OBSTETRICS

Noninvasive uterine electromyography for prediction of preterm delivery

Miha Lucovnik, MD; William L. Maner, BSc, BA; Linda R. Chambliss, MD, MPH; Richard Blumrick, MD; James Balducci, MD, MBA; Ziva Novak-Antolic, MD, PhD; Robert E. Garfield, PhD

OBJECTIVE: Power spectrum (PS) of uterine electromyography (EMG) can identify true labor. EMG propagation velocity (PV) to diagnose labor has not been reported. The objective was to compare uterine EMG against current methods to predict preterm delivery.

STUDY DESIGN: EMG was recorded in 116 patients (preterm labor, n = 20; preterm nonlabor, n = 68; term labor, n = 22; term nonlabor, n = 6). A Student t test was used to compare EMG values for labor vs nonlabor (P < .05, significant). Predictive values of EMG, Bishop score, contractions on tocogram, and transvaginal cervical length were calculated using receiver-operator characteristics analysis.

RESULTS: PV was higher in preterm and term labor compared with nonlabor (P < .001). Combined PV and PS peak frequency predicted preterm delivery within 7 days with area under the curve (AUC) of 0.96. Bishop score, contractions, and cervical length had an AUC of 0.72, 0.67, and 0.54.

CONCLUSION: Uterine EMG PV and PS peak frequency more accurately identify true preterm labor than clinical methods.

Key words: prediction, preterm labor, propagation velocity, uterine electromyography

Other than childbirth, threatened preterm labor is the most common diagnosis that leads to hospitalization during pregnancy.1 Up to 50% of patients admitted for threatened preterm labor are, however, not in true labor and will eventually deliver at term.2 Twenty percent of symptomatic patients who are diagnosed as not being in preterm labor, on the other hand, will deliver prematurely.1 This leads to unnecessary treatments, missed opportunities to improve neonatal outcome, and largely biased research of treatments.

Myometrial activation, required for effective contractions and true labor, is characterized by molecular changes leading to an increase in coupling and excitability of cells.8-14 Electrical activity of the myometrium, which can be monitored noninvasively by measuring the uterine electromyography (EMG), changes at delivery as a result of these events.8-14 Bursts of electrical signals responsible for contractions have been reported to be more frequent and their duration more constant in labor.15,16

An increase in peak amplitude and frequency of EMG signals, assessed by power-spectrum (PS) analysis, has also been observed prior to labor.15,17,18 Propagation velocity (PV) of electrical signals in the myometrium has been shown in vitro to increase before delivery when gap junctions are increased.19,20 As a result, it has been suggested that EMG could be used to assess the PV in vivo. Previous studies mainly focused on methods for assessing EMG signal propagation.21-28 However, the prognostic capability of PV for predicting labor (term or preterm) has not been evaluated yet.

This study investigated whether uterine EMG can be used to evaluate PV of uterine electrical signals in labor and nonlabor patients at term and preterm and compared diagnostic accuracy of various EMG parameters, including PV, to methods currently used in the clinic to predict preterm delivery.

MATERIALS AND METHODS

Patients

One hundred sixteen pregnant women were included in the study at a single institution (St Joseph’s Hospital and Medical Center, Phoenix, AZ). From previous EMG studies, there has been reported difference in means of EMG PS peak frequency in labor vs nonlabor patients of (0.4708 – 0.3982 = 0.0726 Hz), and an average SD of ((0.0459 + 0.0231)/2 = 0.0345 Hz).16 Using a power of 0.80 and an alpha of −0.05, with a Student t test, gives a desired sample size of 5 per group minimum.

Eighty-eight consecutive preterm patients were included. They were admitted with the diagnosis of preterm labor at less than 34 weeks of gestational age. The cutoff of 34 weeks was chosen because the risk of death and handicap is mainly

From the Department of Obstetrics and Gynecology (Dr Lucovnik, Chambliss, Blumrick, Balducci, and Garfield) and the Division of Perinatology, Department of Obstetrics and Gynecology (Drs Lucovnik and Novak-Antolic), University Medical Center Ljubljana, Slovenia.


increased if delivery occurs prior to this
time point, and attempts to stop preterm
labor are very rarely done at later gesta-
tions. Preterm labor was diagnosed
clinically as at least 6 contractions in 60
minutes assessed by tocodynamometer
(TOCO) and/or maternal perception
and a cervical dilatation of at least 2 cm
or effacement of at least 80% assessed by
digital cervical examination.
Calculation of gestational age was based
on the last menstrual period or, when it
differed by 7 days or longer from the ultra-
sonographic estimation (calculated by
crown-rump length measured within the
first trimester) on ultrasound. Women de-
ivering within 7 days from the EMG measure-
ment were classified in the preterm la-
bor group, and those delivering outside 7
days from the measurement were classified
in the preterm nonlabor group.

Twenty-eight consecutive patients
presenting with regular uterine contrac-
tions with intact membranes at term
 (>37 weeks of gestation) were also in-
cluded. Women delivering within 24
hours from the EMG measurement were
defined as being in labor (term labor
group) and those delivering outside 24
hours from the measurement as not be-
ing in labor (term nonlabor group).

Different cutoff measurement-to-de-
ivery intervals for term and preterm la-
bor vs nonlabor groups were chosen
based on previous studies, which showed
that an increase in uterine EMG activity
occurs within approximately 24 hours
from delivery at term and within several
days from delivery preterm.

All women included provided written
informed consent for study participation.
Data from patients who ultimately under-
went cesarean section were not used for
analysis (Figure 1). We chose to exclude
the cesarean section patients because the
decision on when exactly the surgery will
be performed is based on several consider-
ations, including those on fetal well-being
and the subjective assessment of labor
progress. This decision is therefore too
subjective and arbitrary to include in a
proper receiver-operating characteristics
(ROC) analysis in which one wants to also
accurately determine the mean measure-
ment-to-delivery interval.

We chose to include patients with pre-
term premature rupture of membranes
(PROM) because our objective was to
evaluate whether uterine EMG measure-
ments can differentiate between true
preterm labor (ie, patients who are going
to deliver spontaneously within a short
period of time) and those who are not in
true preterm labor, during which the clinical evaluation does not allow us to make this differentiation.

The St Joseph’s Hospital and Medical Center Institutional Review Board approved the study.

**Uterine EMG signal recordings**

Uterine EMG measurements were performed by 5 different researchers within 24 hours from the patient’s admission to the hospital. We standardized the electrode arrangement to the following factors: 2.5 cm electrode-electrode vertical and horizontal separation distances (measured from center to center) in a square-shaped pattern about the navel and with each electrode positioned in the vertex of each of the 4 corners of the square. Uterine EMG was measured for 30 minutes from each patient using a custom-built uterine EMG patient-monitoring system. Patients were asked to remain still while supine without disturbing any of the probes and wires for the recordings.

**Signal analysis**

Analog EMG signals were digitally filtered to yield a final band-pass of 0.34-1.00 Hz to exclude most components of motion, respiration, and cardiac signals from the analysis. Data were sampled at 100 Hz (this high sampling rate was chosen to increase the resolution of PS analysis later).

**Previously described EMG parameters**

EMG parameters were chosen from previous publications. The definition of these parameters, as well as the rationale for their use, can also be found in those publications.

**Propagation velocity analysis**

PV can be calculated by dividing the distance that the propagating wave travels...
by the amount of time required for the propagating wave to traverse this distance. All the time differences in corresponding action potential peaks for each burst of action potentials were calculated, and the average of absolute values of all time differences for bursts in a patient’s uterine EMG recording was used to calculate the PV.

Only those pairs of peaks on different channels (electrode pairs) with congruent shapes and within 2 seconds temporal separation of one another were included in the analysis, ensuring that any peak observed on 1 channel during any 2 second window matched the associated peak on the other channel (Figure 2).

For our EMG instrument, we use differential, bipolar electrode pairs. The advantage of a differential bipolar setup over a monopolar setup is signal quality, allowing us to more accurately identify individual uterine voltage peaks. Only those bursts for which the mean voltage peak value was greater than 2 times the mean baseline voltage peak value were used in these calculations to clearly see and compare uterine voltage peaks at adjacent electrodes. Within each of these electrical contractile bursts, there were found anywhere from approximately 30 to 60 voltage peaks (associated with propagating voltage waves), which were analyzed (Figure 2). More than 25,000 voltage peaks pairs were analyzed, with an average of approximately 215 peaks per patient.

**Common obstetric measures**

Presence or absence of contractions on TOCO at the time of EMG measurement was documented by the researcher recording the EMG. Transvaginal cervical length and Bishop score were also documented but only when they were assessed no more than 24 hours before or after the EMG measurement. Bishop score has not been developed as a predictor of preterm birth. Nevertheless, it gives a metric evaluation of digital cervical examination, which is commonly used to diagnose preterm labor and predict delivery. That is why we chose to compare predictive values of Bishop score with those of uterine EMG. Transvaginal cervical length was measured by 1 of 5 board-certified perinatologists or 1 of 4 certified ultrasound technicians. Digital examination was performed by 1 of 26 resident physicians involved in the care of the patients included in the study.

**Statistics**

A Student t test and a Mann Whitney U test (when appropriate because of non-normal distribution of variables) were used to compare delivery within, vs outside, 24 hours from the measurement in term patients, and 7 days from the measurement in preterm patients. Statistical comparison between preterm and term patients was performed to determine whether gestational age has an impact on EMG PV. Data were analyzed by analysis of variance, and Dunn’s test was used for pair-wise comparisons among groups. Pearson’s correlation analysis was used to determine whether demographic and/or clinical parameters influence the PV. A $P < .05$ was considered significant.

**TABLE 1**

Clinical background variables, preterm patients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Women delivering within 7 days (n = 20)</th>
<th>Women delivering after 7 days (n = 68)</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal age, y</td>
<td>24 (18–40)</td>
<td>27 (18–43)</td>
<td>.59</td>
</tr>
<tr>
<td>Nulliparous</td>
<td>5</td>
<td>16</td>
<td>.99</td>
</tr>
<tr>
<td>Number of previous gestations</td>
<td>1 (0–8)</td>
<td>1 (0–11)</td>
<td>.64</td>
</tr>
<tr>
<td>Previous preterm delivery or late abortion</td>
<td>2</td>
<td>13</td>
<td>.54</td>
</tr>
<tr>
<td>Twin gestations</td>
<td>1</td>
<td>8</td>
<td>.65</td>
</tr>
<tr>
<td>Gestational age at measurement</td>
<td>27 5/7 (22 6/7 to 33 4/7)</td>
<td>28 6/7 (21 5/7 to 33 6/7)</td>
<td>.51</td>
</tr>
<tr>
<td>PPROM</td>
<td>3</td>
<td>2</td>
<td>.42</td>
</tr>
<tr>
<td>Smoking</td>
<td>1</td>
<td>9</td>
<td>.58</td>
</tr>
<tr>
<td>BMI, kg/m$^2$</td>
<td>28 (24–47)</td>
<td>27 (20–45)</td>
<td>.15</td>
</tr>
<tr>
<td>Illicit drug abuse</td>
<td>1</td>
<td>7</td>
<td>.72</td>
</tr>
<tr>
<td>Tocolytic treatment</td>
<td>16</td>
<td>53</td>
<td>.89</td>
</tr>
<tr>
<td>Antenatal corticosteroids</td>
<td>11</td>
<td>54</td>
<td>.09</td>
</tr>
<tr>
<td>Contractions on TOCO</td>
<td>7</td>
<td>19</td>
<td>.64</td>
</tr>
<tr>
<td>Bishop score</td>
<td>7 (2–13)</td>
<td>5 (1–10)</td>
<td>.01*</td>
</tr>
<tr>
<td>Transvaginal cervical length, cm (n = 59)</td>
<td>2.0 (0.5–3.5) (n = 7)</td>
<td>2.8 (0.3–4.8) (n = 52)</td>
<td>.16</td>
</tr>
</tbody>
</table>

Data are median (range) and $n$. $P$ value was calculated by Mann-Whitney U-test and Student’s $t$ test.

BMI, body mass index; EMG, electromyography; PPROM, preterm premature rupture of membranes; TOCO, tocodynamometer.

*Statistical significance ($P < .05$).

The ROC curves were used to estimate the predictive values of the EMG parameters that were significantly higher in preterm patients delivering within 7 days and to assess the diagnostic accuracy of Bishop score, contractions on TOCO, and transvaginal cervical length for predicting preterm delivery within 7 days. Diagnostic accuracy of EMG, Bishop score, TOCO, and the transvaginal cervical length were then compared.

The ROC analysis was also performed on the cohort of patients for whom the results of all the examined methods were available. The ROC curves constructed on this cohort were compared by Student t test.

Repeatability and reproducibility measures
The PV analysis was reperformed on a subset of the data to determine intraobserver and interobserver agreement. Approximately 175 voltage spikes from patients in term labor, term nonlabor, preterm labor, and preterm nonlabor groups were reanalyzed. The intraobserver and interobserver agreements were calculated according to the statistical methods proposed previously.31

RESULTS
One hundred sixteen patients were evaluated in the study. The data regarding the preterm and term groups will be presented in separate sections.

Preterm patients
General
The study population consisted of 88 pregnant women admitted to our institution between September 2009 and February 2010 with the diagnosis of preterm labor at less than 34 weeks’ gestation. Uterine EMG was initially recorded in 98 preterm patients, but 10 patients who underwent cesarean section were subsequently excluded from the analysis. Patients were included in the study at a median of 28 5/7 weeks of gestational age (range, 21 5/7 to 33 6/7 weeks). Nine patients (10%) were less than 24 weeks; 31 (35%), 24-28 weeks; 33 (38%), 28-32 weeks; and 15 (17%) longer than 32 weeks. Delivery within 7 days from the EMG measurement occurred in 23%
(20/88) of the patients. Of 68 patients who did not deliver within 7 days from admission, 23 delivered at term (after 37 weeks), and 45 delivered before 37 weeks of gestation.

The clinical background variables are summarized in Table 1. It should be noted that at the time of EMG measurement (no more than 24 hours after admission to the hospital), the contractions were detected by TOCO in only 30% of patients (26/88), although they were all initially admitted for preterm labor. In spite of this factor, uterine EMG signals were being produced and easily detected in these patients. This fact confirms that EMG is a much more sensitive technology for assessing the contractile activity than is the TOCO.

Transvaginal cervical length was measured in 67% of patients (59/88). Cervical length was not significantly shorter in women who delivered within 7 days (median, 2.0 cm) compared with that in women who did not (median, 2.8 cm) 

EMG parameters
EMG PV was significantly higher in patients delivering within 7 days (32.56 ± 33.94 cm/sec-second) compared with those who delivered after 7 days (11.11 ± 5.13 cm/sec-second) 

<table>
<thead>
<tr>
<th>Variable</th>
<th>PV</th>
<th>PFr</th>
<th>PV plus PFr</th>
<th>PV</th>
<th>PFr</th>
<th>PV plus PFr</th>
<th>PV</th>
<th>PFr</th>
<th>PV plus PFr</th>
<th>PV</th>
<th>PFr</th>
<th>PV plus PFr</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC</td>
<td>0.91</td>
<td>0.61</td>
<td>0.90</td>
<td>0.92</td>
<td>0.92</td>
<td>0.90</td>
<td>0.96</td>
<td>0.74</td>
<td>0.95</td>
<td>0.95</td>
<td>0.78</td>
<td>0.90</td>
</tr>
<tr>
<td>Best cutoff</td>
<td>22.13 cm/s</td>
<td>0.87 Hz</td>
<td>191.96</td>
<td>28.00 cm/s</td>
<td>0.87 Hz</td>
<td>191.96</td>
<td>24.88 cm/s</td>
<td>0.64 Hz</td>
<td>95.33</td>
<td>22.88 cm/s</td>
<td>0.64 Hz</td>
<td>84.48</td>
</tr>
<tr>
<td>Sensitivity, %</td>
<td>100</td>
<td>14</td>
<td>14</td>
<td>77</td>
<td>8</td>
<td>8</td>
<td>82</td>
<td>18</td>
<td>53</td>
<td>85</td>
<td>15</td>
<td>70</td>
</tr>
<tr>
<td>Specificity, %</td>
<td>80</td>
<td>100</td>
<td>100</td>
<td>92</td>
<td>100</td>
<td>92</td>
<td>100</td>
<td>93</td>
<td>100</td>
<td>94</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>PPV, %</td>
<td>30</td>
<td>100</td>
<td>100</td>
<td>83</td>
<td>100</td>
<td>74</td>
<td>100</td>
<td>81</td>
<td>100</td>
<td>100</td>
<td>94</td>
<td>100</td>
</tr>
<tr>
<td>NPV, %</td>
<td>100</td>
<td>92</td>
<td>92</td>
<td>96</td>
<td>83</td>
<td>84</td>
<td>69</td>
<td>80</td>
<td>88</td>
<td>96</td>
<td>78</td>
<td>90</td>
</tr>
</tbody>
</table>

Best cutoff values are presented as centimeters per second and hertz. Their rescaled sum has no units.  
AUC, area under the curve; EMG, electromyography; PPV, positive predictive value; NPV, negative predictive value; PV, peak frequency; PFr, power-spectrum; PV, propagation velocity.  
sible to speculate that the EMG activity increases even before 7 days from delivery, and it may be useful to identify patients in preterm labor even prior to this cutoff.

Figure 6 and Table 4 present ROC analysis results. The ROC curve for uterine EMG differed significantly from the ROC curve for Bishop score ($P < .02$), transvaginal cervical length ($P < .03$), and TOCO ($P < .001$), even when the ROC analysis was performed on the same group of patients for which the results of all the methods were available.

**Term patients**

Uterine EMG was recorded in 36 term patients, and 8 patients who underwent cesarean section were subsequently excluded from the analysis. Gestational age at inclusion did not differ significantly between the 2 groups ($P = .216$). The median gestational age for labor patients was 39 2/7 weeks (range, 38 0/7 to 40 6/7 weeks) and for nonlabor patients, 38 5/7 weeks (range, 37 1/7 to 41 1/7 weeks). The median measurement to delivery interval for nonlabor patients was 8 days (range, 3–14 days) and in the labor group, 4 hours (range, 2–14 hours). PV was significantly higher ($P < .001$) in labor (31.25 ± 14.91 cm/second) compared with nonlabor patients (11.31 ± 2.89 cm/second) (Figure 7).

In an ROC analysis to distinguish between term patients in true vs false labor, PV had an area under the curve (AUC) of 0.98. For predicting delivery within 24 hours, a PV greater than 13.19 cm/second had 100% sensitivity, 83% specificity, 96% positive predictive value (PPV), and 100% negative predictive value (NPV).

**Comparison between preterm and term patients**

PV was significantly higher in labor at term and preterm compared with nonlabor patients at term and preterm. The differences between the term and preterm labor and term and preterm nonlabor groups were not significant ($P > .05$) (Figure 7).

**Repeatability and reproducibility measures**

Intraobserver and interobserver agreements were 99.92 ± 0.04% and 99.67 ± 0.20%, respectively. The technique to assess the PV of uterine EMG signals, described in Materials and Methods, is therefore highly repeatable and reproducible.

**Comment**

Noninvasive measurement of uterine EMG propagation and frequency can identify true preterm labor more accurately than the currently used methods. It can therefore identify those patients who will really benefit from early institution of tocolytic therapy, transport to a hospital with facilities for neonatal intensive care, and administration of steroids. At the same time, uterine EMG also identifies patients in false preterm labor who are not going to deliver within the next 7 days. This can help to avoid substantial economic costs associated with unnecessary hospitalization, the maternal risks associated with tocolytics, and the potential fetal risks associated with steroids.

In the case of low PV and peak frequency values, it therefore stands to reason that it would be safe not to admit, treat, or transfer the patient, regardless of the presence of contractions on TOCO and regardless of digital cervical exam and transvaginal cervical length results because all of the changes in the myometrium required for labor are not yet fully established.

Methods currently available to clinicians to diagnose preterm labor have several major drawbacks. Digital cervical examination is subjective and does not provide accurate diagnosis of true preterm labor. In the present study, the predictive measures of Bishop score were high only at scores of greater than 10, which is not useful clinically because at that point imminent delivery is already obvious.
length was measured only in 67% of the patients included and in only 7 patients who delivered within 7 days. In many of the patients who presented with advanced cervical dilatation, cervical length was not obtained, and those patients were more likely to deliver within 7 days. The predictive values would therefore most likely be better if the transvaginal cervical length of all patients were known. However, several patients with short cervices in this study did not deliver within 1 week, and some did not deliver preterm at all.

Further studies are needed to determine whether the addition of the fetal fibronectin test can improve the predictive value of transvaginal cervical length alone. However, given that the cervical length has much lower predictive values compared with uterine EMG, we doubt that the fetal fibronectin test will significantly change these results.

Our results also confirm that monitoring uterine activity with TOCO is not helpful in identifying patients in preterm labor. Only 23% of patients with contractions on TOCO during the 30 minutes of EMG recording delivered within 7 days, and the absence of contractions apparently does not rule out preterm labor reliably because the NPV was only 79%. Approximately 1 in 5 patients who exhibited no contractions registering on TOCO did nevertheless deliver preterm within 1 week.

We are highly encouraged that measuring uterine electrical activity is superior to TOCO. It not only detects uterine contractions as does TOCO but can also identify myometrial properties that distinguish physiological preterm contractions from true preterm labor.

PS peak frequency has been the most predictive of true labor in both human and animal studies. Our results confirm that shifts to higher uterine electrical signal frequencies occur during transition from a nonlabor state to both term and preterm labor states and can be reliably assessed by noninvasive transabdominal uterine EMG. In addition, we demonstrate that not only can PV of EMG signals in the myometrium be determined by EMG measurement but also that PV predicts preterm delivery more accurately than any other EMG parameter investigated so far.

An interesting finding of this study was that the uterine EMG is better than transvaginal cervical length in predicting preterm birth within 7 days of evaluation. This raises an important aspect related to the clinical utility of the cervical length in predicting preterm delivery within a short time interval. There are compelling data to suggest that cervical length is a good predictive marker for preterm birth between 24 and 32 weeks of gestation but on the long and not on the short time interval.

It can be argued that the cervical length was measured only in 67% of the patients who delivered within 7 days. In many patients who presented with advanced cervical dilation, cervical length was not obtained, and those patients were more likely to deliver within 7 days. The predictive values would therefore most likely be better if the transvaginal cervical length of all patients were known. However, several patients with short cervices in this study did not deliver within 7 days. The predictive values would therefore most likely be better if the transvaginal cervical length of all patients were known. However, several patients with short cervices in this study did not deliver within 1 week, and some did not deliver preterm at all.

Further studies are needed to determine whether the addition of the fetal fibronectin test can improve the predictive value of transvaginal cervical length alone. However, given that the cervical length has much lower predictive values compared with uterine EMG, we doubt that the fetal fibronectin test will significantly change these results.

Our results also confirm that monitoring uterine activity with TOCO is not helpful in identifying patients in preterm labor. Only 23% of patients with contractions on TOCO during the 30 minutes of EMG recording delivered within 7 days, and the absence of contractions apparently does not rule out preterm labor reliably because the NPV was only 79%. Approximately 1 in 5 patients who exhibited no contractions registering on TOCO did nevertheless deliver preterm within 1 week.

We are highly encouraged that measuring uterine electrical activity is superior to TOCO. It not only detects uterine contractions as does TOCO but can also identify myometrial properties that distinguish physiological preterm contractions from true preterm labor.

PS peak frequency has been the most predictive of true labor in both human and animal studies. Our results confirm that shifts to higher uterine electrical signal frequencies occur during transition from a nonlabor state to both term and preterm labor states and can be reliably assessed by noninvasive transabdominal uterine EMG. In addition, we demonstrate that not only can PV of EMG signals in the myometrium be determined by EMG measurement but also that PV predicts preterm delivery more accurately than any other EMG parameter investigated so far.

### TABLE 4

<table>
<thead>
<tr>
<th>Method</th>
<th>AUC</th>
<th>Best cutoff</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>PPV, %</th>
<th>NPV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uterine EMG (PV + PS peak frequency) (n = 88)</td>
<td>0.96</td>
<td>84.48</td>
<td>70</td>
<td>100</td>
<td>100</td>
<td>90</td>
</tr>
<tr>
<td>Bishop score (n = 88)</td>
<td>0.72</td>
<td>10</td>
<td>18</td>
<td>100</td>
<td>100</td>
<td>81</td>
</tr>
<tr>
<td>Transvaginal cervical length (n = 59)</td>
<td>0.67</td>
<td>0.7 cm</td>
<td>14</td>
<td>98</td>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>Contractions on TOCO (n = 88)</td>
<td>0.54</td>
<td>N/A</td>
<td>35</td>
<td>72</td>
<td>27</td>
<td>79</td>
</tr>
</tbody>
</table>

AUC, area under the curve; EMG, electromyography; n, number of patients included in the analysis; NPV, negative predictive value; PPV, positive predictive value; PS, power-spectrum; PV, propagation velocity; TOCO, tocodynamometer.

PV was significantly higher ($P < .001$) in labor groups compared with nonlabor groups. The differences between term vs preterm labor and term vs preterm nonlabor groups were not significant ($P > .05$). Data are presented as box plots and not vertical bar charts because of nonnormal distribution in term labor group. Term labor is delivery within 24 hours; term nonlabor is delivery after 24 hours; preterm labor is delivery within 10 days; preterm nonlabor is delivery after 10 days. Asterisk represents statistical significance. *PV, propagation velocity.


Similar data were obtained with patients at term.

Possible reasons for the increased PV during preterm and term labor are the presence of gap junctions, number of muscle cells recruited, ion channels (size and number), cellular resting potential, cellular threshold potential, and conduction pathways: all of these play a part in what types of EMG signals are ultimately received at the electrodes.

We evaluated many EMG parameters and their predictive values for preterm delivery among patients admitted for threatened preterm labor. EMG PV, PS peak frequency, and their combination (rescaled sum) identified which patients will deliver soon and which will not with highest PPV and NPV. It would be useful to do a prospective clinical trial to confirm our results. They may be extremely important clinically but could also lead to more reliable analyses of treatments and eventually to more effective interventions to prevent preterm birth.

REFERENCES