Use of the Electrohysterogram Signal for Characterization of Contractions During Pregnancy

Hélène Leman,* Catherine Marque, and Jean Gondry

***Abstract*—This article proposes a method to evaluate the ability of the electrohysterogram signal to characterize the contractions during pregnancy, in a population with high risk of preterm deliveries. This study constitutes a first stage of a project intended to develop a monitoring system for the early diagnosis of preterm deliveries.**

After a proper signal denoising, we calculate some parameters characteristic of the extracted contractions. These contractions are then divided into classes of different physiological terms. Classical techniques of data analysis, such as principal component analysis and discriminant analysis, permit us to show an evolution of the contractions during pregnancy, which is different between the groups of preterm deliveries and that of deliveries at term. We show that, in an early term of pregnancy, we can separate the two populations: women delivering at term from women delivering preterm. We then show that these two kinds of pregnancy are of different evolutions.

These results are encouraging, because they would permit, in a follow-up medical study, to diagnose a possible preterm delivery, as well as the proximity of the delivery.

***Index Terms*—Contraction characterization, discriminant analysis, electrohysterogram (EHG) signal, preterm delivery (PD), signal parameters.**

I. Introduction

PRETERM delivery is the primary cause of neonatal morbidity and mortality. In most developed countries, the rate of preterm births evolves between 5% and 9%. In France, a social politic of surveillance and prevention of pregnancies has permitted achievement of a low rate of 6%. Yet, despite a wealth of research work concerning the threat of premature birth, this rate has not changed for ten years.

The purpose of this work is to evaluate the possibility of early detection of preterm delivery (PD), by means of characterization of the contractions, obtained by uterine electromyogram (EMG), on the abdomen of the pregnant woman [electrohysterogram (EHG)]. As there is no current published information concerning EHG recordings so early in the pregnancy, we propose to investigate, in this study, the potentialities of such a signal to determine contraction evolution during pregnancy, and a possible separation between contractions leading to a PD and contractions leading to delivery at term (DT). We are interested in characterizing the uterine contractions, in a population at high risk of PD, from the twenty-first week of gestation (wg) to the thirty-seventh wg. The wg's are counted from the date of the last period.

Manuscript received March 25, 1998; revised April 6, 1999. This work was supported in part by the Pôle régional GBM Périnatalité of the Picardie region and by the CNRS. *Asterisk indicates corresponding author*.

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Publisher Item Identifier S 0018-9294(99)07414-5.

II. Detection of the Risk of Preterm Delivery

A. Uterine Activity During Pregnancy

Many authors have proven that uterine activity changes during pregnancy. For example, Nageotte, in 1988, recorded the frequency of appearance of contractions, with use of an ambulatory tocograph, from 237 patients at low risk of PD [1]. He noticed a significant increase of 4.7% per week, in the maximum uterine activity, between 30 and 44 wg's. He also noticed that average maximum uterine activity was greater in the preterm labor group and lower in the postterm labor group, when compared with patients delivering spontaneously at term. All three groups showed a surge of uterine activity during the three days before the onset of spontaneous labor. Conclusions are similar in the study of Katz in 1986 [2], since he observed that the frequency of appearance of contractions is greater for women who delivered preterm. Zahn, in 1984 [3], like Nageotte and Katz, showed that uterine activity increases at each week of pregnancy. For women who delivered preterm, activity increases earlier and is, at a given term, more frequent than activity associated with a normal pregnancy. But Zahn concluded that the frequency of appearance of uterine contractions is not a sufficient clinical sign for detection of preterm labor. Nevertheless, literature is particularly confusing about the quantification of this activity. Saling, in 1982 [4], Koepke *et al.*, in 1976 [5] considered that three contractions per hour during pregnancy is physiologically normal. Whereas Fisher, in 1973 [6], and others, consider that more than three contractions per hour during pregnancy is normal as well. Consequently, the use of the number of pregnancy contractions, as a sole parameter for the recognition of impeding premature delivery, seems to be controversial for a decent prevention of preterm deliveries.

B. Home Monitoring

Moreover, results concerning clinical trials using home uterine activity monitoring systems using external tocography, in order to detect preterm labor, are also controversial in the literature. Indeed, in a study by Katz in 1986 [7], 76 patients at high risk for preterm labor were recorded from 18 to 33 wg's. Eighty-eight percent of the monitored patients versus

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59% of controls have delivered at term, which indicated that uterine activity monitoring allowed a significantly greater percentage of women to reach term. The same conclusions were obtained by Morrison *et al.*, in 1987 [8], who recorded 67 women at risk for preterm labor, from 14 to 24 wg's. Colton *et al.*, in 1995 [9], performed a meta-analysis of home uterine activity monitoring and discovered statistically significant benefits of such monitoring, in that it was associated with reductions in risks of preterm birth and preterm labor combined with cervical dilatation.

On the other hand, Iams *et al.*, in 1987 [10], established a comparison, between 157 women from 20 to 34 wg's, of the rate of preterm birth, the incidence of preterm labor and successful tocolysis, and the mean birth weight and gestational age, which revealed no significant differences. He suggested that beneficial effects attributed to monitored contraction data in the literature, may, in fact, be the result of frequent nursing contact and careful attention to preterm labor symptoms and perceived contractions. Blondel *et al.*, in 1992 [11], showed, from a study performed on 168 women between 24 to 34 wg's, that such monitoring did not allow the earlier diagnosis of preterm labor. The same conclusions were elaborated by Nagey *et al.*, in 1993 [12]. The Collaborative Home Uterine Monitoring Study (CHUMS) Group in 1995 [13], performed the study on 1355 patients between 24 and 36 wg's and confirmed that uterine activity data obtained from uterine activity monitoring, when added to daily nursing contact, were not linked to earlier diagnosis of preterm labor, lower rates of preterm birth, or neonatal morbidity in pregnancies at high risk for preterm labor and birth.

Considering these controversial results dealing with the frequency of the appearance of contractions, a home monitoring system based on the characterization of contractions obtained by EHG, could be of great value for the prevention of the preterm labor.

III. Electrohysterography

The usual external tocography is a mechanical recording method. It allows the measurement of the abdominal wall deformations due to the effect of uterine contractions. It measures only the rate of the appearance of contractions and is very sensitive to abdominal wall motions. An internal recording method allows the measurement of intrauterine pressure by means of an intrauterine catheter. Nevertheless, catheter positioning is an invasive act that requires a strict aseptic state and cannot be considered as a routine procedure for pregnancy monitoring.

The uterine EHG has been studied since the 1950's [14]. A few studies have already proven that the EHG signal is able to provide reliable information about uterine contractions [14]–[19]. As for striated muscle, the uterine mechanical contraction is due to an electrical command, the electromyographic activity of uterine smooth cells. The electrical activity, collected on the abdominal wall, represents the summation of electrical activities of the uterine cells underlying the electrodes. The EHG, thus, represents this electrical contraction command. As the trigger of the contraction, it should be much more representative of the physiology of uterine activity than external tocography and, therefore, would provide an attractive way of monitoring uterine activity.

More recently, studies on contractions recorded at the end of normal pregnancy proved that EHG is representative of the contraction efficiency [18]. Indeed, it enables a classification in efficient or inefficient contractions. This classification was based on the computation of temporal and spectral parameters from the EHG. The efficient contractions from the abdominal EHG were recorded during normal parturition. Inefficient contractions were recorded during the last month of normal pregnancy (37–41 wg's).

The study of internal EMG and EHG signals, recorded on pregnant monkeys either by means of internal electrodes located on the uterus, or by external electrodes located on the abdomen of the animal, permits us to assert that the external signal is representative of the contractility of the uterus [20].

The analysis of EHG signal during pregnancy has shown that it was possible to detect contractions as soon as the eighteenth wg [19]. EHG is, thus, a noninvasive means, providing pertinent information of uterine contractility and fetal movements during pregnancy [see Fig. 1(a)]. It would permit us to develop an ambulatory system based on abdominal EHG analysis, to monitor patients during pregnancy. Such a home monitoring would be of great value for the prevention of preterm labor in patients at high risk of PD. This paper constitutes then the first stage of this project and aims at investigating the potentialities of such a signal to detect an evolution of contractions during pregnancy, as well as a possible separation between contractions leading to a PD and contractions leading to DT.

IV. Materials

The EHG signals were captured by means of two Ag–AgCl Beckman electrodes, plus one reference electrode located on the patient's hip. After careful preparation of the skin (cleaning with an abrasive paste and degreasing with a mixture of ether, alcohol, and acetone), which lowers the interelectrode impedance to about 10 kΩ, the electrodes are aligned directly above the median axis of the uterine muscle, on the epidermis, spaced of 25 mm, midway between symphysis and uterus fundus.

The resulting EHG is amplified, bandpass filtered (0.2–8 Hz), and 16-Hz sampled, using a compact battery, operating signal acquisition system (Myodata$^{\text{TM}}$).[1]

After a thorough briefing to insure best interpatient consistency, a hand held event marker was used to record simultaneously the subject's perception of contractions and of fetal movements.

The information obtained by EHG recordings was then analyzed on a computer, with Matlab.

V. Methods

A. Denoising of the EHG Signal

Because the EHG is an external signal, and in spite of the analogical bandpass filtering during acquisition, the EHG is

[1] Mazet électronique, 41000, Le Mazet Saint Voy, France.

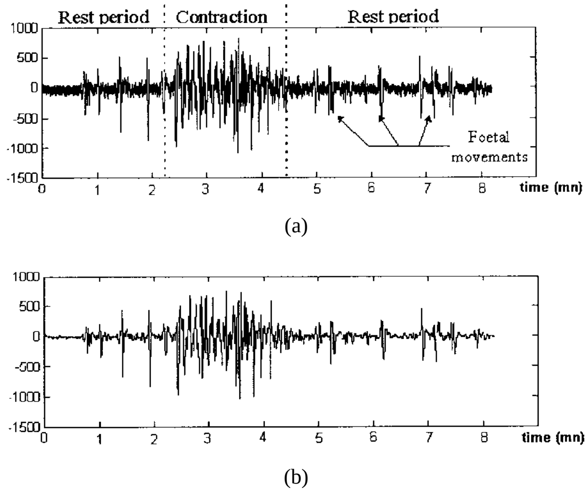

Fig. 1. Example of denoising an EHG signal: (a) original noised signal and (b) signal after denoising. The magnitude is in arbitrary units.

still corrupted by electronic and electromagnetic noises and by the remaining electrocardiogram of the mother. It is, therefore, necessary to remove noise from the signal to increase the signal-to-noise ratio. Indeed, the parameters calculated from a noisy signal would be strongly distorted by the presence of noise. An efficient denoising is, thus, very important for a proper contraction characterization.

Nevertheless, noise and signal have overlapping spectra. Consequently, a classical filtering is unusable since it would eliminate some information related to the EHG signal.

Wavelet shrinkage has provided very satisfying results for denoising purposes during the last few years [21]. Our denoising technique is, thus, based on wavelets. This algorithm is detailed in [22].

Fig. 1 shows the results of the denoising on a portion of an EHG signal. We can see that the baseline amplitude is reduced, while preserving the other events of interest: spikes related to fetal movements. The burst of activity related to the uterine contraction is also preserved.

B. Parameterization of the EHG Signal

After a proper denoising of the EHG signal, we chose some parameters from the temporal signal representation, the power spectral density, and from the instantaneous frequency of the signal. Such parameters are commonly used to characterize the frequency and temporal content of the electromyographic activity of striated or smooth muscle [18], [23]–[25].

1) Temporal Parameters: Two temporal parameters in the EHG signal are chosen as follows:

- duration of the contraction;
- relative magnitude of the contraction computed as the ratio between the variance of the contraction and the variance of the baseline, to become free from the different recording conditions.

2) Spatial Parameters: The averaged periodogram [26], applied on windows corresponding to locally stationary zones defined in [20], is divided into ten bands of equal width, B1, B2, ..., B10, between 0 Hz and 3 Hz, because most of the uterine activity is concentrated in these bands.

The parameters that we select from the periodogram of each contraction are:

- frequency of the main peak;
- median frequency;
- kurtosis and skewness coefficients: considering the periodogram as a probability density function, its shape is compared with a Laplace–Gauss distribution.

3) Nonstationary Parameters: As the EHG signal is not stationary, it is interesting to characterize the frequency evolution over time. Indeed, Devedeux realized a study on monkey's signals. She observed that a high-frequency component is distinguishable from that of a low one and is frequency modulated [27]. She showed that the shape of the curve describing the evolution of the time-frequency distribution maximum, reflects the efficiency of the contractions, because it is related to the emission frequency of action potentials. This emission frequency is directly responsible for the intensity of the cellular mechanical contraction. Nevertheless, it is very difficult to separate the high- and low-frequency components from human EHG signal, because they are too close. We try to resolve this problem by considering the evolution of instantaneous frequency, estimated by the method of the analytic signal [28].

The parameters extracted from this curve are:

- frequency of the peak of the curve;
- relative time related to this peak (it permits us to become free from the duration of the contraction);
- frequency of the minimum;
- relative associated time.

C. Definition of Classes

1) Population: After informed consent was obtained, the signals were recorded on 42 pregnant women, from 21 to 37 wg's, admitted to the Obstetrics and Gynecology Department of the Amiens' Hospital, due to spontaneous uterine contractions. All women received the same tocolytic treatment (48 hours of betamimetic), followed by bedrest. Fifty-six recordings, from one to two hours, were performed on these women. Indeed, some of them were recorded several times.

Twenty-nine women delivered at term, 12 women delivered preterm and one woman was subject to a medical abortion.

2) Extraction of Uterine Contractions: A peer review of the signal, performed by the experimenter, allowed the extraction of contractions. Each contraction was, thus, extracted if the experimenter agreed with the mother's perception or if, in absence of marker, he detected a contraction. We extracted 0–6 Braxton Hicks contractions per woman.

One-hundred-seventy-nine contractions were extracted (of which 58 were not felt by the mother), 43 were low-amplitude, high-frequency contractions (LAHF) [29], 13 were contractions from twin pregnancy, and one was from a medical abortion. We excluded the contraction from the medical abortion as well as the twin pregnancy contractions, because of the over-distension of the uterine wall, which represents, for a given term, a different physiological situation compared to singleton pregnancies. The LAHF contractions were analyzed separately.

Finally, we extracted 122 Braxton Hicks contractions of which 80 were contractions related to pregnancies leading to DT's, and 42 were contractions related to pregnancies leading to PD's.

3) Classes: The contractions were divided into classes which were defined, following medical advice, according to the term measured in wg's, at time of recording. We, thus obtained five classes:

- 21–24 wg's of which we extracted six contractions from three different women;
- 25–26 wg's of which 11 contractions were from five different women;
- 27–29 wg's of which ten contractions were from six different women;
- 30–33 wg's of which 49 contractions were from 18 different women;
- 34–37 wg's of which 46 contractions were from 13 different women.

Nevertheless, this classification according to the term, in wg's, is not physiological. Indeed, inside of a group (PD or DT), women are not at the same delay before their deliveries. Thus, we have chosen to work with a classification according to the proximity of delivery, that is the number of weeks before delivery (wbd). We obtained the following five classes as well:

- 9.5–15 wbd of which 20 contractions were from nine different women;
- 6–8.5 wbd of which 30 contractions were from 13 different women;
- 4.5–5.5 wbd of which 20 contractions were from eight different women;
- 2.5–4 wbd of which 24 contractions were from seven different women;
- 0.5–1 wbd of which 28 contractions were from seven different women.

We do not possess contractions of PD for the class 4.5–5.5 wbd.

We then calculated the 20 parameters from all the extracted contractions, resulting in a matrix which size is 122*20.

D. Data Analysis

We first used the principal component analysis to reduce the dimension of high-dimensional data without losing significant scatter.

We then used discriminant analysis, whose objective is to find the best set of discriminant vectors in order to separate predefined classes of objects or events. The discriminant analysis permits us to obtain, from the original space (basis parameters), the best subspace in the sense of the best discrimination between the classes. The extracted features are linear combinations of the basis parameters. The criterion used for this feature extraction is the ratio between-class scatter (matrix B) to within-class scatter (matrix W). If L classes are defined, it can easily be proved that there are $L-1$ discriminant axes [30]. The two-class problem can be solved using a combination of principal component analysis and discriminant analysis [31]. The first axis is then the Fisher axis [30], the second is the axis of best projected variance. The obtained discriminant plane offers a means to simply represent the classes' separability. To evaluate the ability of the discriminant axis to separate the classes, the discriminant ratio is used. The closer it is to 100%, the more discriminant is the axis. The discriminant ratio of the kth discriminant axis is directly obtained from the kth eigenvalue of the matrix $T^{-1}B$, where B is the between-class variance matrix and T is the total variance matrix $(T = W + B)$. The eigenvalues are indeed ordered in the decreasing order.

We have used this factor analysis just as a descriptive method (no decision making), in order to indicate a possible separation between:

- different classes of term in order to follow the evolution of contractions during pregnancy;
- PD group and DT group (in wg's or wbd) in order to show a possible difference between normal and pathological situations.

VI. RESULTS

The correlation matrix obtained during the principal component analysis allows the elimination of eight correlated variables. The 12 remaining parameters are: duration of the contraction, relative magnitude, B2 (0.3–0.6 Hz), B3 (0.6–0.9 Hz), B4 (0.9–1.2 Hz), B5 (1.2–1.5 Hz), high-frequency bands BHF (1.5–3 Hz) obtained from the concatenation of bands B6–B10, kurtosis coefficient, maximum instantaneous frequency, relative associated time, minimum instantaneous frequency, and relative associated time.

A. Evolution of the Contractions During Pregnancy

We attempt to investigate the evolution of contractions during pregnancy. In order to compare the contractions at the same physiological state, we chose to work with the second classification, in wbd.

1) Contractions of All Women: Fig. 2 represents the discriminant plane obtained with the two first discriminant axes.

- The discriminant ratio is rather weak (35% for the first axis and 19% for the second one).
- The class 9.5–15 wbd spreads over the other classes.
- Two classes are linearly separated from the others: 6–8.5 and 0.5–1 wbd.
- The most discriminant parameters are kurtosis coefficient and B5.

The class 9.5–15 wbd is not separated from the others, because the early term induces a great interclass variance and, thus, a spread of the points in the discriminant plane.

The two separated classes are not neighbors chronologically. Class 6–8.5 wbd is singular. It seems that the energy of the band B5 is the maximal in this class. It then disappears at 0.5–1 wbd, which explains that both classes are distinguishable from the others.

Due to the weak discrimination ratio, we then attempted to investigate the evolution of contractions in each different women's group (group of DT and group of PD).

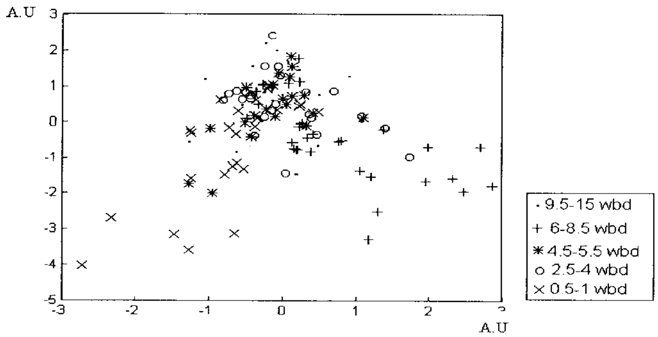

Fig. 2. Discriminant plane illustrating the evolution of the contractions from the two groups, during pregnancy.

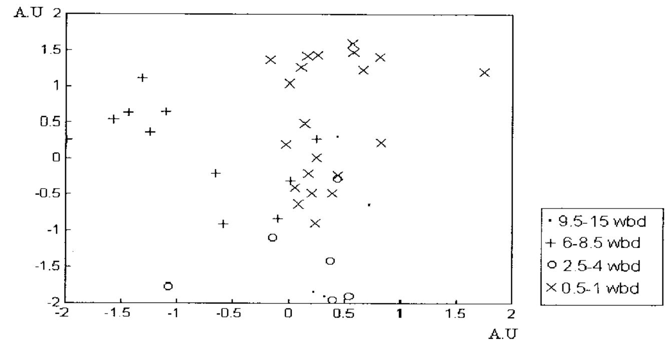

Fig. 4. Discriminant plane illustrating the evolution of the contractions during pregnancy for women who delivered preterm.

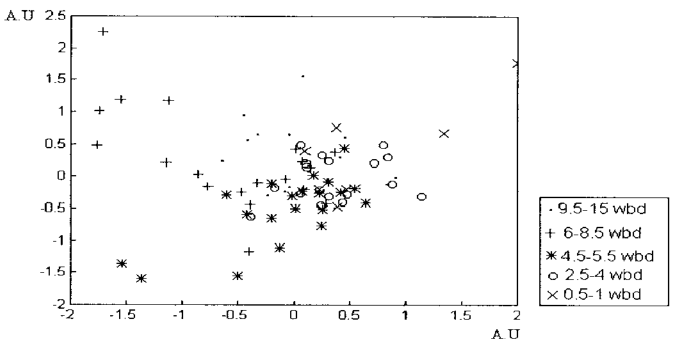

Fig. 3. Discriminant plane illustrating the evolution of the contractions during pregnancy for women who delivered at term.

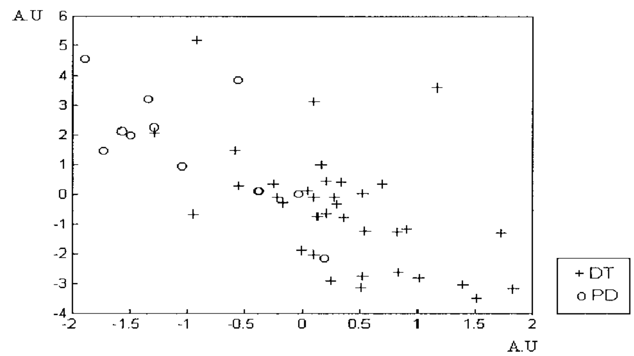

Fig. 5. Separation DT/PD at 30–33 wg's. The first axis is the Fisher axis, and the second is that of best projected variance.

2) Contractions of Women who Delivered at Term (DT): Fig. 3 represents the discriminant plane obtained with the two first discriminant axes.

- the discriminant ratio is weak (34% for the first axis and 25% for the second one);
- the same two classes are partially separated;
- the best discriminant parameters are the kurtosis coefficient and band B4.

This evolution of the frequency content can be explained by an increase of the energy of the band B4 at 6–8.5 wbd and a decrease at 4.5–5.5 wbd. At 0.5–1 wbd this energy is maximal.

We can still notice the spread of the earliest class.

3) Contraction of Women who Delivered Preterm (PD): Fig. 4 represents the discriminant plane obtained with the two first discriminant axes.

- The discriminant ratio is much higher (52% for the first axis and 47% for the second one).
- The three last classes are partially separated.
- The most discriminant parameters are B3, B2 and B5.

The class 9.5–15 wbd do not possess enough points to be separated from the others.

The separation of the three last classes can be explained by an increase of the energy of the bands B2, B3, and B5 at 6–8.5 wbd, then a decrease at 4.5–5.5 wbd and, at last, an increase again at 0.5–1 wbd.

4) Conclusion: The chosen parameter set is able to represent the evolution of contractility during pregnancy. We can notice that this evolution is different and more pronounced for the women who delivered preterm.

B. Separation of the Two Populations DT/PD for a Given Term

One of the purposes of this study is to determine whether it is possible to separate the two populations at an early term of the pregnancy, in a view of further clinical diagnosis. We have first worked with terms in wg's, which is the usual clinical way of classifying pregnant women.

At this time, the separation from 21 to 29 wg's is not possible with this parameter set, due to the low contraction number in these classes. We show below the result of the separation from 30 wg's.

1) Discriminant Analysis at 30–33 wg's: Fig. 5 represents the plane obtained with a first discriminant axis (Fisher axis), and a second axis of maximum projected variance:

- the discriminant ratio is 41%;
- the separation between the two classes is weak;
- the most discriminant parameters are the maximum of the instantaneous frequency and bands B2 and B3.

The weak separation between the two populations at this early term is nevertheless interesting in a perspective of diagnosis. This separation is due to the frequency content of the contractions: bands B2 and B3 are more important for the group PD.

2) Discriminant Analysis at 34–37 wg's: Fig. 6 represents the plane obtained with a first discriminant axis, and a second axis of maximum projected variance:

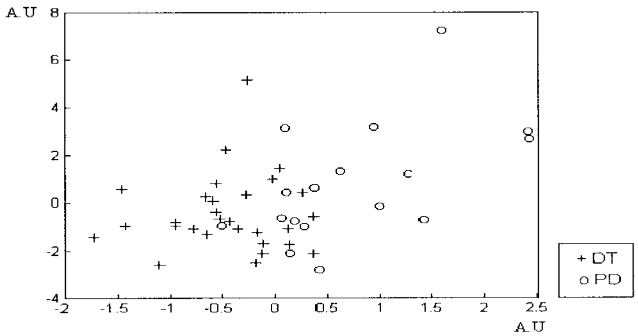

Fig. 6. Separation DT/PD at 34–37 wg's. The first axis is the Fisher axis, and the second is that of best projected variance.

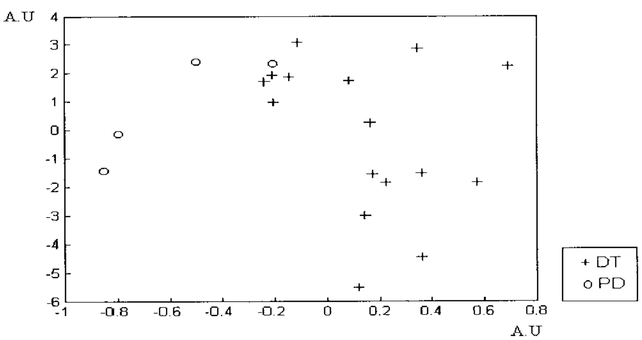

Fig. 7. Separation DT/PD at 9.5–15 wbd. The first axis is the Fisher axis, and the second is that of best projected variance.

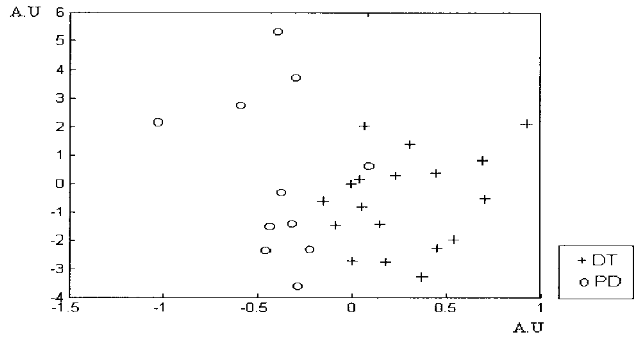

Fig. 8. Separation DT/PD at 6–8.5 wbd. The first axis is the Fisher axis, and the second is that of best projected variance.

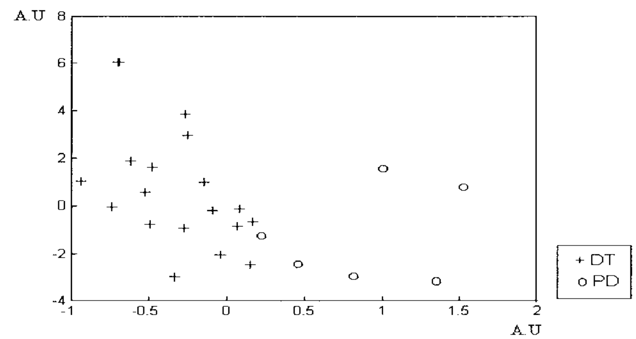

Fig. 9. Separation DT/PD at 2.5–4 wbd. The first axis is the Fisher axis, and the second is that of best projected variance.

- the separation between the two populations is better (45.5%);
- the most discriminant variables are bands B5 and BHF.

The contractions of PD again present higher frequencies than those of the DT group. Consequently, bands B5 and BHF have more energy in the PD group.

3) Conclusion: These results permit us to make the assumption that it is possible to separate the two populations as soon as 30 wg's.

C. Separation of the Two Populations in wbd

We then attempted to investigate whether the two types of pregnancy follow the same evolution or not. Indeed, published information is not complete on this subject and people suppose preterm labor could be associated with an earlier but identical phenomenon of contraction maturation.

In order to investigate this hypothesis of earlier maturation, we compare the two populations at the same number of wbd.

1) Discriminant Analysis at 9.5–15 wbd: Fig. 7 represents the plane obtained with a first discriminant axis, and a second axis of maximum projected variance.

- The discriminant ratio is 54% and the two populations are separated, although the number of contractions is low in the PD class.
- The most discriminant parameters are the kurtosis coefficient, band B2 and duration.

The energy of the bands B2 and B3 of the PD contractions is greater than that of the DT group. The duration of the contractions for the PD group is shorter than for the DT group.

2) Discriminant Analysis at 6–8.5 wbd: Fig. 8 represents the plane obtained with a first discriminant axis, and a second axis of maximum projected variance.

- The separation of the two populations is better (64%).
- The most discriminant parameters are the maximum of the instantaneous frequency, band B3, and the minimum of the instantaneous frequency.

The energy of the band B3 of the group PD is more important than that of the group DT.

3) Discriminant Analysis at 2.5–4 wbd: Fig. 9 represents the plane obtained with a first discriminant axis, and a second axis of maximum projected variance.

- The separation between the two populations is even better (67%).
- The most discriminant parameters are the duration, the magnitude of the contractions, band B2, and kurtosis coefficient.

The bands B2 and B3 of the DT group are more important that those of the PD group. Moreover, the duration and magnitude of contractions from the PD group are greater than those of DT group.

4) Discriminant Analysis at 0.5–1 wbd: Fig. 10 represents the plane obtained with a first discriminant axis, and a second axis of maximum projected variance.

The discriminant ratio is weaker (47%) and the two populations are less separated than earlier in term.

5) Conclusion: With the chosen parameter set, we are able to separate the contractions of the two groups as soon as 15 wbd. This result shows that the two evolutions of pregnancy

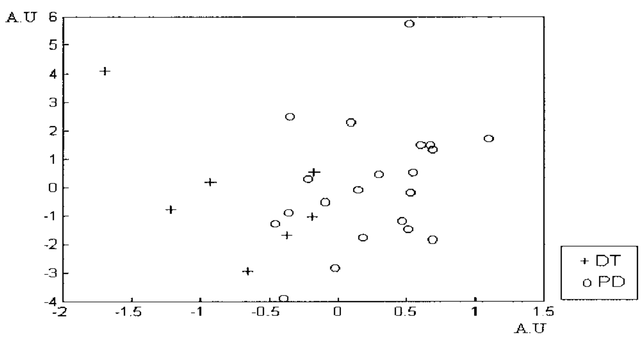

Fig. 10. Separation DT/PD at 0.5–1 wbd. The first axis is the Fisher axis, and the second is that of best projected variance.

are different. A pregnancy leading to a PD should not simply be due to an earlier evolution of the maturation process leading to DT. In this case, the two populations, classified in wbd, would have demonstrated the same contractile characteristics. This difference between the two populations disappears as the women get closer to the delivery. Indeed, at 0.5–1 wbd, contractions of the two populations are similar because they are at the same stage of maturation and propagation of activity.

VII. Discussion

In this study, we studied a group of women hospitalized for high risk of PD. As soon as they enter the hospital, these women are given tocolytic drugs. This treatment was strictly the same for all women (48 h of betamimetic). Nevertheless, it may have some influence on their contractility (frequency of the appearance of contractions and their intensity). The contractions are, thus, very few at early terms, which could explain our low number of contractions in these terms.

Sometimes it was difficult to extract contractions in the EHG signal, for the following reasons.

- Sometimes women did not feel their contractions, or were inattentive and consequently forgot to press the event button recording the subject's perception.
- Sometimes women mistook fetal movements for contractions and pressed the wrong event button.

This observation is confirmed by Newman, in 1986 [32], who studied 44 women at high risk of PD. He showed that women identify only 15% of their contractions. Neither the term of pregnancy nor the intensity of contractions have influence on maternal perception. Paradoxically, patients who perceived more than 50% of their contractions possess the greatest rate of false perception (49%). Only the presence of preterm labor is associated with an increase of false perception.

- Sometimes women pressed the two event buttons at the same time.

Thus, the operator's expertise was necessary to validate the contractions and to make the difference between contractions and fetal movements. Consequently, for our study, we have kept some contractions unidentified by the mother, but detected by the experimenter.

Due to the circadian activity of the contractility and to the weak duration of the recordings, we did not take into account the frequency of appearance of contractions. Moreover, as we said previously, many authors showed that the results are confusing regarding the possibility of detection of PD by means of the measurement of this parameter. We chose to characterize each contraction by the analysis of its electrical burst of activity, since the EHG does represent the electrical command of the contraction.

The chosen parameters are all more or less discriminant, either for the evolution of the contractions during pregnancy, or for the discrimination DT/PD for one given term. The variables concerning the instantaneous frequency are generally less discriminant than the others. As we said previously, we know that the high frequency wave of the time-frequency distribution reflects the efficiency of the uterine contractions in the monkeys. For women, it is very difficult to separate the low frequency component from that of a high one. The instantaneous frequency is a solution to take into account the two components. The drawback is that the low-component frequency is also taken into account, and that its evolution modifies the values of the parameters which should have been possibly discriminant.

At last, discriminant analysis is of no use in making a decision. It is only a means to represent the classes.

Some discrimination methods could be used for the purpose of further medical diagnosis. However, some clinical information can be obtained from this analysis (classification of a contraction as a supplementary point). Indeed, a new contraction, recorded at a given term of pregnancy (in wg's) will project, from this classification, either in the DT group or in the PD group (using the separation of the two populations at a given term of the pregnancy). In this latter case, it would then be possible to project this contraction on the discriminant plane, showing the contraction evolution during pregnancy, for the PD group (Fig. 4). The relative position of the projected point would give information about the delay before delivery (in wbd), depending on which class is projected the contraction.

VIII. Conclusion

The chosen parameter set permits us to represent the evolution of the contractions during pregnancy. This contraction evolution during pregnancy is more pronounced for the group of PD than the group of DT. It also permits us to separate, at a given term of the pregnancy, the groups delivering preterm or at term.

We have shown that the two kinds of pregnancy demonstrate different evolutions as soon as 15 wbd, and throughout the pregnancy, up until one wbd. Thus, the pregnancy leading to a PD is not simply related to an earlier evolution of the contractility. One wbd, contractions of the two groups are similar because they reach the same stage of maturation of activity propagation and of all excitability.

As early as 30 wg's, it is possible to separate the two populations. Such results are then very encouraging and permit us to think that it would be possible to diagnose a probable PD and to predict the proximity of delivery from the abdominal EHG analysis.

ACKNOWLEDGMENT

The authors would like to thank J. Rossi for the quality of the EHG recorded signals.

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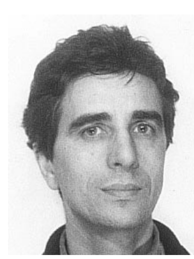

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