

## OBSTETRICS

# Uterine electromyography for identification of first-stage labor arrest in term nulliparous women with spontaneous onset of labor

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**OBJECTIVE:** We sought to study whether uterine electromyography (EMG) can identify inefficient contractions leading to first-stage labor arrest followed by cesarean delivery in term nulliparous women with spontaneous onset of labor.

**STUDY DESIGN:** EMG was recorded during spontaneous labor in 119 nulliparous women with singleton term pregnancies in cephalic position. Electrical activity of the myometrium during contractions was characterized by its power density spectrum (PDS).

**RESULTS:** Mean PDS peak frequency in women undergoing cesarean delivery for first-stage labor arrest was significantly higher (0.55 Hz),

than in women delivering vaginally without (0.49 Hz) or with (0.51 Hz) augmentation of labor ( $P = .001$  and  $P = .01$ , respectively). Augmentation of labor increased the mean PDS frequency when comparing contractions before and after start of augmentation. This increase was only significant in women eventually delivering vaginally.

**CONCLUSION:** Contraction characteristics measured by uterine EMG correlate with progression of labor and are influenced by labor augmentation.

**Key words:** cesarean delivery, electromyography, labor arrest, parturition, uterine electromyography/EMG

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Worldwide cesarean delivery (CD) rates increase rapidly.<sup>1</sup> The majority of intrapartum CD (about 47%)

are performed for failure to progress in term nulliparous women with a fetus in cephalic position.<sup>2</sup> Effective treatment strategies to address the problem of labor arrest are needed to reduce or at least stabilize the CD rate. Paradoxically, the widespread use of uterotonic drugs does not seem to be the answer to the problem. Comparison between a historic cohort and modern practice has shown that the length of labor has increased during the last 50 years, while the proportion of women receiving uterotonic drugs has increased several fold, even when controlling for factors such as maternal age and body mass index.<sup>3</sup> These data stress the importance of studies on the normal process and progress of labor and on prognostic factors regarding the efficacy of uterotonic medication. The challenge is to identify which labors will respond to oxytocin and which would benefit from other, not-yet-defined interventions.

Current monitoring techniques of uterine contractility, either by external tocography or by intrauterine pressure catheters, have not been shown to improve outcomes.<sup>4</sup> However, in the last 15 years

several groups have revived interest in uterine electromyography (EMG), a noninvasive technique enabling measurement of electrical activity through the maternal abdominal surface, developed 70 years ago.<sup>5-9</sup> In case of threatened preterm labor, EMG identifies patients delivering at short term more accurately than other current methods.<sup>10-13</sup> We hypothesized that the findings in preterm labor could be translated into the possibility to differentiate between normal and protracted labor at term.

The objective of this study was to investigate whether uterine EMG can differentiate between inefficient contractions resulting in a CD for first-stage labor arrest, and efficient contractions (with or without labor augmentation) leading to a vaginal delivery in term nulliparous women with a spontaneous onset of labor.

## MATERIALS AND METHODS

A prospective multicenter observational study was conducted in 3 centers in The Netherlands from August 2009 through May 2011. The inclusion criteria were singleton pregnancies in cephalic position

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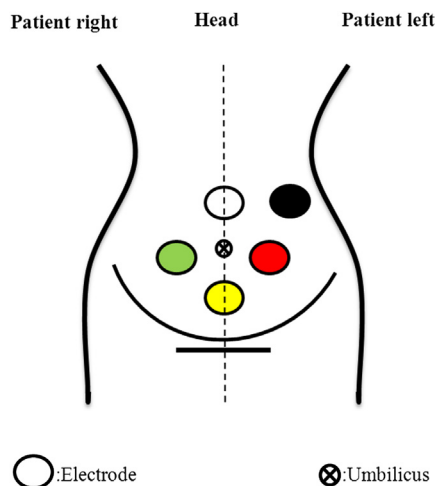
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**FIGURE 1**  
Positioning of electrodes on maternal abdomen



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(gestational age  $\geq 37$  weeks and  $\leq 42$  weeks) admitted to the labor ward for spontaneous labor. Exclusion criteria were suspected congenital or chromosomal abnormalities. The study was approved by the institutional medical ethical committees of the participating hospitals. Patients who were eligible for participation were approached consecutively. After informed consent was obtained, measurements of uterine activity were performed using EMG as recorded noninvasively from the maternal abdominal surface. EMG recordings started from the onset of labor or during first stage of labor upon arrival at the labor ward until delivery. There was no predefined time frame for registration duration and EMG recordings were conducted for as long as possible after inclusion. Registrations were analyzed post hoc.

All participating centers belong to a network of teaching hospitals taking part in the same residency program in obstetrics and gynecology. They follow a similar clinical policy inspired by the active management of labor approach.<sup>14</sup> According to this common policy, onset of active labor was defined as: painful regular contractions  $\geq 2/10$  minutes and ruptured membranes or cervical effacement  $\geq 75\%$  and/or cervical dilation  $\geq 2$  cm. Progress

of labor was monitored with the use of cervical examinations performed at least every 2 hours, or more frequently when indicated. The diagnosis of labor arrest was made by the clinician using the following criteria: patient in active labor (according to the definition outlined previously) with no increase in dilation for at least 2 hours. Protracted labor was defined as a rate of cervical dilation  $\leq 1$  cm/h. In both cases oxytocin augmentation was started. A CD for labor arrest was generally performed if labor arrest persisted despite augmentation of labor with oxytocin during an additional 2 hours.<sup>15,16</sup>

Maternal, neonatal, and labor characteristics were collected from the patient's charts.

### Uterine activity registration and analysis

Uterine activity was monitored using a portable maternal/fetal heart rate/EMG recorder (AN24, Monica Healthcare Ltd, Nottingham, United Kingdom) through 5 disposable electrodes that were positioned on the maternal abdomen in a standardized manner. The electrodes were positioned in the following way: 2 electrodes vertically along the midline, approximately 3-5 cm on both sides of the umbilicus; and 2 electrodes horizontally at the level of the umbilicus and symmetrical with respect to it, about 3-10 cm from the umbilicus. Finally, a (ground) electrode was placed on the left flank (Figure 1). Skin preparation before electrode placement ensured that skin impedance was  $< 5$  k $\Omega$  in all recordings. The raw abdominal EMG was recorded at 300 Hz and filtered in the 0.34- to 1-Hz bandwidth to obtain the uterine EMG. This procedure is similar to that reported by others in term of electrode placement and signal filtering.<sup>11-13</sup> Filtering in the 0.34- to 1-Hz bandwidth aims at removing heart rate artefacts  $> 1$  Hz and respiration artefacts  $< 0.34$  Hz. However, in contrast with the works cited previously, we developed an algorithm to identify contractions and compute the power density spectrum (PDS) due to the large number of contractions to be analyzed. This algorithm has been tested and described previously

by comparing it against intrauterine pressure catheter measurements.<sup>17</sup>

PDS analysis was performed on each contraction and the peak frequency was used as a contraction characteristic to be linked with clinical outcomes (Appendix; definitions can be found in the Glossary). The signal processing steps are illustrated in Figure 2. This method of analysis has been one of the most predictive EMG parameters in both human and animal studies for prediction of true labor.<sup>7,10,12,13,18,19</sup> The investigators who analyzed the data were not blinded to the labor and delivery data. However, the numerical data of the EMG signal prevented subjective interpretation.

### Statistical analysis

Data analysis was performed using software (SPSS, version 20.0; IBM Corp, Armonk, NY). The number of inclusions was estimated beforehand at 250 patients to result in around 10 CD for first-stage labor arrest, based on an expected rate of 4%. This was chosen such that in a univariate regression analysis the influence of 1 contraction parameter could be analyzed. It was difficult beforehand to estimate the degree of intercorrelation and intracorrelation due to the nested structure of the data and hence to perform a more precise power analysis. The study was terminated prematurely because 14 cases of CD for first-stage arrest had already been included.

The cohort was divided in different groups depending on the outcome. Patients with a CD for reasons other than first-stage labor arrest were excluded from analysis. Groups were defined as: group 1, women who delivered vaginally without labor augmentation; group 2, women who received labor augmentation because of protracted labor and who delivered vaginally; and group 3, women with a CD for first-stage labor arrest. The effect of labor augmentation on the mean PDS peak frequency was studied by a subanalysis of the contractions before (group a) and after (group b) administration of oxytocin. Due to the nested structure of the data with multiple measurements per subject, linear mixed models were used to evaluate the difference in peak depolarization frequencies between the different

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