Active contractions of the cervix in the latent phase of labour

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Objective To study the activity of the human uterine cervix at the onset of labour and further characterise cervical asynchronous electromyographic (EMG) activity in the latent phase.

Design Prospective observational study. Setting Clinical ho spi tal in Ljubljana.

Participants Forty-seven healthy nulliparous women with relatively unripe cervices requiring induction of labour.

Methods Simultaneous registration of a cervical EMG and of the intrauterine pressure at the very early stage of labour; subsequent EMG signal processing to determine its time, amplitude and frequency parameters.

Main outcome measures Simultaneous comparison of the cervical EMG and the mechanical activity of the uterine corpus to deduce electric al properties of the cervical smooth muscle tissue and its activity.

Results EMG bursts, asynchronous with the contractions of the uterine corpus, were registered in 20 out of 47 women. In 14 women bursts appeared independent of uterine corpus contractions and in six they followed the peak of contractions. The bursts had low average median frequency (0·3 Hz). In seven women bursts were superimposed onto a background EMG (median frequency = 1·2 Hz).

Conclusions Bursts in the cervical EMG may appear asynchronously with the uterine contractions. Bursts not related to contractions suggest active and independent cervical muscle activity. The bursts which follow contractions may be an active response of the cervical musculature to passive stretching during a contraction. The EMG frequency content suggests two different contraction mechanisms or a different origin of the EMG in the cervix.

INTRODUCTION

According to recent findings, the cervix should be considered a dynamic muscular structure playing an important role during pregnancy and labour[1-7]. The smooth muscle fibres present in the cervix[8-10] can actively contract during pregnancy[11] and labour[6,12]. In the latent phase of labour the cervix may contract rather than dilate in response to uterine corpus myometrial activity[6]. The latter may have clinical implications for the management of the early stage of labour[5,13-15]. A better understanding of the role of smooth muscle in the cervix at term is required if clinicians wish to influence the process of cervical ripening and dilatation. This is particularly true for the management of induced labour in women with an unripe cervix.

The electromyographic (EMG) signal, recorded from the cervix, is believed to reflect actual activity of cervical smooth muscle cells.[1,6,12,16-19]. EMG activity can be independent of myometrial contractions of the uterine corpus, or related to them [12,19-21]. Independent activity of the smooth muscle characterises the latent phase of labour[6,22,23].Olah[19] registered the EMG activity in the cervix which exhibited active cervical contractions in the latent phase of labour, and which differed from the activity registered when the cervix dilated only passively with uterine myometrial contractions.

It has already been proven that in uterine corpus smooth muscle, EMG bursts preceded uterine corpus mechanical activity. Actually, they appear synchronously with contractions[24-28]. Analysing EMG records derived from the cervical muscular tissue in relatively unripe cervices during the early latent phase of induced labour, we noticed that bursts in the cervical EMG signal also appear asynchronously with uterine contractions. The aim of this study was to characterise this asynchronous EMG activity and relate it to uterine contractions. It was suspected that the activity represented an independent smooth muscle activity of the cervix originating in the cervix.

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METHODS

Forty-seven healthy nulliparous women undergoing induction of labour at term with amniotomy and subsequent oxytocin infusion were enrolled in the study. These cases were selected from among 200 cases in which EMG and IUP were registered electronically. Criteria for selection were:

1. EMG and IUP data registered electronically for at least one hour after amniotomy;
2. No major artefacts in the selected 20 minute interval records;
3. Syntocinon not administered within the selected interval.

Main indications for induction were period of gestation exceeding 40 weeks and milky or meconial amniotic fluid. In most of the 47 women the CTG showed no or infrequent uterine contractions before the onset of labour.

The study was approved by the national medico-ethical committee and informed consent was obtained from each woman before undergoing the measurements.

After admission to the delivery room, cervical ripeness was estimated according to the Bishop score~9 (mean 5·6, SD 1·99), and an amniotomy was performed. Intrauterine pressure (IUP) was measured by a fluidfilled open-end intra-amniotic catheter inserted into the uterine cavity and a pressure probe (Hewlett Packard 1286). Prior to each recording, baseline pressure was adjusted to O mmHg. IUP was recorded by a cardiotocograph (CTG-HP8030A, Hewlett Packard, San Diego, California, USA). In this study the IUP records were used only as a synchronisation signal for the cervical EMG, giving information on uterine peak contraction and duration. Additionally, an ECG electrode was attached to the infant's head to monitor the fetal heart rate by the CTG. Syntocinon was commenced after the 20 minutes of observation had elapsed in most subjects.

To record the EMG activity of smooth muscle tissue on the exterior wall of the cervix, a pair of fetal spiral steel electrodes (Hewlett Packard 15130A) was applied to the outer aspect of the cervix (proximal part of the portio), circumferential to the cervical canal at 9 o'clock and 12 o'clock. A reference flat metal (Sn) electrode was attached to the woman's thigh. Neither the electrodes themselves nor their application caused any pain or discomfort to the women.

The differential preamplifier and the amplifier with an isolation unit were used to amplify (A = 2000) and process the obtained EMG signals. Analogue signals of EMG and asignal corresponding to IUP were registered on the CTG chart recorder. Additionally, the EMG and the IUP were sampled at 20 Hz and the data were written on a personal computer hard disk for subsequent processing. The EMG activity was registered throughout the duration of labour. For the purpose of this study, a 20 minute interval was selected out of each lab our record, starting as close to amniotomy as possible. A personal computer with a MathLab software tool (Version 4, MathWorks Inc, Natik, Massachusetts, USA) was used for signal processing, analyses and graphic presentation. IUP and EMG recordings were filtered digitally (Butterworth band pass filter $0·08$ Hz $<$ EMG $< 4·0$ Hz; lowpass second order Butterworth filter IUP $< 0·03$ Hz). In this way the influence of artefacts was also diminished.

EMG and IUP signal records were visually assessed according to the time of appearance of bursts of EMG activity with regard to contractions (peaks in IUP). Additionally, EMG signal recordings were processed in time and frequency domains, respectively. The root mean square (RMS) of the EMG signal voltage (U_{RMS}) and the median frequency of the EMG signal were calculated for each 5 second interval of the 20 minute observation period. The power spectral density (PSD) was also calculated and plotted for the analysis of frequency content of the EMG signal.

RESULTS

Time domain

Visual assessment of EMG and IUP signal records according to the time of appearance of bursts of EMG activity with regard to contractions (peaks in IUP) showed that in 27 (57-4%) women EMG signals contained only bursts synchronous with uterine corpus contractions. In 20 (42·6%) we established that along with synchronous bursts of EMG activity, asynchronous EMG bursts also appeared. Data for cervical ripeness for the women expressing asynchronous EMG bursts re shown in Table 1. Asynchronous bursts appeared either independent (n = 9; 19·2%) of a uterine corpus contractions (during the burst no significant increase in IUP was registered), or were delayed to the peak in

Table 1. Average cumulative and some components of the Bishop secre[29], with standard deviation in parentheses. for the observed groups.

	Group with asynehronous independent bursts (n =14)	Group with asynehronous delayed bursts (n = 6)	p
Bishop	5·36 (1·95)	6·83 (0·98)	<0·098
Effaeement	2-20 (0·96)	2·83 (0-41)	<0·058
Consisteney	1·36 (0·74)	1·50 (0·55)	<0·679
Dilatation	1 07 (0·27)	1·]7 (0-41)	<0·540

Bishop' is a cumulative score, 'effacement', 'consistency' and 'dilatation' are three of five Bishop score components IUP *(n = 11; 23-4%)*. Delayed bursts start at a trailing edge of the IUP curve (the contraction culminates) and last for up to several minutes. Among the 20 women with asynchronous EMG bursts, in seven (35%) EMG bursts were superimposed onto a background EMG activity. The amplitude of the background EMG signal, compared with that at bursts, differed from woman to woman. In some women the background signal amplitude was almost the same value as that of bursts.

In Fig. 1, IUP and EMG signals, together with the calculated variables (U_{RMS} and median frequency) of a representative member of the group also expressing delayed EMG bursts, are presented. Four contractions, registered as an increase in the IUP signal (trace 1), occurred in the observed 20 minute interval.

The EMG signal of the cervix (trace 2) is composed of two components: a permanent high density background activity of low amplitude (approximately ± 30 μVp) and superimposed low density EMG bursts with an amplitude almost three times higher (approximately ± 100 μVp). The EMG signal contains both independent and delayed asynchronous bursts. The first EMG burst is not associated with any contraction as no increase in the IUP signal is observed. The second and the third EMG bursts start at a trailing edge of the IUP curve (contraction), whereas the last burst is synchronous with the corresponding contraction.

EMG signal amplitude values (U_{RMS}) (trace 3) are high in the periods of burst appearance and low for the EMG background activity. Median frequency variable (trace 4) has high value (l·3 Hz) in the absence of EMG bursts. The

median frequency value drops to 0·3 Hz at the time of uterine contractions. U_{RMS} and median frequency almost alternate in the amplitude: when median frequency is high, U_{RMS} is low and *vice versa.*

Frequency domain

The EMG signal frequency spectrum diagrams, the power spectral density charts, presents the frequency content of the EMG signal. For the group with asynchronous bursts, the power spectral density chart consisted of one (n = 13), or two (n = 7) frequency bands. In all 20 women with asynchronous EMG activity, the low frequency band was present containing frequency components up to 0·6 Hz. The second high frequency band, ranging from 1·0 Hz to 1·3 Hz, was noticed in seven women. The wellexpressed EMG bursts with high amplitude, low frequency signal s contributed to the low frequency part of the spectrum. The background EMG activity contributed to the second frequency band. Average values of the median frequency of EMG bursts in the 20 minute intervals was 0·30 (0·04 SD) in the group having asynchronous EMG bursts not related to contractions, and 0·29 (0·02 SD) in the group with delayed EMG bursts.

The power spectrum of the EMG signal for the representative case described above has two clearly separated bands as shown in Fig. 2: the lower with frequencies up to 0·6 Hz and the higher ranging from 1·0 Hz to 1·3 Hz. There is a clear gap between these two bands. The median frequency of the lower band is 0·3 Hz and the upper band 1·2 Hz.

DISCUSSION

In early labour the cervical smooth muscle tissue may contract. Its activity is characterised by a pattern of EMG signal s derived from the tissue during labour. The detection of EMG signals by spiral electrodes inserted into the outer surface of the cervix enables a closer look into the behaviour of the smooth muscle tissue of the cervix *in vivo*[12].

As the observed 20 minute intervals were taken as close to the onset of each labour as possible, we considered the dilatation process

of the cervix during the 20 minute period to have been minimal. It was assumed that the EMG electrodes stayed almost at the same position throughout the observed interval and that the minimal electrode repositioning did not influence the measurements considerably.

All women were nulliparous, admitted for delivery with relatively unripe and most likely pathological cervices. The average cumulative Bishop score (Table 1) in cases with asynchronous EMG bursts was relatively high, cervices were almost effaced but rigid and the dilatation scores were low. Although there is a difference in the average Bishop score between the cases expressing independent asynchronous bursts and those al so having delayed asynchronous bursts, the differences in cervical ripeness are statistically not significant, probably due to the low number of cases with delayed bursts.

Two types of EMG activity were registered from the cervix; a permanent background activity and more pronounced bursts superimposed onto it. It is a common opinion that EMG bursts of the uterine smooth muscles are synchronous with myometrial contractions of the uterine corpus[19,24-27]. Besides ynchronous EMG bursts we also found asynchronous bursts in the cervix not associated with the uterine contractions. In the presented case (Fig. 1, trace 2), the first EMG burst appears at the moment when a contraction of the uterine corpus itself is not expressed (no increase in the intrauterine pressure). Asynchronous EMG activity not being associated with uterine contractions could be attributed to the functionally independent muscle activity of the human cervix[6,12,19,20,30]. Pajntar[7] states that in an unripe cervix such activity represents prolonged muscular activity, which helps to keep the fetus in the uterus during pregnancy.

time (minutes)
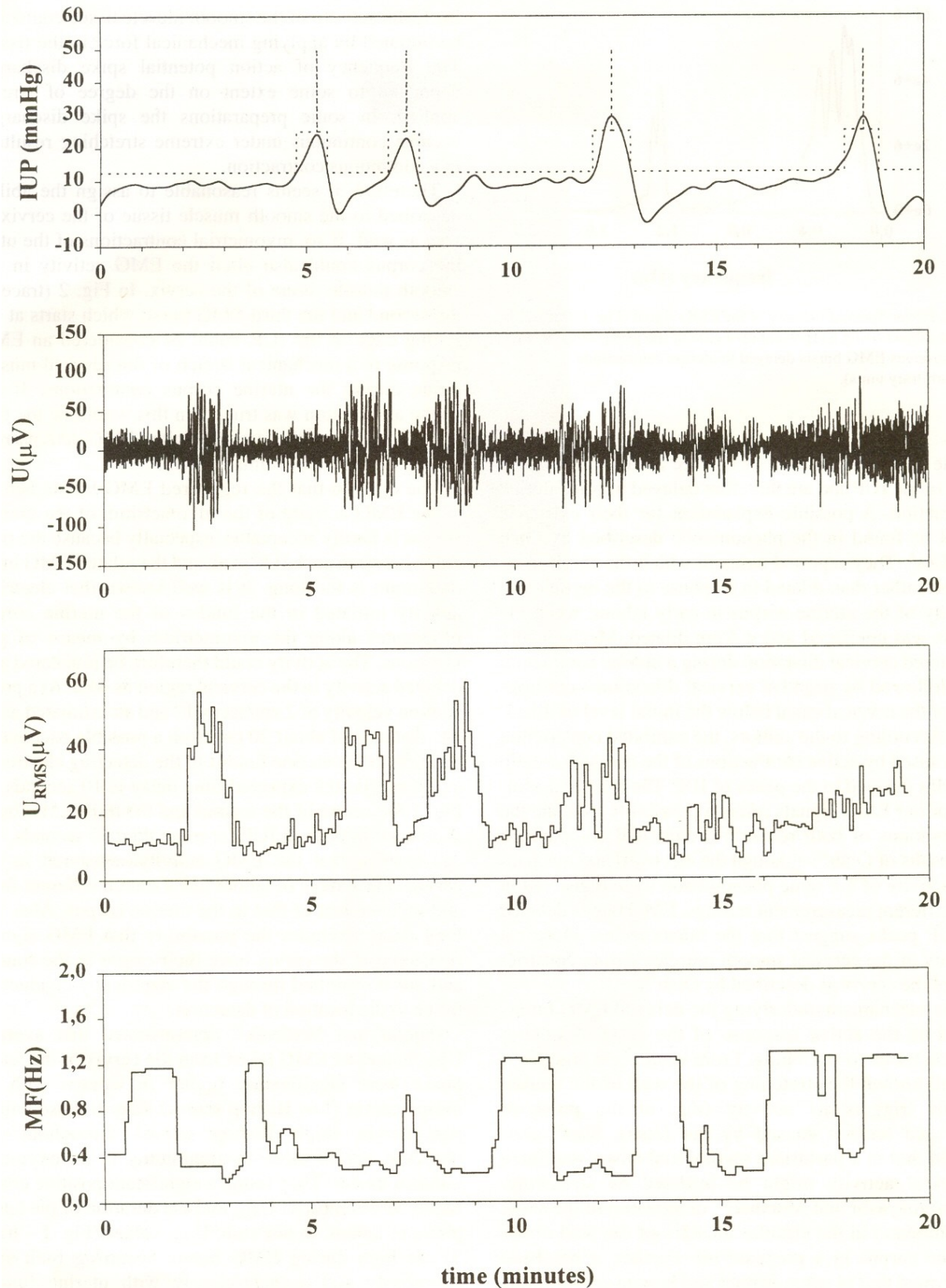
The next two EMG bursts in trace 2 start at the falling edge of the IUP and are therefore delayed to peak uterine contraction. A possible explanation for their existence could be found in the phenomenon described by Olah and Gee[6]. They reported cases in which the cervix contracted rather than dilated in response to the myometrial activity of the uterine corpus in early labour, when the cervix was uneffaced and < 4 cm dilated. Mechanically registered cervical dilatation during a uterine contraction was followed by negative cervical dilatation-constriction of the cervical canal below the initial level of dilatation. According to the authors, the exhibited constriction was caused by active contractions of the cervical smooth muscles delayed to the peaks of IUP. The temporal analysis of our EMG signals offers a possibility to relate the observations of both research group s and complement the results of Olah[19], although the electric al and mechanical activity of the same phenomenon were registered in two different measurement settings. EMG bursts delayed to IUP peaks suggest that the bursts reflect electrical activity of the cervical smooth muscles during constriction of the cervix as described by Olaih[19].

The mechanism underlying the delayed EMG bursts could be the active response of the cervical smooth muscle tissue to stretching. From obstetrical practice it is well known the stretching of the wall of the uterine corpus triggers its activity (e.g. at the point of increased tension caused by the fetus). Ka0[2X] confirmed that in a parturient myometrial tissue specimen electrical activity might be initiated by stretching. Kawarabayashi and Marshall[31] demonstrated the same phenomenon in the circular muscles of the wall of the uterine corpus in a pregnant rat. Further, it has been confirmed that in some animal and human preparations the stretching of the smooth muscle tissue may elicit the EMG $activit_y$32-3-l. On sample strips taken from pregnant human myometrium Kao[28] demonstrated that the EMG activity of the smooth muscle tissue could also be initiated by applying mechanical force to the tissue. The frequency of action potential spike discharges depended to some extent on the degree of stretch applied. In some preparation s the spike discharges became continuous under extreme stretching resulting in a continuous contraction.

Therefore, it seems reasonable to assign the ability described to the smooth muscle tissue of the cervix *in viva* as well. If so, myometrial contractions of the uterine corpus could also elicit the EMG activity in the smooth muscle tissue of the cervix. In Fig. 2 (trace 2) the second and the third EMG burst, which starts at the falling edge of the IUP, could be considered an EMG response to a mechanical stretch of the cervical muscle tissue during the uterine corpus contractions. If the above assumption was true, then this would be the first documentation of the stretch-elicited EMG activity registered *in vivo* in the human cervix.

The opinion that the registered EMG bursts belong to the EMG activity of the myometrium of the uterine corpus is hardly acceptable, especially because the time delay between each IUP peak and the related EMG burst maximum is too long. It is well known that electrical activity initiated in the fundus of the uterine corpus propagates along the myometrium by means of gap junctions. The activity could therefore be registered as a delayed activity in the cervical region as well. At a propagation velocity of 2 cmJsecond[2]-l and an estimated average distance of about 20 cm from a possible pacemaker location in the uterine fundus to the detecting electrodes at the cervix, the expected time delay is 10 seconds. In Fig. 1 the centre of the second and the third EMG burst is delayed to peak in IUP for more than 50 seconds. We can assume that the EMG activity registered in the cervix at this stage of labour has a source different from and independent of that in the uterine corpus. Also, the long delay excludes the possibility that EMG signals registered at the cervix have their origin in the fundus and are transmitted through the electrically conductive tissue to the location of detection.

Pajntar and Verdenik[20] demonstrated that average U_{RMS} values of EMG taken from the cervix in the latent phase were significantly higher in women with an unripe cervix (low Bishop scores) than in those with a ripe cervix (high Bishop scores) throughout the observed period close to amniotomy in an oxytocin induced labour. They found a significant

positive correlation between EMG U_{RMS} and the duration of the latent phase of labour. In our case, U_{RMS} values (Fig. l - trace 3) are high during EMG bursts occurring both synchronously and asynchronously with uterine fundus contractions. Asynchronous EMG bursts having high U_{RMS} indicate independent cervical smooth muscle activity and advocate for a relatively unripe cervix.

A closer look into the frequency content of the registered EMG could further characterise the EMG activity in the cervix. Median frequency value alternates with URMS value (see temporal presentation in Fig. 1 - trace 3 and trace 4). When median frequency is high, U_{RMS} is low. In unripe cervices, median frequency is high (1·1 Hz-l 4 Hz) when only the permanent background EMG activity is present. The decrease in median frequency to 0·25 *Hz-0 4* Hz could always be related to an EMG burst appearance.

The results of EMG spectral analyses presented as power spectrum are in agreement with the results of authors analysing the EMG of the smooth muscles of the uterine COrpUS[25].n.:1" and those analysing the EMG derived from the cervix 1830.:10-:18 .. The EMG signals of the cervical smooth muscles, as recorded by our group, lie within the frequency band width defined by Devedeaux *et al.*[26] as 'fast wave band'.

Power spectrum of the cervical EMG activity may have one or two separated frequency bands[12,18,36,38]. In Fig. 2 the results of spectral analysis of the EMG signal presented in Fig. 1 - trace 2 are given. The lower part with frequency components up to 0·6 Hz reflects the frequency content of EMG bursts, whereas the higher part with frequencies ranging from 1·0 Hz to 1·3 Hz corresponds to the permanent background EMG activity. A clear gap between those bands advocates for two different contraction mechanisms and/or a different origin of the EMG activity in the cervix.

CONCLUSIONS

During labour EMG bursts asynchronous with uterine contractions can be generated by smooth muscles of a relatively unripe cervix. EMG bursts with low median frequency and high signal amplitude (U_{RMS}) appear independent of uterine contractions or are delayed to the intrauterine peak value. Independent asynchronous EMG bursts advocate for active smooth muscle contraction in the relatively unripe cervix during labour. The delayed EMG bursts may be an active response to the passive stretching of the cervical smooth muscle tissue during a uterine corpus contraction. The observations are in agreement with the findings of Olah, who mechanically registered a cervical constriction as a consequence of prior dilatation during contraction of the uterine corpus.

The frequency content of the registered EMG signals is divided into two separate frequency bands where the lower band belongs to the EMG bursts and the higher to the EMG background activity. A clear gap between these bands advocates for two different contraction mechanisms of the cervical smooth muscle tissue and/or a different origin of the EMG activity in the cervix.

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