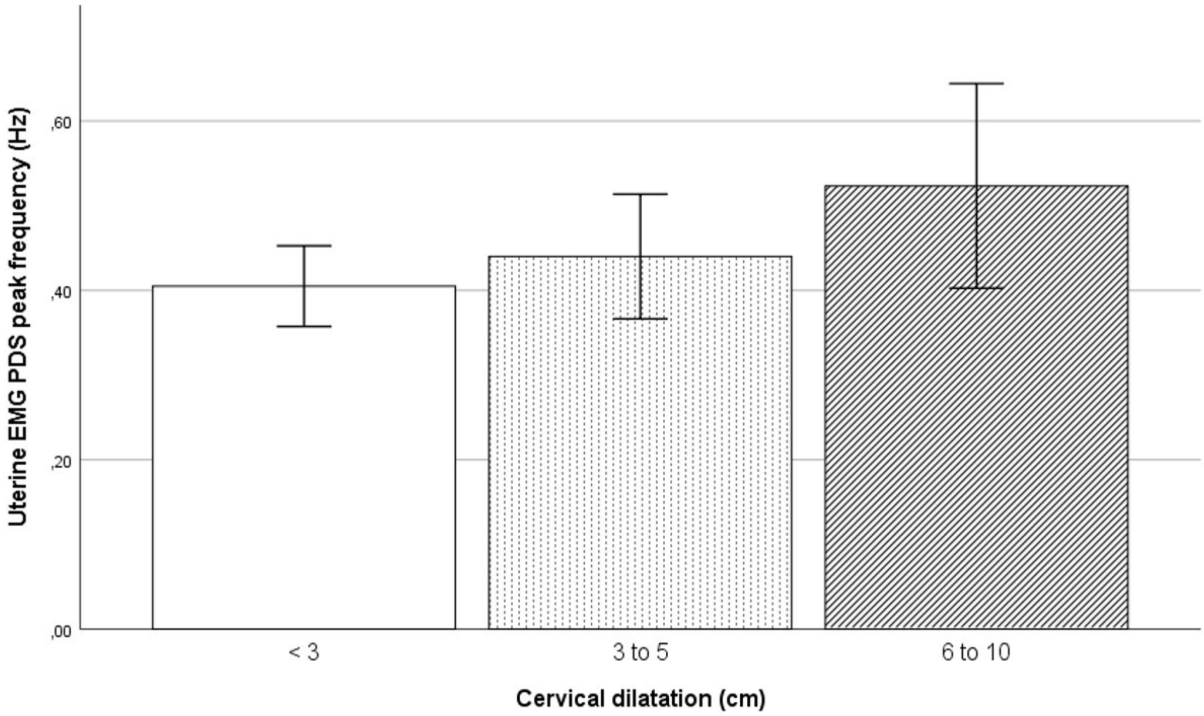

Fig. 1. Comparison of uterine electromyography (EMG) power density spectrum (PDS) peak frequency in three groups of women in the first stage of labor according to cervical dilatation. PDS peak frequency differed significantly among groups ($p < 0.001$). PDS peak frequency was significantly higher in the ≥6 cm dilatation group vs. <3 cm (p = 0.001) and 3 to 5 cm (p = 0.001), but not between <3 cm and 3 to 5 cm groups (p = 0.55). Means with standard deviations are shown.

cal EMG activity after oxytocin administration and animal studies have found changes in uterine and oviduct EMG associated with oxytocin use. Moreover, Maul *et al.* [23] have described a correlation between uterine EMG properties and intrauterine pressure. Our conclusions on increase in EMG PDS peak frequencies with advancing cervical dilatation were probably not influenced by oxytocin use, as there were no significant differences augmentation rates between the three study groups. However, further studies are needed to determine whether same findings apply to spontaneous (non-augmented) labors alone. Parity is another characteristic that merits discussion. Although there were no statistically significant differences in parity among groups, it has to be noted that all women in the <3 cm cervical dilatation group were nulliparas, compared to 47% in the 3–5 cm and 56% in the 6–10 cm groups. As with oxytocin use, this has probably not influenced our results significantly, as uterine EMG PDS peak frequency has been shown not to be affected by parity [31]. Several uterine EMG parameters have been studied so far and found to indicate onset of true labor [10]. Moreover, various EMG signal processing techniques focusing on different frequency bands have been shown to yield important information on uterine contractility [13, 32–34]. For the purpose of the present study, we chose to focus on the PDS peak frequency, as this has been one of the most studied uterine EMG parameters in both human and animal studies so far [9, 10, 25]. We found an increase in uterine electrical signal frequencies as labor progressed. Further studies may very well demonstrate that addition of other (linear or non-linear) EMG parameters could make uterine EMG an even more accurate methodology for labor progress assessment.

The main limitation of our study is the relatively small number of women included. The cross-sectional nature of the study can also be viewed as a limitation. We did not track EMG changes in individual women longitudinally. Instead, we compared three groups of women with different degrees of cervical dilatation at EMG recording. Studies of longer EMG recordings throughout labor will be needed to confirm or refute our results. Nevertheless, our results may be viewed as a proof of concept that uterine EMG could potentially be used as a noninvasive tool for assessing labor progress that could help minimizing the number of unnecessary and potentially harmful vaginal examinations.

Author contributions

ML and ATB designed the research study. ATB performed the research. KG provided help and advice on the writing an article. NSP, ER and ML analyzed the data and write an article. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

Ethics approval and consent to participate

The National Medical Ethics Committee approved the study (reference number: 137/02/10). Patient consent was waived as it is a retrospective study without risks to the participants, evaluating and improving current clinical management.

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Conflict of interest

The authors declare no conflict of interest.

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