A uterine electromyographic activity as a measure of labour progression

Elektromiografska aktivnost maternice kot mera za spremljanje poroda

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Izvleček

Izhodišča: Za potek normalnega poroda je potrebno usklajeno delovanje materničnega telesa in materničnega vratu. V praksi porodničar ob sprejemu porodnice poda oceno po Bishopu, ki je sicer uveljavljena, a je le subjektivna ocena. Sam porod porodničar spremlja tudi z izrisovanjem partograma. Morebitni zastoj pa je v partogramu viden šele po nekaj urah. Eden od razlogov za počasno diagnosticiranje patološkega poroda je pomanjkanje kvalitativnih merilnih metod za vrednotenje aktivnosti maternice med porodom. V različnih študijah so pokazali, da je merjenje elektromiografske (EMG) aktivnosti maternice obetajoča metoda, ki bi lahko postala novo diagnostično orodje.[6-9] V študiji nas je zanimalo, ali lahko z določitvijo ustreznih parametrov iz elektromiografske aktivnosti sklepamo, kako poteka porod.

Metode: Meritve elektromiografske aktivnosti maternice so bile zasnovane za potrebe predhodnje študije Pajntarja in sodelavcev.[18] V študiji so merili EMG-aktivnost materničnega vratu, v nekaterih primerih pa tudi materničnega telesa. Popadke so v študiji spremljali z meritvijo znotrajmaterničnega tlaka. V pričujočo študijo smo vključili 28 porodnic. Vse porodnice so rodile vaginalno. Porode smo na podlagi partograma in ostale porodne dokumentacije razdelili v dve skupini (Tabela 1): normalno napredujoči porodi (14) in porodi z zastojem v napredovanju (14). Iz porodne dokumentacije smo izluščili oceno po Bishopu, dolžino aktivne faze poroda, obseg glavice novorojenca in težo novorojenca. Iz zajetih EMG-posnetkov smo iz zaporednih, 8,2-minutnih intervalov izračunali vzorčno entropijo. Vzorčna entropija je mera kompleksnosti signala. Potek izračunanih vrednosti vzorčne entropije smo primerjali s potekom poroda, ocenjenega s partogramom.

Rezultati: Statistična primerjava ocen po Bishopu, podatkov o trajanju aktivne faze poroda, velikosti glavice in teži novorojencev iz obeh skupin je pokazala, da se skupini statistično značilno razlikujeta le v trajanju aktivne faze poroda. Pri normalnem poteku poroda je izračunana vrednost vzorčne entropije iz EMG-aktivnosti materničnega telesa (Slika 1) na začetku aktivne faze poroda od 0,13 do 0,25 (vrednost mediane je 0,15). Z napredovanjem aktivne faze poroda se vrednosti vzorčne entropije zmanjšujejo. S približevanjem rojstva otroka so izračunane vrednosti vzorčne entropije med 0,08 in 0,11 (vrednost mediane je 0,09). Podobno dinamiko imajo tudi izračunane vrednosti vzorčne entropije iz EMG-aktivnosti materničnega vratu. Na začetku aktivne faze poroda so te vrednosti med 0,08 in 0,13 (vrednost mediane je 0,12).

S približevanjem rojstva otroka se izračunane vrednosti vzorčne entropije znižajo in so na območju od 0,03 do 0,05 (vrednost mediane je 0,03).

Na začetku aktivne faze poroda so vrednosti vzorčne entropije med skupinama primerljive. Vrednosti vzorčne entropije, izračunane iz EMG-aktivnosti maternične vratu na začetku aktivne faze poroda pri porodih z zastojem v poteku (Slika 2), so med 0,08 in 0,15 (vrednost mediane je 0,14). Z napredovanjem poroda se izračunane vrednosti vzorčne entropije zmanjšajo in so na območju od 0,02 do 0,13 (vrednost mediane je 0,05). Med zastojem v poteku poroda se izračunane vrednosti vzorčne entropije povečujejo do območja med 0,18 in 0,25 (vrednost mediane je 0,22). Povišane vrednosti opazimo ves čas zastoja. Po končanem zastoju v poteku poroda se vrednosti vzorčne entropije ponovno zmanjšujejo do vrednosti na območju od 0,02 do 0,05 (vrednost mediane je 0,04), ki pa so ponovno primerljive z vrednostmi, pridobljenimi pri normalnem poteku poroda.

Zaključki: V naši študiji smo iz EMG-aktivnosti maternične telesa in iz EMG-aktivnosti maternične vratu izračunali vrednosti vzorčne entropije. Z razliko od nekaterih drugih avtorjev smo se pri obdelavi EMG-zapisov, zajetih med porodom, osredotočili na celoten EMG-zapis in ne zgolj na popadke ter vrednosti vzorčne entropije računali ves čas poroda.

S približevanjem rojstva se pri normalnem poteku poroda vrednosti vzorčne entropije manjšajo, kar nakazuje, da je EMG-aktivnost maternične telesa in maternične vratu vedno manj kompleksena. Zastoj v poteku poroda spremlja večja kompleksnost elektromiografske aktivnosti maternične vratu. To zaznamo s povišanjem vrednosti vzorčne entropije. Ko porod ponovno steče, se vrednosti vzorčne entropije znižujejo in so primerljive z vrednostmi, izračunanimi pri normalnem poteku poroda.

Iz omenjenih rezultatov sklepamo, da bi s sočasnim merjenjem EMG-aktivnosti in računanjem vzorčne entropije porodničar lahko pridobil dodatne kvantitativne informacije o poteku poroda.

Abstract

Background: The purpose of this study was the possibility to follow the progress of labour using electromyographic (EMG) signals obtained from the uterine corpus and the cervix.

Methods: 28 healty primiparous women with induced labour at an age from 19 to 29 years were enrolled in the study. For interpretation of EMG signals Sample entropy (SampEn), the measure of time series regularity was used. SampEn values were related to the progress of labour recorded in the partogram. The main outcome is association between labour progress and values of SampEn.

Results: Approaching the childbirth during normally progressing labour, regular activity of uterine corpus muscles and cervical muscles is indicated as a decreasing trend in values of SampEn. A delay in the active phase of labour due to active contractions of cervical circular muscles is indicated in greater values of SampEn calculated from cervical EMG activity.

Conclusions: By measuring and processing of EMG signals from the uterine corpus and the cervix an obstetrician can obtain an additional useful information on the progress of labour.

Introduction

Intensive care monitoring systems that continuously record and evaluate fetal heart rate and uterine pressure inform obstetricians about fetus situation and uterus activity. However, obstetricians have a limited ability to prospectively define key events in labour and to evaluate how well the labour is progressing. Some information about labour progressing can be found only retrospectively. For example, labour has a delay in progress if there is no or minimal progress in cervical dilatation and/or fetal head station from the last examination performed an hour or more before.[1] Cervical dilatation and fetal head station are graphically outlined during the labour as partogram.

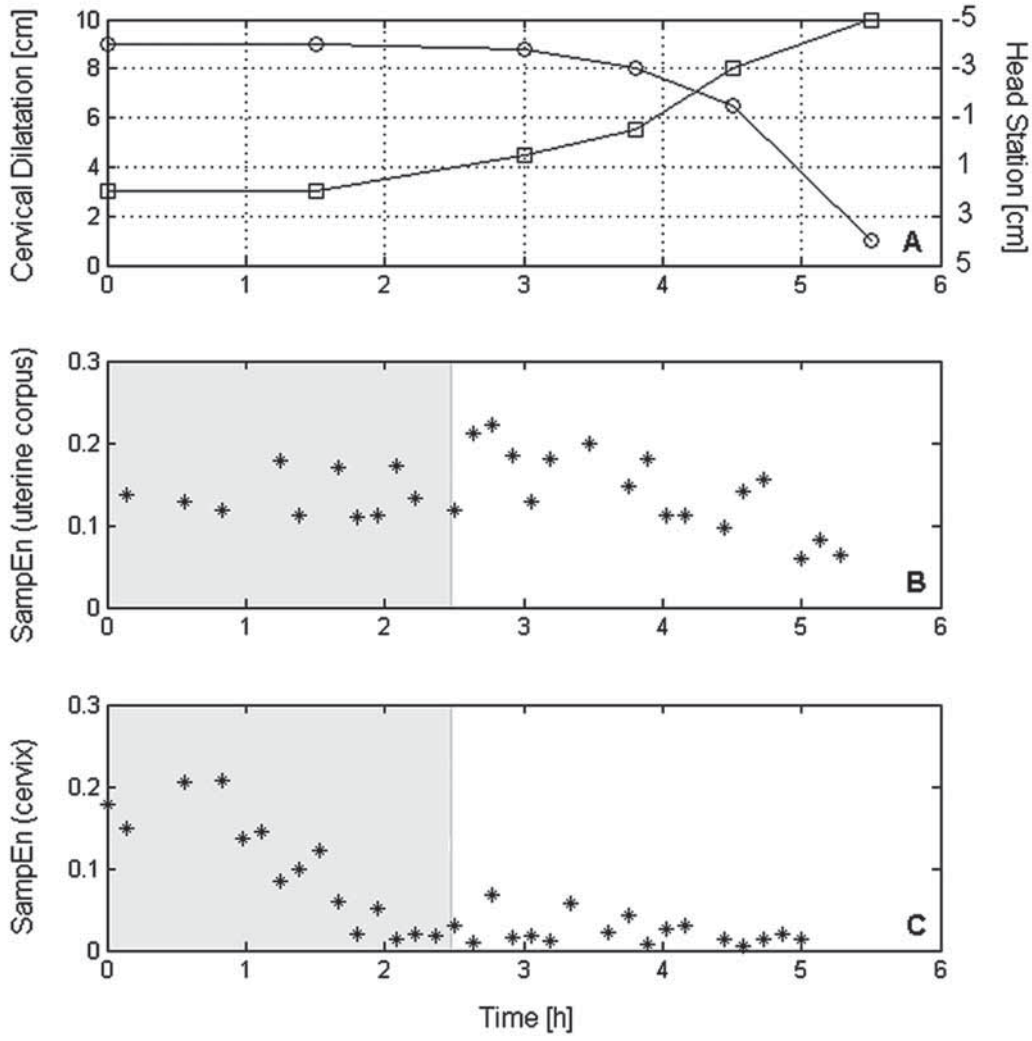

Figure 1: Normally progressing labour is recorded on a partogram(A), where cervical dilation is marked with squares and head station with circles; part B – the values of SampEn obtained from uterine corpus EMG activity; part C – the values of SampEn obtained from cervical EMG activity. A grey zone separates the latent phase (the left side of the zone) from the active phase (the right side of the zone).

Presently, assessment of Bishop score (BS)[2,3] and recording of partogram[4] are carried out blindly, solely by palpation, and are therefore subject to errors.[5] Various methods and devices have been designed for accurate measurements of cervical dilatation, fetal head station or the progress of labour,[5] but none is currently used in clinical settings. Besides, progression of the labour cannot be accurately monitored by following a single factor. Measurement of uterine electromyographic (EMG) activity provides precise information about myocyte electrical activity directly, and investigations have indicated that it is a sensitive method having a potential in the clinical practice.[6-9] As the uterine EMG activity is a complex voltage-time signal influenced by many physiological factors, its understanding has been a great challenge to many research groups for years. Most often the EMG segments taken during uterine contractions were analyzed[10] by calculating the power density spectrum and its peak frequency[7,8] or amplitude distribution in some cases.[6-8] Possible nonlinear nature of the EMG segments measured during uterine contractions was also tested by nonlinear signal processing methods.[10] The results indicated that uterine EMG signals have nonlinear characteristics. Therefore, nonlinear signal processing methods could be promising for analyzing the uterine activity.[16] Studies of uterine EMG activity during normally progressing labours indicated that EMG activity of both, the uterine corpus and the cervix, groups into bursts through the latent phase of the labour.[11]

Table 1: According to their partograms, the labours monitored in this study are divided into two groups: normally progressing labours (14) and labours with a delay in progress in the active phase (14). The characteristics (Bischop score on admission to the delivery room, duration of the active phase, weight and circumference of the newborn's head) of both types of labours are listed in the table as the median with maximum and minimum values in brackets. A significant difference (*) between the labours is present only in the duration of active phase (p=0.002).

Type of labour (No.)	Bishop score	Duration of active phase*	Newborn's weight [g]	Newborn's head circumference [cm]
Normally progresing labours (14)	6 (8 2)	2h 45min (4h 15min 1h 30min)	3640 (4360 2850)	34.75 (37 33)
Labours with a delay in progress(14)	6 (9 3)	5h 17min (7h 30min 2h)	3590 (4280 3100)	35 (38 33)

The cervical smooth muscle activity is present through the entire courseof the labour and contributes to the duration of the latent phase.[12] The smooth muscle fibres present in the cervix may act partially independent of the uterine corpus.[13] In our previous studies we found asynchronous EMG bursts of the uterine corpus and the cervix that could be attributed to independent muscle activity of the relatively unripe cervix.[14]

In this study we investigated a possibility to monitor the labour progress by processing EMG signals obtained from the uterine corpus and the cervix. In particular we focused on the early recognition of a labour that is becoming dysfunctional. Due to nonlinear nature of uterine EMG signals,[10] entropy methods were chosen for the recognition purposes. In general the entropy is a measure of stochastic processes complexity or its opposite, regularity. It increases with complexity[15-17] and decreases with regularity of the signal. As an entropy measure Sample entropy (SampEn) was selected.[15]

Methods

Subjects

The measuring protocol of the study was designed previously. It is described in details in Pajntar et al.,[18] therefore only the necessary information is given here. The investigation was approved by the National Medical Ethics Committee. Informed consent was obtained from all patients enrolled in the study. Patients were undergoing their first labour at an age from 19 to 29 years. After admission to the delivery room the value of BS was assessed for each primipara. The values of cervical dilatation and fetal head station were recorded into the partogram that was carefully drawn over the whole course of the labour. All labours ended with vaginal childbirth. The EMG signals were recorded on the cervix; but in some cases an obstetrician also measured the EMG signals on the uterine corpus. All EMG signals were sampled at 18.2 Hz, low-pass filtered at 5 Hz and saved for post processing. During all labours the contractions were monitored with measurements of intrauterine pressure.

We have selected from the labour base all labours that were according to the partogram traces and labour documentation recognized as normally progressing or labours with a delay in progress. Thus 14 normally progressing labours and 14 labours with a delay in progress have been included in the study.

EMG processing

For the purpose of this study the EMG signals were first detrended and band-pass filtered (0.1–3 Hz) using a second order Butterworth digital filter. The values of SampEn are usually calculated from 100 to 5000 data points.[19] To include at least one contraction at the latent phase of the labour in the calculation of values of SampEn, we have decreased the sampling rate of the EMG signal by keeping every second sample. Values of SampEn were calculated on 4500 data points, thus being available every 8.2 minutes. The values of SampEn were calculated on non-overlapping

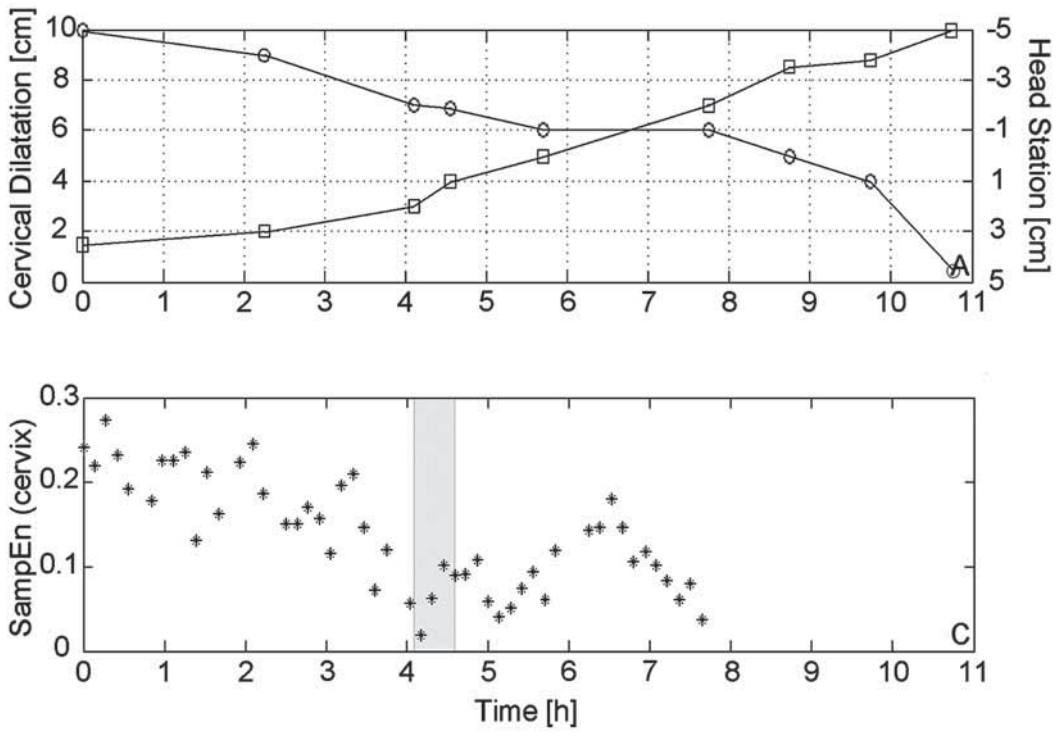

Figure 2: Labour with a delay in progress is recorded on a partogram (A), where cervical dilation is marked with squares and head station with circles, and part C – the values of SampEn obtained from cervical EMG activity. A grey zone separates the latent phase (the left side of the zone) from the active phase (the right side of the zone). Owing to the obstetrician's decision EMG signals were not measured on the uterine corpus.

intervals of the whole uterus EMG records. In this way the uterine EMG activity during labour was continuously processed. SampEn is a negative natural logarithm of probability that dataset, having repeated itself within a tolerance r for m points, will also repeat itself for $m+1$ points.[19] SampEn was calculated using $m=2$ and $r=1$. Signal processing and SampEn calculations were done in Matlab.

Data presentation and Statistical analysis

In view of the fact that each labour is a unique set of events and that monitoring has started at various labour phases, it is difficult to statistically compare values of SampEn. To get an impression how the labours of each group look like, we outline a typical labour to characterize each labour group. The observations of these two labours in the course of time are shown in Figures 1 and 2. Each figure represents one type of labour. In part A the partogram of labour is shown. In part B the calculated values of SampEn obtained from the uterine corpus EMG activity are shown. In part C the calculated values of SampEn obtained from the cervical EMG activity are shown. Time in hours is on the abscissa in every part of each figure. In all figures the transition from the latent to the active phase is marked as a grey zone. The beginning of the active phase was considered at 4 cm cervical dilatation, determent by obstetrician.

Other labours characteristic are listed in Table 1. Each labour was characterized by BS, duration of the active phase of labour and the weight and head circumference of the newborn. BS was determined at the admission to the delivery room; the duration of the active phase was assessed from the partograms; the weight and head circumference of the newborn were outlined from labour documentation.

The statistical analysis of these results was performed with SigmaStat 3.1. The two groups, i.e. normally progressing labours and labours with a delay in progress, were compared using the Mann–Whitney rank-sum test. A p value < 0.05 was regarded as significant.

Results

According to our results (Table 1) a statistically significant difference between the normally progressing labours and labours with a delay in progress is present only in the

duration of active phase ($p = 0.002$). There is no statistically significant difference in other labour characteristics; BS ($p = 0.927$), weight ($p = 0.818$) and head circumference ($p = 0.890$) of the newborn.

Normally progressing labours

The BS values of normally progressing labours range from 2 to 8 (Table 1) – the median value is 6. The active phases of all 14 normally progressing labours included in the study lasted from 1 h 30 min to 4 h 15 min (Table 1). Typical trace of a normally progressing labour is outlined in Figure 1A. Dilatation of the cervix is progressing in the course of time and the head of the fetus evenly drops to the brim, without any delays. The active phase of the labour presented lasted 3 h.

The values of SampEn calculated from uterine corpus EMG activity during normally progressing labours range from 0.13 to 0.25 at the end of the latent phase (3 cm cervical dilatation); the median value is 0.15. At the beginning of the active phase the values of SampEn start to decrease and keep decreasing with approaching delivery. Before delivery the values of SampEn range from 0.08 to 0.11; the median value is 0.09. These characteristics of normally progressing labours are presented in Figure 1: the values of SampEn calculated from uterine corpus EMG activity (Figure 1B) are still above 0.2 at the beginning of the active phase of labour and drop below 0.1 with approaching delivery.

Similar trend can be noted observing the values of SampEn calculated from cervical EMG activity. Considering all normally progressing labours, the values of SampEn range from 0.08 to 0.13 with the median value of 0.12 at the end of the latent phase. With approaching delivery, the values of SampEn decrease to the values from 0.03 to 0.05 with the median value of 0.03. The observations mentioned are presented in Figure 1C; the values of SampEn calculated from cervical EMG activity start to decrease at the end of the latent phase and fall below 0.05 with approaching delivery.

Labours with a delay in progress

BS of labours with a delay in progress range from 3 to 9 – median value is 6 (Table 1). The duration of the active phase of the labours with a delay in progress is from 2 h to 7 h 30 min – median value is 5 h 17 min (Table 1). Typical trace of this type of labour is presented in Figure 2. In partogram (Figure 2A) the curve representing the fetal head station maintains the same value for nearly two hours before the downward trend continues. During the delay the cervical dilatation rising trend is limited. Such a pattern can be noticed in all partograms in this group.

In the case presented in Figure 2C the values of SampEn calculated from the cervical EMG activity are around 0.1 at the beginning of the active phase of labour. As the active phase of labour progresses the values of SampEn decrease to the value 0.05. But instead of dropping below 0.05 with approaching delivery, the values of SampEn rise up to 0.2 at the time of head stagnation (Figure 2A). The values of SampEn decrease to 0.05 again as delay ends.

Taking into account all labours with a delay in progress, the values of SampEn calculated from cervical EMG activity range from 0.08 to 0.15 with the median value of 0.14 at the beginning of the active phase. As the active phase of labour progressed the values of SampEn already decreased to the values ranging from 0.02 to 0.13, with the median value 0.05. But instead of keeping a downward trend with approaching delivery, the values of SampEn increase to values between 0.18 and 0.25 (the median value is 0.22) during the delay. At the end of delay the values of SampEn decrease to the values ranging from 0.02 to 0.05, with the median value 0.04. We have no records of uterine corpus EMG activity in the group of labours with a delay in progress.

Discussion

Uterine activity can be traced accurately by measuring the EMG signals.[6,7] In our present study we analyzed uterine corpus and cervical EMG activity by calculating the values of SampEn. This is a new approach

in processing and evaluating uterine corpus and cervical EMG activity. This way the uterine EMG activity of the latent as well as the active phase of labour was continuously processed. During normally progressing labour uterine corpus and cervical EMG activity becomes more and more regular with approaching delivery. As a consequence, the values of SampEn have a decreasing trend. A delay in progress in the active phase of labour is accompanied by less regular cervical EMG activity as compared to the active phase of the normally progressing labours. Therefore the values of SampEn increase during the delay.

Cervical EMG activity was measured in the circular direction of the cervical axis and probably represents the circular muscle fibre activity, which may hinder effective dilatation of the cervical canal during the active phase of labour[16] and consequently causes its delay. Our results show that cervical contractions are not present only during the latent phase of labour,[13] but may be present also during the active phase causing its prolongation. Due to the obstetrician's decision to measure only the cervix we have no EMG activity recorded on the uterine corpus in this group.

According to previous studies, the assessment of BS,[2,3] which is still the most widely used, the most cost effective and accurate method for the evaluation of the patient's readiness for labour, is the best predictor of the latent phase duration.[8,20] Roman H et al showed that duration of the active phase does not always correlate with BS,[20] and our results presented in Table 1 confirm their study.

Conclusion

This study was performed offline, but it confirms that it is possible to track the progress of labour by measuring uterine corpus and cervical EMG activity and calculate the values of SampEn. The values of SampEn reflect abnormal uterine muscle activity and may serve, if calculated on-line, as continuous and accurate assessment of labour progress.

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