Contribution of cervical smooth muscle activity to the duration of latent and active phases of labour

Marjan Pajntar*, Branimir Leskošek, Drago Rudel, Ivan Verdenik

Objective To identify the effect of cervical muscle activity as an additional factor influencing the duration of the latent and active phase of labour.

Design Prospective observational study.

Setting The Ljubljana Maternity Hospital.

Participants Fifty healthy nulliparous women requiring induction of labour having relatively unripe cervices.

Methods At the onset of labour an open-ended catheter was inserted to measure intrauterine pressure during the latent and active phase of labour. Electromyographic activity of the cervix was registered by two bipolar spiral needle electrodes placed in the transverse direction on the proximal part of the cervix in the vagina. The mean intensity of distinctive peaks in an electromyographic spectrogram were calculated in the time/frequency domain. Multiple linear regression was used to find factors affecting the duration of the latent and active phase of labour.

Main outcome measures Duration of the latent and active phase of labour.

Results Eleven independent variables explained 64% of the variance of the latent phase duration, the most important being the effacement and consistency of the cervix, and intensity of electromyographic signals. For the duration of the active phase the same variables explained 36% of the variance; the most important variables were mean duration of uterine contractions, mean maximum intensity of uterine contractions and the newborn's head circumference.

Conclusions The cervical smooth muscle activity, expressed as an electromyographic signal, contributes to the duration of the latent phase but not to the duration of the active phase. However, frequent cervical contractions are not associated with a longer latent phase.

INTRODUCTION

Our previous studies and others have shown that smooth muscles in the uterine cervix are active during pregnancy and labour in animals[1,2] and during labour in humans[3,4]. This activity is partly independent of the activity of the uterine corpus[1,5]. We hypothesised[6,7] that circularly arranged muscle fibres constrict the cervical canal. In pregnancy this activity helps the cervix to remain closed, but the effect of this activity on the course of labour is still unknown. Using electromyographic signals as a measure of smooth muscle cell activity[8,9], we aim in this study to assess the effect of cervical muscle activity on the duration of the latent and active phases of labour.

METHODS

The investigation was approved by the National Medical Ethics Committee, and informed consent was obtained from all the patients enrolled in the study.

Two hundred women undergoing induction of labour with amniotomy and subsequent oxytocin infusion at term were included in the study of cervical electromyographic activity. From that cohort 50 primiparous women were selected in whom electromyographic activity and intrauterine pressure were registered electronically throughout the whole latent and active phase of labour without major artefacts.

The main indications for induction of labour were gestational age exceeding 40 weeks with milky or meconium stained amniotic fluid on amnioscopy. After admission to the delivery room, cervical ripeness was quantified with the Bishop score[10] (median 6, range 1–9), an amniotomy was performed and oxytocin infusion administered. The intrauterine pressure was measured by a fluid-filled open-ended intra-amniotic catheter (Hewlett Packard 14099C) inserted into the uterine cavity and by a pressure probe (Hewlett Packard 1286). An ECG electrode was attached to the fetal head to monitor the fetal heart rate (CTG monitoring). The duration of the latent and of the active phases of labour was assessed from the partograms. The end of the latent phase was set at 3 cm cervical dilatation. The data on the woman's and the

Department of Obstetrics and Gynaecology, University Medical Centre, Ljubljana, Slovenia

* **Correspondence**: Professor M. Pajntar, Department of Obstetrics and Gynaecology, University Medical Centre, Slajmerjeva 3, SI-1000 Ljubljana, Slovenia.

newborn's weight, and newborn's head circumference, were taken from the labour record.

To record the electromyographic activity of smooth muscle tissue on the exterior wall of the cervix, a pair of adapted fetal spiral steel electrodes (Hewlett Packard 15130A) was applied to the outer aspect of the cervix (proximal part) at 09:00 and 12:00. A reference flat metal (Sn) electrode was attached to the woman's thigh (Fig. 1). Neither the electrodes nor their application caused any pain or discomfort to the women.

A differential preamplifier (A = 1000, CMRR 90 dB, bandwidth = 0.1–1000 Hz) was used. The signals from the preamplifier were fed to an amplifier with a built-in low-pass filter (cut-off frequency at 4.5 Hz, 60 dB/decade) with an additional user-selected gain (A = 2). A paper recorder was used to monitor the electromyographic activity. Amplified and low-pass filtered electromyographic signals were digitised in real time by a PC-based 8-channel, 12-bit data acquisition system. The sampling frequency was 20 Hz. The data were written to a hard disk concurrently with the sampling.

A linear trend and a basal tonus were set to zero in the recorded intrauterine pressure signals. The signals were furthe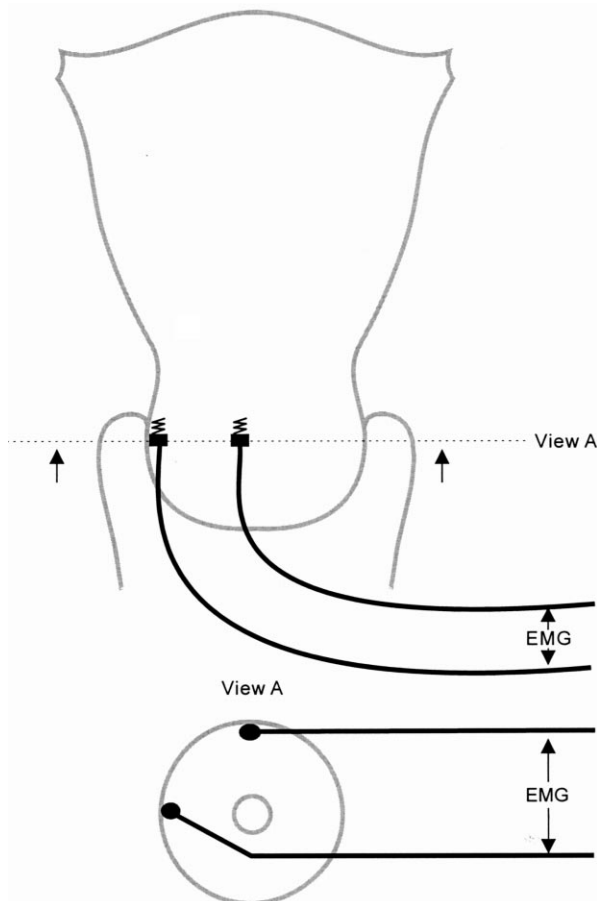r filtered with a low-pass digital filter having the pass-band edge frequency at 0.03 Hz. The characteristic parameters of intrauterine pressure signal were then determined using an algorithm that automatically identifies contractions and defines their characteristics. The algorithm can distinguish between single and multiple contractions but sometimes cannot identify weak contractions, especially at the onset of induced labour[11].

All recorded electromyographic signals were pre-processed by excluding artefacts and removing a linear signal trend. The signals were then digitally filtered by a band-pass filter (0.08–4 Hz). For each minute of the signal we calculated the power spectral density using Fast Fourier Transform. All spectra for each labour were then successively joined together to form a three-dimensional time/frequency domain spectrogram, separately for the latent and the active phases. The time was x-axis (minutes) and frequency was y-axis (Hz). The z-axis shows the power spectral density in arbitrary units. (Figs. 2 and 3).

The following parameters were determined from electromyographic signals for the latent and the active phase of each labour:

1. Number of distinctive peaks in a spectrogram;
2. Mean intensity of distinctive spectrogram peaks which represents the intensity of cervical muscle contractions;
3. Mean frequency of spectrogram distinctive peaks (number of spectrogram distinctive peaks/labour duration in minutes).

The number of distinctive peaks throughout the duration of labour served as a measure of muscle activity in the cervix. It was determined as follows:

1. Average power spectrum density for the whole electromyographic recording was calculated;
2. Integral of this power spectrum density was determined;
3. The electromyographic recording was divided in one-minute sections;
4. For each one-minute section a power spectrum density was calculated;
5. From each of these power spectrum densities an integral was determined;
6. All integrals of one-minute power spectrum densities were compared with the integral of the average power spectrum density, and the number of one-minute power spectrum density integrals which exceeded 10% of the average integral value were counted. This number was named the number of distinctive peaks.

The following parameters were determined from intrauterine pressure signals for the latent and the active phase of each labour:

1. Mean maximum intensity of uterine contractions;
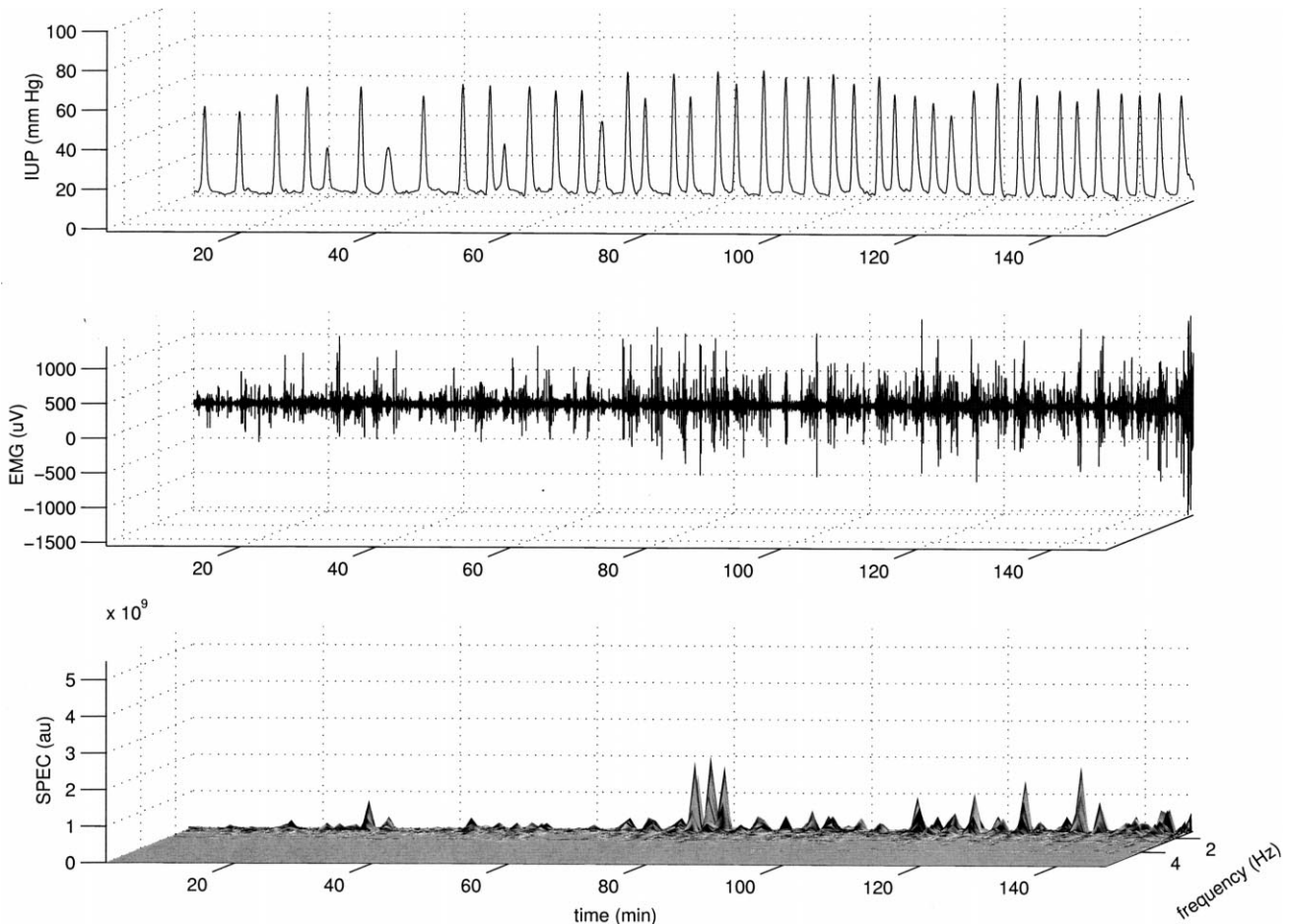2. Mean duration of uterine contractions;

Fig. 1. The electrode positioning on the cervix.

Fig. 2. Recording of intrauterine pressure (top), digitally filtered raw EMG recording (middle) and time/frequency spectrogram (bottom) for latent phase of labour OS2407.

3. Frequency of uterine contractions (number of contractions/labour duration in minutes).

All signal processing and statistical analysis was done on an MS Windows-based PC computer, and a Linux-based PC computer was used for image processing. We used Matlab 5.0 for MS Windows (MathWorks Inc, USA) for signal processing, Statistica 4.5 for MS Windows (StatSoft, Inc, USA) for statistical analysis, and GIMP and Ghostview for Linux for image processing. Multiple linear regression statistics were implemented.

RESULTS

The results of multivariate linear regression analyses are presented in Table 1 and Table 2 for the latent and active phase of labour, respectively. The dependent variables were the duration of the latent phase and the duration of the active phase in minutes. For both linear regression analyses the independent variables were the newborn's head circumference; dilatation, effacement, consistency and position of the cervix; station of the fetal head (Bishop scores); mean duration of uterine contractions; mean maximum intensity of uterine contractions; frequency of uterine contractions; mean intensity of distinctive peaks in a spectrogram, and mean frequency of spectrogram; distinctive peaks.

Independent variables explained 64% (R^2) of the variance of the latent phase duration. A model without electrical parameters was also computed. We found that independent variables in that case explained 54% of the variance. The most important variables for the duration of the latent phase were the effacement and consistency of the cervix, and the mean intensity of distinctive peaks in electromyographic spectrograms. The longer duration of the latent phase was related to the formed and the rigid cervix and higher intensity of cervical muscle contractions.

The following variables did not contribute significantly to the variance of the latent phase duration: dilatation and position of the cervix; station of the fetal head; newborn's head circumference; frequency of uterine contractions, mean frequency of spectrogram distinctive peaks; mean maximum intensity of uterine contractions; and mean duration of uterine contractions (Table 1).

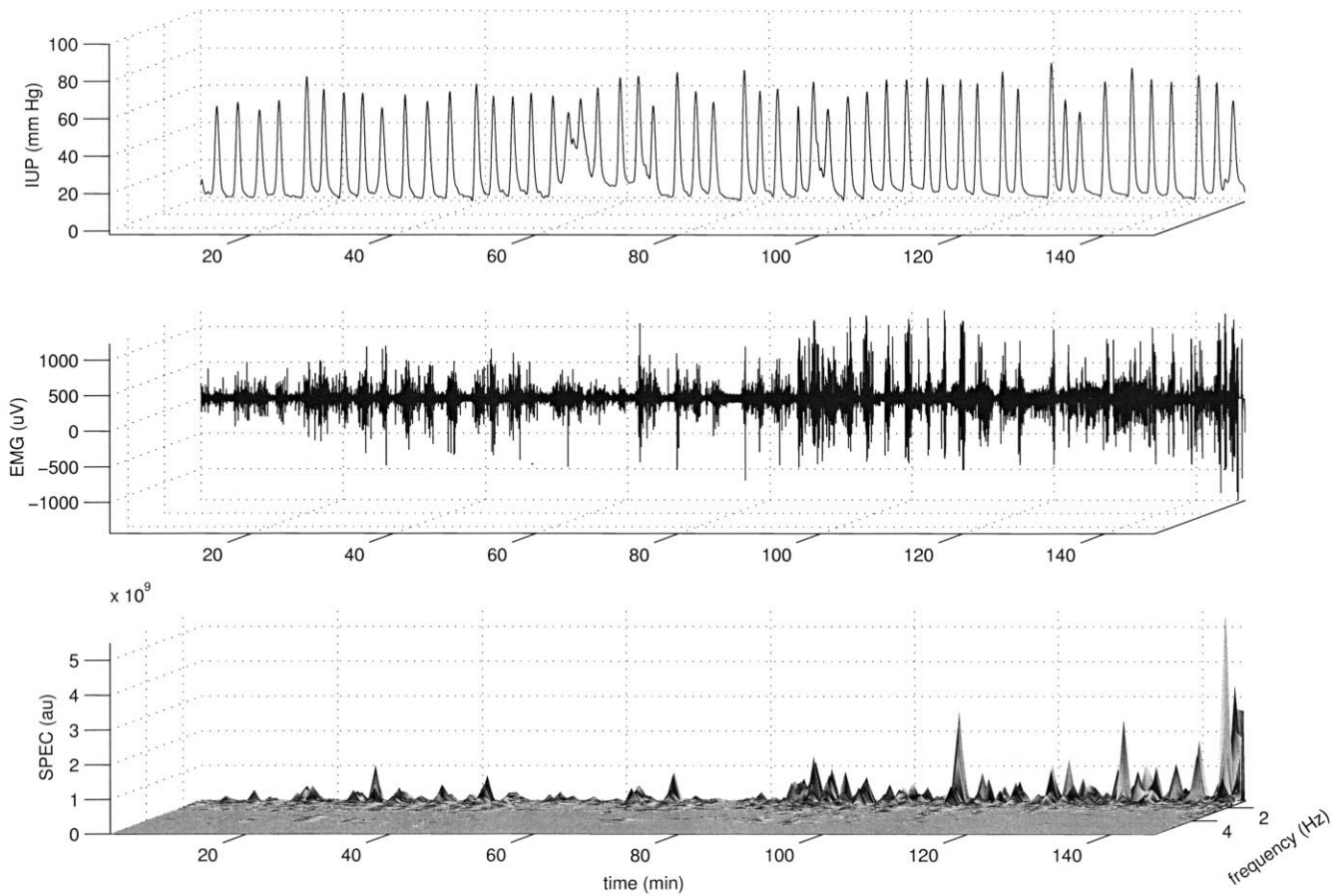The regression model explained 36% of the variance of

Fig. 3. Record of intrauterine pressure (top), digitally filtered raw EMG recording (middle) and time/frequency spectrogram (bottom) for active phase of labour OS2407.

the duration of the active phase. In a model without electrical parameters we found that independent variables in that case explained 35% of the variance. Most important variables, related to the duration of the active phase, were: mean duration of uterine contractions; newborn's head circumference; and maximum intensity of uterine contractions. The longer duration of the active phase was mostly related to the long duration of contractions; larger head circumference, and lower maximum intensity of uterine contractions.

The following variables did not contribute significantly to the variance of the latent phase duration: intensity and frequency of cervical muscle contractions, frequency of uterine contractions, dilatation, consistency and effacement of the portion, anterior position of the cervix; and fetal head station (Table 2).

Table 1. Regression model for duration of the latent phase of labour - with and without cervical EMG parameters.

	Model with cervical EMG ($R^2 = 0.64$)			Model without cervical EMG ($R^2 = 0.54$)		
	Std Coeff Beta	t	Sig	Std Coeff Beta	t	Sig
Effacement of the cervix	−0.452	−3.743	0.001	−0.449	−3.547	0.001
Mean intensity of distinctive peaks in a spectrogram	0.342	2.949	0.006			
Consistency of the cervix	−0.327	−2.757	0.009	−0.290	−2.272	0.029
Newborn's head circumference	0.124	1.175	0.248	0.107	0.928	0.359
Frequency of uterine contractions	0.133	1.081	0.287	0.152	1.141	0.261
Position of the cervix	−0.094	−0.792	0.433	−0.115	−0.886	0.381
Dilatation of the cervix	−0.089	−0.766	0.449	−0.077	−0.635	0.529
Mean duration of uterine ontractions	0.092	0.762	0.451	0.018	0.137	0.892
Mean frequency of spectrogram distinctive peaks	−0.052	−0.403	0.690			
Mean maximum intensity of uterine contractions	−0.028	−0.228	0.821	0.131	1.073	0.290
Station of the fetal head	0.006	0.050	0.961	−0.018	−0.146	0.885

Table 2. Regression model for duration of the active phase of labour - with and without cervical EMG parameters.

	Model with cervical EMG ($R^2 = 0.36$)			Model without cervical EMG ($R^2 = 0.35$)		
	Std Coeff Beta	*t*	Sig	Std Coeff Beta	*t*	Sig
Mean duration of uterine contractions	0.476	2.635	0.012	0.480	2.919.	0.006
Newborn's head circumference	0.398	2.592	0.014	0.401	2.672	0.011
Mean maximum intensity of uterine contractions	−0.310	−2.049	0.048	−0.307	−2.076	0.045
Frequency of uterine contractions	0.280	1.716	0.095	0.250	1.622	0.113
Position of the cervix	−0.280	−1.692	0.100	−0.256	−1.669	0.104
Station of the fetal head	−0.180	−1.228	0.228	−0.165	−1.165	0.251
Effacement of the cervix	−0.129	−0.814	0.421	−0.150	−1.016	0.316
Mean intensity of distinctive peaks in a spectrogram	−0.092	−0.599	0.553			
Consistency of the cervix	0.076	0.480	0.634	0.089	0.587	0.561
Dilatation of the cervix	−0.062	−0.424	0.674	−0.060	−0.415	0.681
Mean frequency of spectrogram distinctive peaks	0.053	−0.338	0.738			

DISCUSSION

In our previous studies[3,5] we have found that the cervical smooth muscle activity, recorded transversely in the cervix, is present through the entire course of labour. We have presumed that this activity represents contractions of the muscle fibres lying more or less in a circular direction. These contractions, found by mechanical means in animals[1] and in humans[4], can produce cervical resistance during labour. If true, the activity of these muscles must influence the duration of the first stage of labour.

In our previous studies[12,5] we evaluated the electromyographic signals separately in time and frequency domains. In this study we decided to evaluate the electrical activity of cervical smooth muscles in the time/frequency domain to join up the advantages of both methods.

Most signals generated by biological systems are non-stationary and their spectral characteristics may change suddenly with time. To analyse these signals a two-dimensional Fourier transform is often used. It provides a representation of the instantaneous spectrum of the observed time period[13]. In our study we used the same Fourier transform in one-minute time intervals, which provided one-minute power spectra densities. By successively combining these one-minute densities we obtained a 3D-time/frequency presentation, a spectrogram, from which we could easily follow the dynamics of the changes in the cervical activity during the entire labour. The time/frequency domain technique can track sudden variations and is useful for studying the electromyographic signals in dynamic as well as in static conditions of muscular activity[13].

The method we used allowed us to take into consideration short intervals, the minute slices of the electromyographic signals, which mostly contribute to the activity of the cervical smooth muscles. The advantage of this analysis over the root mean square evaluation is the possibility of observing activity in different frequency ranges. By using frequency range between 0.08 and 4 Hz we avoided low frequency (mechanical) artefacts. The advantage over the median frequency evaluation is in providing the information about intensity of muscle activity.

This study shows that the muscle activity in the cervix, registered in the transverse direction, is present throughout entire course of labour (Fig. 2), confirming our previous observations[3]. The new data suggest that cervical smooth muscle activity is important only for the duration of the latent phase of labour. However, we found that only the intensity of cervical contractions is significant and not their frequency.

Other factors found to be affecting the duration of the latent phase of labour were effacement and consistency of the cervix. It is interesting that dilatation of the cervix is less important than effacement, consistency, and intensity of cervical muscle contractions. We have also found that the duration and intensity of uterine contractions did not affect the duration of the latent phase.

The situation is completely different in the active phase of labour. Variables important for the latent phase duration are unimportant for active phase duration and vice versa. For the duration of active phase the head circumference and duration and intensity of contractions are very important.

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