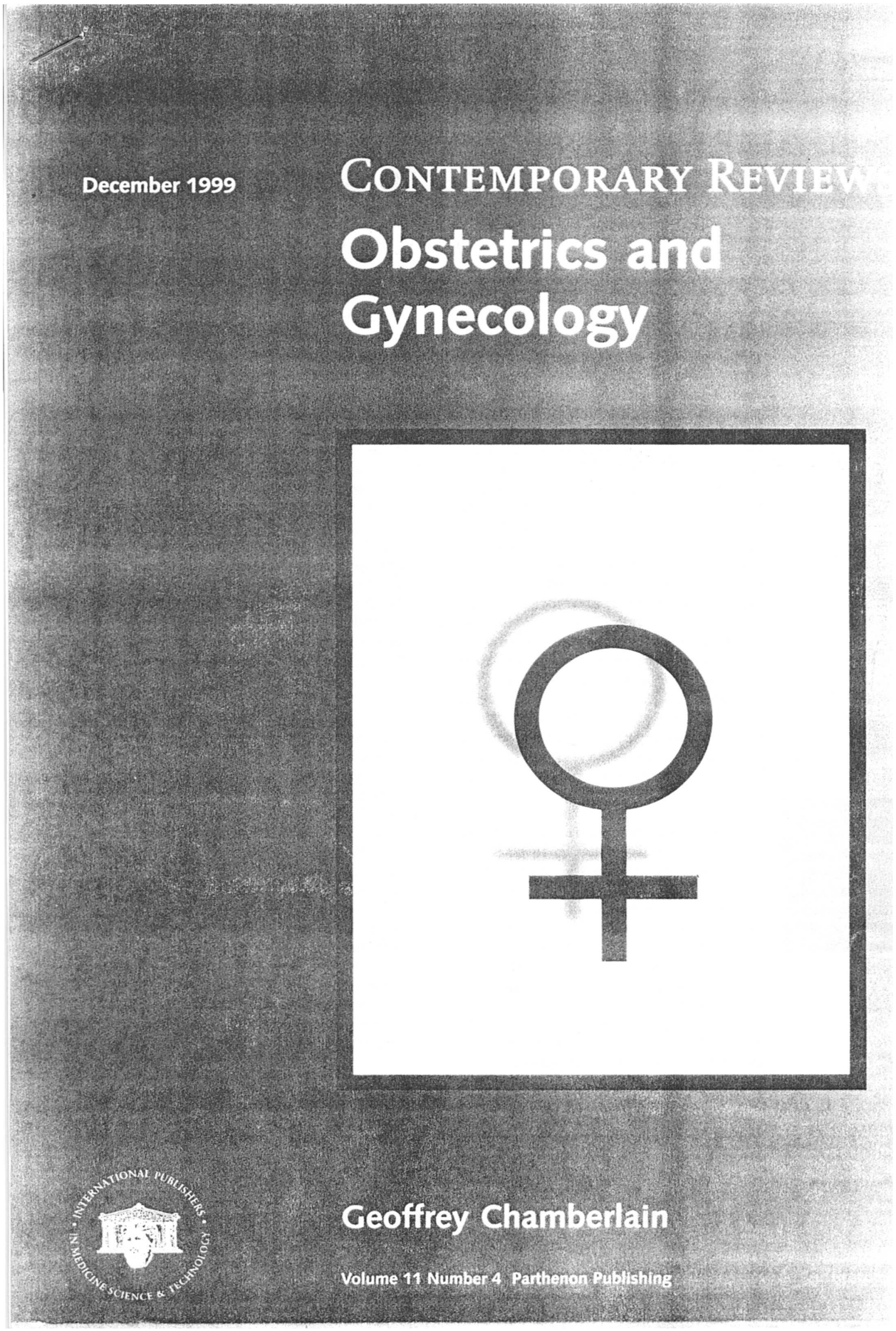
December 1999
CONTEMPORARY REVIEW
Obstetrics and Gynecology
Geoffrey Chamberlain
Volume 11 Number 4 Parthenon Publishing

Contractions of the cervix in the latent phase of labour

D. Rudel and M. Pajntar

According to recent findings the uterine cervix plays an active role during the progress of labour. Some consider this to be determined by biochemical processes, but others understand that smooth muscle cell contractions actively influence the course of labour. A hypothesis exists that contractions of circular muscle cells contribute to the constriction of the cervical canal, while longitudinal cell contractions contribute to cervical canal dilatation. Different investigations have shown the independent activity of the cervix from that of the uterine corpus myometrium in the latent phase of lab our. Mechanically registered contractions and electrically registered cervical muscle cell electromyographic (EMG) activity may help to explain clinically observed situations where the cervix does not dilate as expected, or a previously soft cervix becomes suddenly rigid during the latent phase of labour.

An EMG signal derived from the cervix has the same general characteristics as a smooth muscle EMG. A permanent background EMG activity indicates continuous muscle cell activity and is a sign of an unripe cervix. It might represent prolonged muscular activity, which helps to keep the fetus in the uterus during pregnancy but disrupts the onset of labour. Low-frequency EMG bursts appear periodically synchronously or asynchronously with uterine contractions. In the early latent phase they are of ten superimposed on the permanent background activity. Two different EMG signal patterns indicate two different contraction mechanisms and a different origin of the EMG activity in the cervix.

THE ACTIVE ROLE OF THE CERVIX IN LABOUR

The cervix is an anatomica1, biochemical and physical system, the function of which is of vital importance for pregnancy and the outcome of labour. In the past the cervix was considered to be a passive organ; its function of retaining the conceptus should be concluded at term. The importance of the condition of the cervix or its ripeness at the time of the onset of labour is well known in clinical practice, but the active role of the cervix during parturition has been neglected1• According to recent findings. the uterine cervix plays an active role during pregnancy and labour. It appears that the adjective active has been accepted, but that the term has been understood differently by various investigators. Uldbjerg and associates[1] and Garfield and colleagues[3] claim that cervical ripening is an active biochemical process. Those convinced of cervical smooth muscle activity understand smooth muscle cell contractions to be an activity contributing to cervical resistance [1.4-10]. According to Pajntar's hypothesis•, contractions of circular muscle cells contribute to the constriction of the cervical cana1, while longitudinal cells contribute to cervical canal dilatation. The contractions possibly accelerate collagen decomposition during the cervical ripening process[10], This may have clinical implications for the management of the early stage of labour.

The wall of the human cervix is predominant1y a connective tissue structure, made up of collagen fibres, elastin and smooth muscle fibres[11-14]. Muscle fibres grouped in bundles, lie in the cervix in various orientations: longitudinally, spirally circularly or scattered sparsely and at random. throughout the cervical tissue[13.14]., In some animals the cervix is dearly composed of longitudinal outer and circular inner layers[15] while in human s such

The wall of the human cervix is predominantly a connective tissue structure, made up of collagen fibres, elastin and smooth muscle fibres.

D. Rudel, PhD, Senior Clinical Research Consultant, and M. Pajntar, MD, Professor, Head of Research Unit, Department of Obstetrics and Gynaecology, University Medical Centre Ljubljana, Slovenia

organization and orientation is not well expressed. The amount of muscle fibres in different cervices varies great1y from 0% to 40% of cervical substance, although ordinarily it does not exceed 10-15%[11,13]. Therefore, the muscular component in the connective tissue is supposed by some authors to be insufficient to play any important role in this process. However, Danforth[13] stated that it is unreasonable to presume that smooth muscle cells would exist, if they did not have some function. Clinicians often observe situations during labour where a soft and dilated cervix suddenly becomes rigid and less dilated. This phenomenon could not be explained by collagen restructuring. The most probable answer is that smooth muscle cells contract, causing cervical resistance.

Active contraction of cervical musculature has been proven by mechanical and electrical measurements of cervical muscle activity during pregnancy[16] and labour[5,16,17]. In the early seventies Theobald[18] published findings based on the previous works of Karlson[19] and Woodbury[20] stating that the cervix contracted rhythmically and independently of uterine corpus myometrium contractions. His findings were considered suspect among obstetricians for years. Further in vitro and in vivo investigations in animal settings[16] confirmed the observations. The findings of Pajntar and associates[17], demonstrating contractions of the smooth muscle cells in the cervix in humans during the latent phase of labour, based on electromyographic (EMG) recordings. were initially rejected by reviewers of a prominent US journal simply because they did not believe the results. After several years they allowed the paper to be published.

Many researchers believe that contractions are a normal physiological activity and have a certain role during pregnancy. at the onset of labour with an unripe cervix. and in the process of cervical ripening[1,2.5,17,21.22]. The contractions have been registered in almost all observed unripe cervices[4,17] and in half of observed labours[1,5].

Many articles report a modulation of contraction properties of muscle tissue strips, taken from the parturient cervix. by administering doses of hormones and different pharmacological substances[23-25]. Pajntar and coworkers have demonstrated the influence of oxytocin (Syntocinon)[26] and a spasmoanalgesic (Dolantin) on cervical muscle electrical activity in the latent phase of labour[27].

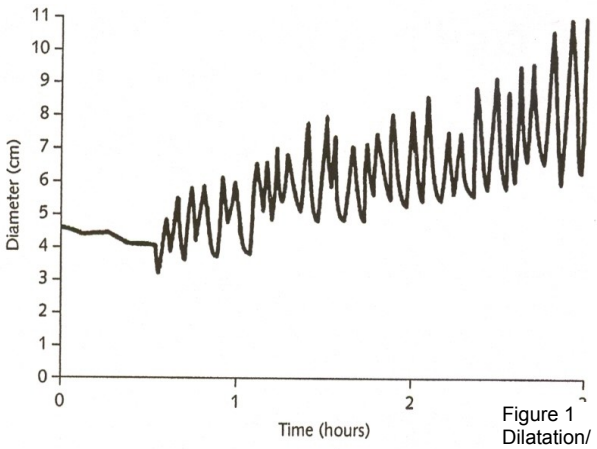

Figure 1 Dilatation/ constriction of a cervical canal during labour. (Reprinted from Pajntar M, Novak·Antolic Z. Vodenje poroda. Cankarjeva zalozba, Ljubljana, 1984)

OBJECTIVE ASSESSMENT OF CERVICAL SMOOTH MUSCLE CONTRACTIONS

Objective assessment of contractions of cervical smooth muscles is possible only if we consider it as a mechanical system whose physiological, physical and electrical properties could be measured and/or modulated. There is a lack of interdisciplinary knowledge and quantitative methods in this field. Investigations in humans are limited owing to ethical restrictions and subjective reasons as well as technical problems (additional measuring devices used along with routinely used equipment during labour). Not surprisingly, the number of participants involved in studies is low. Consequently papers reporting in vivo studies of smooth muscles in human cervices are rare. Ljubljana and Birmingham have been the only two centres reporting results of in vivo measurements in humans during the last decade.

Passive dilatation during a uterine contraction was followed by cervical constriction below the initial level of dilatation

At the present time contractions of the smooth muscles of the cervix can be studied in vivo mechanically by measuring constriction of the cervical canal, or by detection of electrical signals produced by smooth muscle fibres in the cervix using electromyography (EMG). Simultaneous recording of mechanical and electrical activity would be optimal. providing the opportunity to present results verified from two different standpoints[7].

Registration oft he cervical canal dilatation or constriction in labour by a cervimeter shows dynamic changes in cervical canal diameter (Figure 1), where the cervix. after a uterine contraction, does not simply retract to the level prior to the contraction. Olah and Gee[1,5,8] paid special attention to 'negative dilatation' of the cervical canal registered. in some cases, with an uneffaced cervix dilated less than 4 cm (Figure 2). Passive dilatation during a uterine contraction was followed by cervical constriction below the initial level of dilatation. According to the authors the exhibited constriction was caused by active contractions

of the cervical smooth muscles. They also reported cases where the cervix constricted rather than dilated in response to the myometrial activity of the uterine corpus. For five subjects constrictions were also documented by EMG signals recorded simultaneously (Figure 3)[7].

Electromyography

The basic process that controls smooth muscle contractions is the underlying chemical, and consequently. electrical activity. Components of the EMG signal are action potentials in the form of spikes[28-30] or plateau-like signals[30-33]. They can be generated sporadically. as a single event. as a continuous train of consecutive events. or in the form of bursts. Temporary and spatially summated action potentials are registered by macroelectrodes inserted into a muscle tissue as an electromyographic (EMG) signal. EMG activity therefore indicates muscle cell activity (contractions) in the region.

Contractions of smooth muscle cells are closely related to their electrical activity[28-30]. This relationship was confirmed by in vitro measurements on strips taken from animal specimens[30] and humans during pregnancy. at labour and post-partum[19,30,33]. Changes in the action potentials regulate the amplitude. duration and frequency of contractions[14]. Contraction intensity (level of force generated by muscle or the amplitude of contraction) strictly depends on the frequency of appearance of action potentials and the amount of muscle mass involved[3]. The intensity increases with increasing frequency of action potentials. Contraction duration is proportional to the duration of (above threshold) electrical excitation. Contraction frequency is equal to the frequency of bursts of electrical activity[30]. If frequency is high enough. contractions become continuous[19,30].

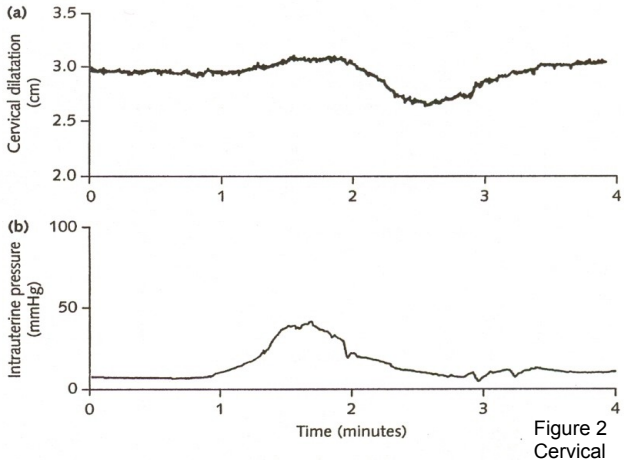

Figure 2 Cervical dilation/ constriction (a) and intrauterine pressure (b). Passive dilatation of the cervix during a uterine contraction is followed by cervical constriction below the initial level of dilatation when the uterine contraction concludes. (Adapted from reference 7)

The EMG signal presented in a time domain (Figure 4b) has the character of a random signal. very similar to a low-frequency noise[34]. EMG results. presented at different international conferences, were therefore often questioned on the basis of 'signals detected at the cervix consist of noise and signals originating from remote organs e.g. colon, heart (ECG) and striated muscles of the stomach [wall] at breathing, rather than reflecting cervical smooth muscle activity'. These objections could be rejected owing to the fact that four different research groups have described EMG activity having very similar characteristics[17,35-37]. Additionally. signals measured at the cervix have almost identical time and frequency parameters to those derived from the uterine corpus myometrium[29,38-41]. By implementing adequate EMG signal pre-processing methods (band pass filtering, artefacts limitation and manual removal of artefacts), the influence of possible disturbing signal components having remote origin can be substantially reduced.

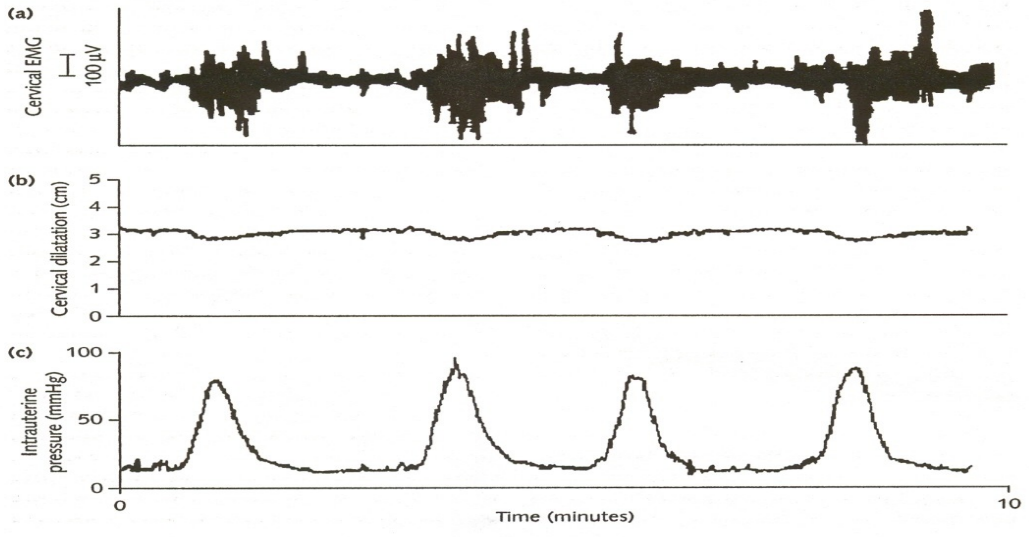

Figure 3 EMG activity registered in the cervix (a), cervical canal constrictions at the uterine corpus contractions (b) and 10 intrauterine pressure (c). (Adapted from reference 7)

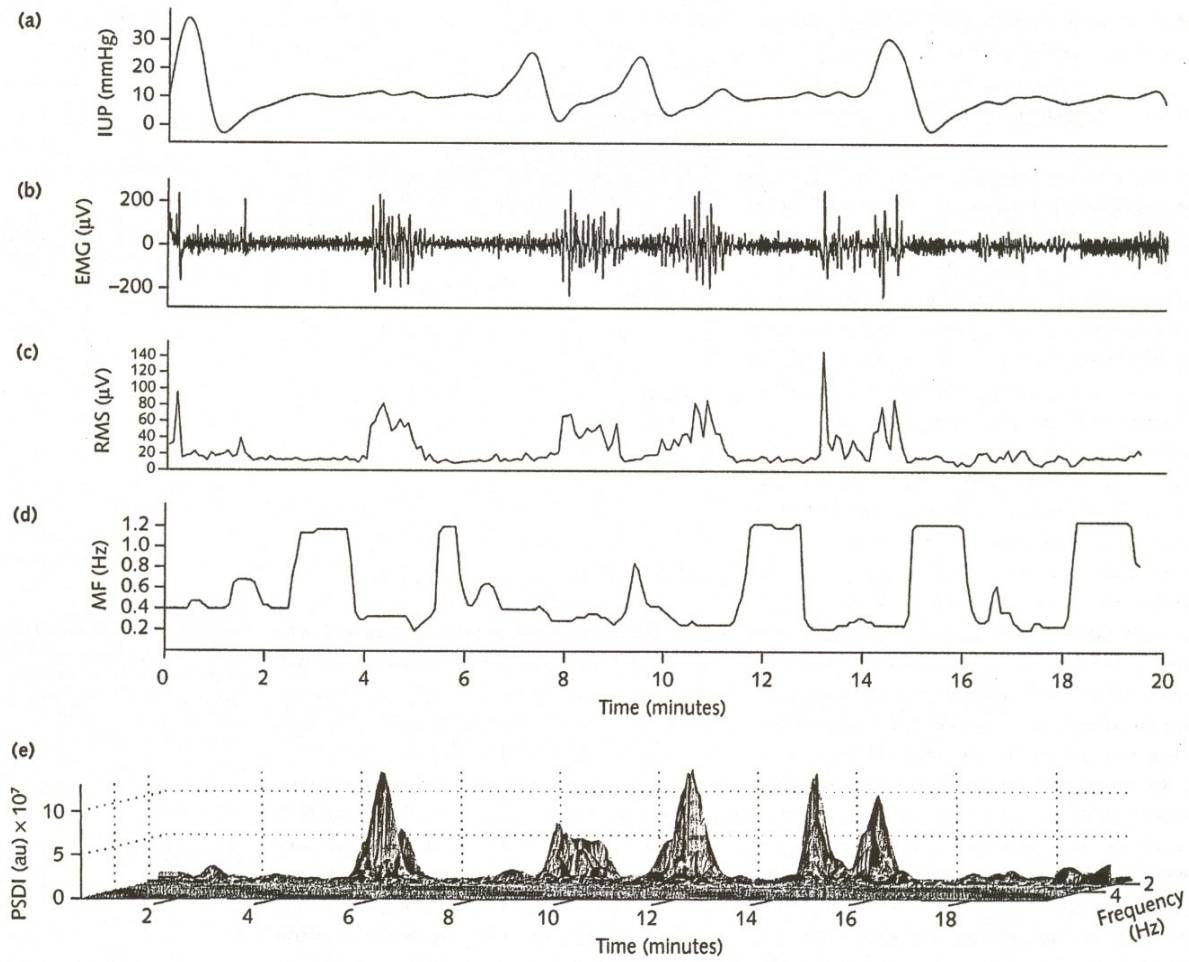

Figure 4 Signals recorded from a patient with a Bishop score B = 8 during a 20-minute period, and results of the signal processing. (a) intrauterine pressure (IUP); (b) EMG activity in the cervix; (c) root mean square (RMS) of the EMG signal; (d) median frequency (MF); (e) spectrogram - time/ frequency diagram (PSD, power spectrum density; au, arbitrary units

Electromyography of the cervix - historical review

Several results have been reported and many conclusions made based on EMG signal analysis. In vitro electrophysiological studies have been performed on sample strips[21] and at the cellular level[28,30,33,43]. Recently developed electrophysiological techniques designed to detect electrical activity on a cellular level enable a closer look at smooth muscle cell mechanisms. Not surprisingly, they confirm results acquired by macroelectrode detecting techniques[44].

Compared with in vitro studies, the number of in vivo studies done in the 1960s and 1970s is low. Serr and colleagues[35] registered EMG activity in a pregnant woman by using a rubber cup with needle electrodes inserted in it. They detected spike-like potentials that presumably had their origin in the cervix. Jarakov and Nedeltschewa[36] described the detected EMG activity, derived from the cervix, as a slowly changing monophasic and rapidly changing biphasic activity. The slow activity lasted for 45 to 50 s. It appeared synchronously with uterine contractions, but there was a delay in reaching the peak of the contractions for 15 to 20 s. The fast activity was weaker in signal amplitude, having frequencies from 0.5 to 2 Hz. It was detected at, and sometimes also between, consecutive uterine contractions.

In the 1980s the group in Ljubljana seems to have been the only one working on in vivo registration of EMG activity in the human cervix[40]• In the early 1990s Gee's group from Birmingham produced several results based on the critical view of clinical practice in obstetrics. Both research groups have been using similar measuring techniques; consequently the results are comparable and supportive.

EMG signal processing methods

The EMG signal (Figure 4b) could be defined by several attributes: presence or absence of characteristic signal patterns; superposition of different types of activities; number of bursts; appearance of bursts with regard to uterine corpus myometrial contractions (Figure 4a); amplitude; duration; frequency; energy (power), etc. When additionally processed, the EMG signal can better describe the contractions in the cervix and represent a measure of the level of the contractions.

Different EMG signal processing methods have be en implemented. Basically, they could be classified as time domain methods, frequency domain methods and statistical methods. In the past descriptive methods were dominant. followed bybursts-eounting, amplitude processing and frequency spectra calculation. The EMG root mean square (RMS) value is a continuous electrical parameter, being a measure of the signal amplitude (Figure 4c).

Median frequency (MF) is a single number average value of the EMG signal, indicating the frequency content of a selected short time interval, for example 5 s. For longer intervals it is calculated continuously (Figure 4d), giving information on changes in the frequency content of the EMG.

Power spectra density (PSD) is a graphic presentation of the frequency content of an EMG signal over a selected time interval. It also contains information on the energy of the analysed EMG signal that is proportional to the work done by smooth muscle cells in the cervix (Figure 5).

Tools developed for sound signal processing, such as time/frequency analysis, can al so be used for the analysis of EMG data, giving a three-dimensional presentation of the activity in the cervix (Figure 4e). Each time frequency diagram consists of series of time slices containing PSDs for consecutive time intervals. In this way the changes in the EMG signal frequency content and its power are recognized. More recently, statistical methods have been implemented to relate EMG to clinically assessed Bishop score components[9]•

EMG activity during the latent phase

The EMG activity in the cervix could be registered continuously to allow monitoring of cervical smooth muscle activity throughout the duration of labour. It has different characteristic patterns which are shown in Figure 6 along with an intrauterine pressure signal (IUP). Basically, three types of EMG activity could be distinguished: a permanent EMG activity; EMG bursts appearing singly; or a combination of both. A permanent background EMG activity (Figure 6a, upper trace) with frequency content from 1.0 to 3.0 Hz indicates continuous smooth muscle cell activity. It is registered only in the early and mid latent phase of labour and diminishes with cervical ripening'7. EMG bursts (Figure 6b, upper trace) demonstrate a low-frequency (up to 0.8 Hz) EMG activity appearing periodically and lasting for some minutes. They are observed in the mid to late latent phase, at a certain level of the cervical ripening process. In the intermediate phase of the cervical ripening process, EMG bursts are superimposed onto the permanent background activity (Figure 6c, up per trace). Later in the latent phase the amplitude of the permanent activity diminishes, but bursts become more prominent and synchronous with uterine corpus contractions[17,21]•

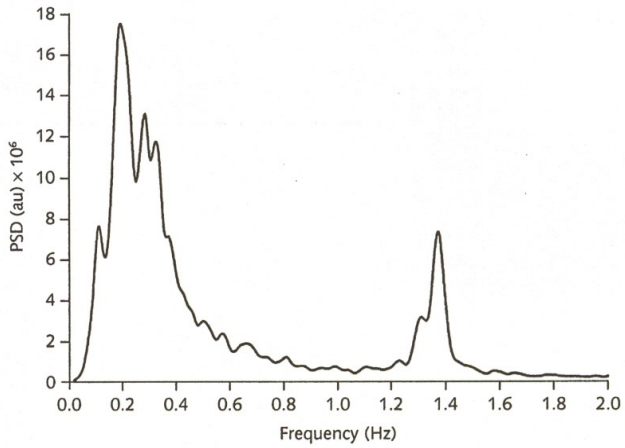

Figure 5 Frequency content of the EMG signal: the lower part with frequency components up to 0.6 Hz reflects the frequency content of EMG bursts, whereas the higher part with frequencies ranging from 1.0 Hz to 1.3 Hz corresponds to the permanent background EMG activity. PSD, power spectrum density; au arbitrary units

In general. the EMG activity at the onset of an induced labour is stronger (higher amplitudes) than later in the latent phase, when the cervix dilates and effaces[9,17,22,45]. Pajntar and Verdenik[22] demonstrated that in an oxytocin-induced labour average RMS values of EMG, taken from the cervix in the latent phase, were significantly higher in women with unripe cervices (low Bishop scores) than in those with ripe cervices (high Bishop scores) throughout the observed period close to amniotomy. They found a significant positive correlation between RMS of EMG and the duration of the latent phase[4].

In principle, the intensity of the cervical electrical activity decreases with parity. In secundiparous patients with an extremely unripe cervix, electrical activity similar to that found in primiparous patients with unripe cervices could be found. However, in most secundiparous patients the electrical activity of the cervix bears more resemblance to that characteristic of primiparous women with ripe cervices. In triparous and multiparous women the activity is smaller. As a rule, the amplitudes of individual bursts in multiparous women are much smaller[17].

Activity of the cervix independent of that of the uterine corpus myometrium has been claimed and often demonstrated clinically by using mechanical and/or electrical means[1,4,5,7,10,16,17,21]. A high amplitude (up to 100 uV) of permanent EMG activity registered at the cervix characterizes a very unripe cervix. It is considered that local smooth muscle cell activity is not associated with myometrial contractions but that it represents prolonged muscular activity, which helps during

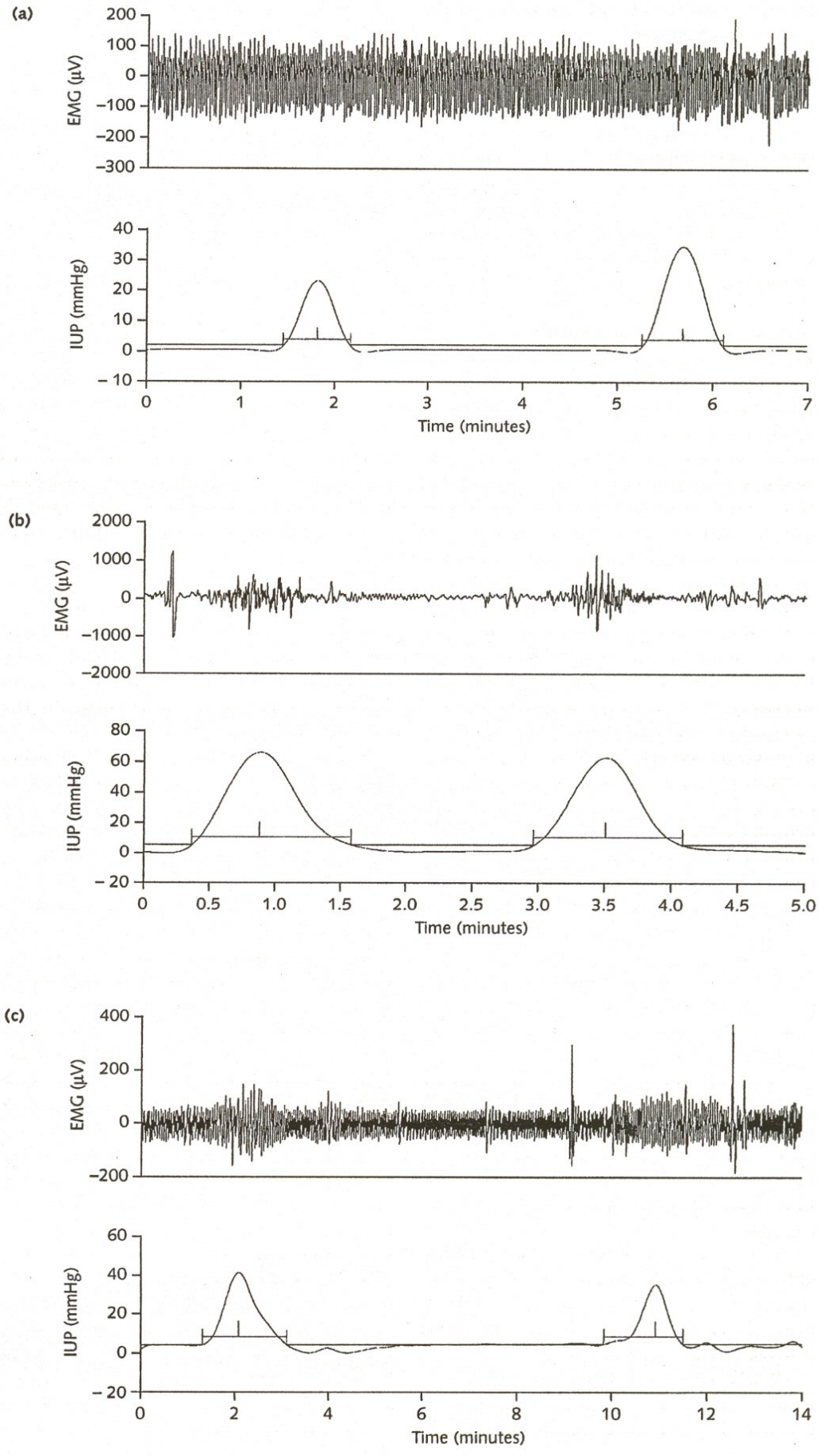

Figure 6 Three characteristic EMG signal patterns (upper trace a-c) presented along with intrauterine pressure signal, IUP (lower trace a-e): (a) continuous EMG activity; (b) EMG bursts; and (c) combination of both

pregnancy to keep the fetus in the uterus but disrupts the onset of labour[1,10,22].

EMG bursts are low-frequency temporal activity, which could be synchronous with myometrial contractions of the uterine corpus[7,9,17,22,26,27] or asynchronous, not associated with the uterine contractions[9,10]. In the case shown (Figure 4), the first EMG burst (b) appears at the moment when a contraction of the uterine corpus (a) itself is not expressed (no increase in the IUP - (a)). Asynchronous bursts, when observed, could be attributed to the functionally independent muscle activity of the human cervix[9,26,45] and suggest a relatively unripe cervix. The delayed EMG bursts (the second and third in Figure 4b) are considered to be an active response to the passive stretching of the cervical smooth muscle tissue during a uterine corpus contraction[10].

Olah[7] registered EMG activity in a cervix which exhibited active cervical contractions, confirmed by cervimetric measurements in the latent phase of labour. The EMG pattern differed from that, registered when the cervix dilated only passively, with uterine myometrial contractions.

Results obtained by different researchers concerning the frequency range of EMG signals concur. The EMG derived from the cervix belongs to the 'fast-wave frequency band' on the EMG frequency band scale suggested by Devedeux and colleagues[40]. The lower frequency is assessed to be as low as 0.01 Hz, while the upper is less than 3 Hz. Usually frequency components lower than 0.1 Hz[46-48] or 0.03 Hz[9,10] are cut off by filtering because of technical reasons.

Frequency analysis of the EMG signal shows that at the onset of labour frequencies in the PSD are grouped into one or two separated frequency bands, namely, up to 0.8 Hz and from 1 Hz to 1.8 Hz (Figure 5). The PSD of an unripe cervix is composed of two or three bands, while relatively unripe and ripe cervices have only one, the lower frequency band component[9,10,46]. The grouping of frequencies indicates different characteristics of the permanent and burst like EMG activity[9.10.38]. A clear gap between the bands suggests two different contraction mechanisms and/or a different origin of the EMG activity in the cervix[10].

The frequency content of the EMG signal changes with the progress of labour. Median frequency as a measure of frequency content therefore varies accordingly (Figure 4d). When an interval of a superimposed EMG signal belonging to an unripe cervix is analysed, the MF is high (about 1.2 Hz) in intervals between two consecutive contractions. It drops (to about 0.3 Hz) when EMG bursts with their low frequencies and higher amplitude prevail[9,10]. Generally, the MF tends to be lower at the end of the latent phase than at the onset of labour. Dynamic changes in the frequency content of the EMG signal are also obvious from a three-dimensional time/frequency diagram (Figure 4e).

Statistical analysis based on a group of 47 patients showed that Bishop score components for cervical consistency and effacement, given by an obstetrician at the onset of labour, were significantly related to the EMG signal amplitude (RMS) and its median frequency (MF)[9].

CONCLUSIONS

A better understanding of the role of the smooth muscles in the cervix at term is required. if clinicians wish to influence the process of cervical ripening and dilatation. There is a lack of new knowledge. an obstacle that has to be overcome if they want to manage the resistance of the cervix better[49,50].

In clinical practice EMG measurements provide good results. The application of EMG spiral electrodes to the cervix is as simple a procedure as the application of CTG electrodes to the fetal head. Therefore. EMG recording is a suitable method for clinical practice. Some work is required to produce additional simple rules for interpreting EMG recordings. The authors believe that much could be gained if animal model s were used. Investigations should also be widened to include studies on the sympathetic and parasympathetic nerve systems. which innervate the cervix. Additionally. remote excitation of the observed system by electrical stimuli is a great challenge. which could bring results for further characterization of contractions of the cervix in the latent phase of labour.

REFERENCES

1. Gee H. The cervix in labour. Contemp Rev Obstet Gynecol1994;6:84-8
2. Uldbjerg N. Ulmsten U. Ekman G. The ripening of the human uterine cervix in terms of connective tissue biochemistry. In Pitkin RM. Scott JR. Ulmsten U. Ueland K. eds. Oln Obstet Gynecol No. 1, Vol. 26. Philadelphia: Harper & Row. 1983:14-26
3. Garfield RE. Saade G. Buhimshi C. et al. Control and assessment of the uterus and cervix during pregnancy and labour. Hum Reprod 1998;4:101-9
4. Pajntar M. The smooth muscles of the cervix in labour. EurJ Obstet Gynecol Reprod Blo11994; 55:9-12
5. Olah KS, Gee H. Brown JS. cervical contractions: the response of the cervix to

oxytocic stimulation in the latent phase of labour. BrJ Obstet Gynecol1993;100:635-40
6. Olah KS. Neilson JP. Failure to progress in the management of labour. BrJ Obstet Gynaecol 1994;101:1-3
7. Olah KS. Changes in cervical electromyographic activity and their correlation with the cervical response to myometrial activity du ring labour. EurJ Obstet Gynaecol Reprod Blol 1994;57:157-9
8. Olah KS. Gee H. The active mismanagement of labour. BrJ Obstet Gynaecol 1996;103:729-31
9. Rudel D, Cervical Electromyographic Activity as an Indicator of Cervical Ripeness. PhD thesis. University of Ljubljana. Faculty of Medicine. 1996 (in Slovene)
10. Rudel D. Pajntar M, Active contractions of the cervix in the latent phase of labour. BrJ Obstet Gynaecol1999;106:446-52
11. Hughesdon PE. The fibromuscular structure of the cervix and its changes during pregnancy and labour.J Obstet Gynaecol Br Emp 1952;59: 763-76
12. Danforth ON. Distribution and functional significance of the cervical musculature. Am.J. Obstet Gynecol 1954;68:1261
13. Danforth DN. The Morphology of human cervix. In Pitkin RM, Scott JR. Ulmsten U. Ueland K. eds. Oln Obstet Gynecol No. 1, Vol. 26. Philadelphia: Harper & Row. 1983:7-13
14. Leppert PC. Anatomy and physiology of cervical ripening. Glin Obstet Gynecol 1995:38:267-79
15. El Banna AA. Hafez ESE. The uterine cervix in mammals. AmJ Obstet Gynecol 1972;109:145-64
16. Stys S, Clewell WH, Mechia G. Changes in cervical compliance at parturition independent of uterine activity. AmJ Obstet Gynecol1978;130:414-18
17. Pajntar M. Roškar E. Rudel D. Electromyographic observations on the human cervix during labor. AmJ Obstet Gynecol 1987;156:691-7
18. Theobald GW. Endocrine Control of Uterlne Innervatlon. Norwich: Butterworths. 1973:366
19. Karlson S. On the motility of the uterus du ring labour and the influence of the motility pattern on the duration of the labour. Acta Obstet Gynecol Scand 1949:28:209-50
20. Woodbury WJ. Physiological principles of contraction in uterine muscle. In MarshallJM. Burett WM. eds. Initiation of Labor. Washington: Public Health Service Publishers. 1965
21. Conrad Jr. Ueland K. Reduction of the stretch modulus of human cervical tissue by prostaglandin E~. AmJ Obstet Gynecol1976;127: 218-23
22. Pajntar M. Verdenik I. Electromyographic activity in cervices with very low Bishop score during labor. Int] Gynecol Obstet 1995;49:277-81
23. Bryrnan 1. Norstrom A. Lindblom B. Influence of neurohypophyseal hormone s on human cervical smooth muscle contractility in viltro. Obstet Gynecol1990:75:240-3
24. Kawarabayashi T. Izumi H. Ikeda M. et al. Modification by magnesium of the excitatory effect of oxytocin in electrical and mechanical activities of pregnant human myometrium. Obstet Gynecol1990;76:183-8
25. Huszar GB, Walsh MP. Relationship between myometrial and cervical function in pregnancy and labor. Semln PerlnatoI1991;2: 97-117
26. Pajntar M. Rudel.D. Changes in electromyographic activity of the cervix after stimulation of labour with oxytocin. Gynecol Obstet Invest 1991 ;31 :204-7
27. Pajntar M. Rudel D. Effect of spasmoanalgetic Dolantin on the electromyographic activity of the cervix during labour. Glin Exp Obstet Gynecol 1992;19:9-14
28. Csapo Al. The uterus: a model for medical considerations. In Laki K. ed. Contractile Proteins and Muscle. New York: Marcel Dekker. 1971: 413-82
29. Wolfs G. Van Leeuwen M. Electromyographic observations of the human uterus during labour. Acro Obstet Gynecol Scand (Suppl) 1979; 90:1-62
30. Kao CY. Electrophysiological properties of uterine smooth muscle. In Wynn RM.Jollie