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External four channel tocography in preterm labor. First results

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1 Introduction

The use of betamimetic drugs to treat preterm labor is controversial because of its limited success and its severe side-effects [3, 6]. As not all preterm labor leads to preterm birth it would be desirable "to differentiate between contractions that will or will not lead to early delivery" [4] in order to avoid unnecessary therapy with beta-adrenergic agents.

CALDEYRO-BARCIA and co-workers [2] described criteria to predict the progress of labor using several, partly invasive electrodes during delivery. We have developed the non-invasive four-channel tocography to give similar information about uterine motility [8]. It can also be used safely during the course of pregnancy.

The study illustrates a possible access to the identification of "real" preterm labor. Our investigation should show whether there is a correlation between the spatial and temporal pattern of uterine contractions and the duration of pregnancy.

2 Subjects and methods

2.1 Patients

The study included 50 patients between 21 and 35 weeks of pregnancy who were admitted to our hospital for preterm labor and treated with Fenoterol, a betaadrenergic agent¹. No other selection criteria was used. Table I shows the distribution

of gestational age at time of measurement. The median age was 27 years (min: 17 years, max: 40 years). The distribution of gravidity was: I, n = 24; II, n = 17; III and more, n = 9. Parity was as follows: 0, n = 32; I, n = 15; II and more, n = 3. At admission vaginal examinations showed the following Bishop Scores: 0, n = 8; 1–2, n = 22; 3–4, n = 12; 5–6, n = 8. 27 patients showed a left occiput presentation, seven a right occiput presentation, eight a not further classified occiput presentation, seven a breech presentation and one a transverse lie.

Twenty seven women delivered spontaneously, six required a forceps extraction and two required a vacuum extraction. Five patients under a primary and ten patients a secondary Cesarean section respectively. The following diagnoses led to a primary Cesarean section at the corresponding gestational age: preterm rupture of membranes (25 and 31 weeks), heavy vaginal hemorrhage (34 weeks), previous Cesarean section (40 weeks), breech presentation in a first pregnancy (39 weeks). The distribution of gestational age at delivery of all patients is shown in table II.

2.2 Instrumental setup

Four identical external tocometric transducers were used. These sensors have signal characteristics similar to those of the routinely used and commercially available transducers. The use of piezoelectric pressure-sensitive elements allowed a particularly flat and light construction especially suitable for the intended purpose. Before measurement, the transducers were calibrated

¹ Partusisten, Boehringer Ingelheim, Germany

Table I. Gestational age at measurements

WoG	21-23	24/25	26/27	28/29	30/31	32/33	34/35
n	2	6	8	9	10	8	7

WoG = Weeks of gestation; n = number of patients

Table II. Gestational age at delivery

WoG	26	31/32	33/34	35/36	37/38	39/40	41/42
n	1	2	5	6	12	18	6
cum. %	2	6	16	28	52	88	100

WoG = Weeks of gestation; n = number of patients; cum. % = cumulative percentage

electronically. They were stabilized on the abdomen by using an elasticated tubular support bandage.

After signal processing and four-channel analog-to-digital conversion, the data were stored on floppy disks with 11 bit samples at a rate of two Hz per channel, using a bedside portable computer (Zenith 180).

Analysis of the signals was performed with the help of a specially designed computer program (computer-aided visual analysis) allowing the determination of the beginning, the maximum and the end of each uterine contraction, its amplitude and form for all four transducers separately.

2.3 Management protocol

After obtaining informed consent from the patients a first measurement was performed lasting six hours. The four transducers were fixed at left and right upper and lower abdomen using an elasticated tubular support bandage (figure 1) to guarantee reasonable mobility. A second three-hour measurement was performed within the next 1-4 days. Measurements did not interfere with routinely performed cardiotocography.

2.4 Study evaluation

The recorded pressure signals were displayed simultaneously on the computer screen. Only five-minute-periods of each single track were selected to assure an unbiased analysis, uninflu-

enced by the course of the other tracks of the same contraction. Using a mouse-controlled cursor, each contraction signal was characterized by marking the start, the maximum and the end of each contraction. The start of a contraction was marked when the signal showed a significant difference from the baseline. Possible interactions due to fetal or maternal movements did not influence the course of evaluation, because they could be eliminated by the visual process of trace analysis.

The following parameters were evaluated:

1. Localization:

Local contractions = typical labor pattern in only one or two registration tracks

Global contractions = typical labor pattern in three or four registration tracks

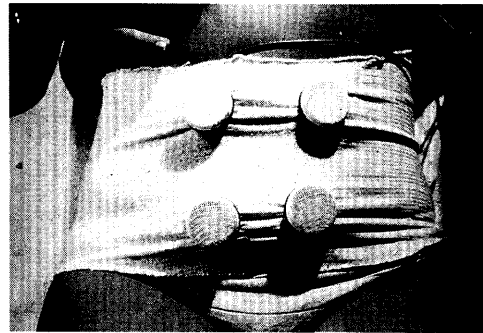


Figure 1. Positions of the transducers on the abdomen of the pregnant woman.

2. Center of dominance:

Registration track showing the highest sum of amplitudes

3. Origin of labor:

Registration track where the contraction could first be identified

The following criteria were derived from the listed parameters and correlated to the duration of pregnancy:

- 1) Predominant local or global contraction
- 2) Reproducibility of the center of dominance in the first and second measurement
- 3) Predominant origin of labor in the upper right segment.

2.5 Statistics

In order to investigate the correlation between duration of pregnancy and the parameters of four channel tocography, the patients were divided into two groups according to the median value of pregnancy duration of all patients. The median was 271.5 days (38 5/7 weeks of gestation), with 25 patients having pregnancy duration < 271.5 days (group A) and 25 patients having gestational age > 271.5 days at delivery (group B).

Differences in relative frequencies of the above mentioned criteria were tested with the Chi-Square-test. Differences in central tendencies of unpaired data were tested with the U-test of Mann and Whitney. Statistical significance was accepted with $p < 0.05$.

3 Results

In a total of 403 recorded hours of measurement 2349 contractions could be identified. In 29 hours, no signal was registered because of breaks by patients' demand. The number of contractions was normalized to real measuring time. Group A and group B showed 6.4 and 5 contractions per hour respectively. In 44 patients two measurements were performed, six patients did not undergo a second measurement for various reasons. Figure 2 shows an example of four-channel-tocography in which the great variety of possible forms of contractions is obvious. In the selected example, the contribution and the intensity of

contractions of each uterine segment changes rapidly. Contractions are not equally distributed. Periods of frequent contractions were followed by periods of infrequent contractions and vice versa.

3.1 Localization

Fifty-one percent of all recorded signals fulfilled the criteria of local contractions. Forty-nine percent of all contractions appeared in three or four uterine segments and were classified as global contractions. Analyzing each registration track separately, the following contribution was found: upper right 70%, upper left 61%, lower right 58% and lower left 56%. The frequency of local and global contractions was different in both groups. Patients of group A (gestational age at birth < 271.5 days) showed a higher rate of global contractions compared to those of group B. However this difference was not significant.

3.2 Center of dominance

Twenty-four of 44 patients had an identical center of dominance in the first and second measurement. Sixteen of these patients belonged to group A while only 8 were part of group B. Six of 20 patients showing an inconstant center of dominance belonged to group A and 14 were part of group B ($p = 0.015$, table III).

Figure 3 correlates the gestational age at delivery with the measurements of the four-channel-tocography. It shows that for every week of gestation at delivery, the cumulated percentage of women with identical center of dominance exceeded those with inconstant center of dominance.

3.3 Origin of labor

In 10 of 50 patients contractions could be seen first in the upper right segment of the uterus. Eight of them belonged to group A and two to group B. The difference between both groups was significant ($p = 0.034$; table IV). As already demonstrated for the center of dominance, women with the origin of labor in the upper right segment showed a higher cumulated percentage of deliv-

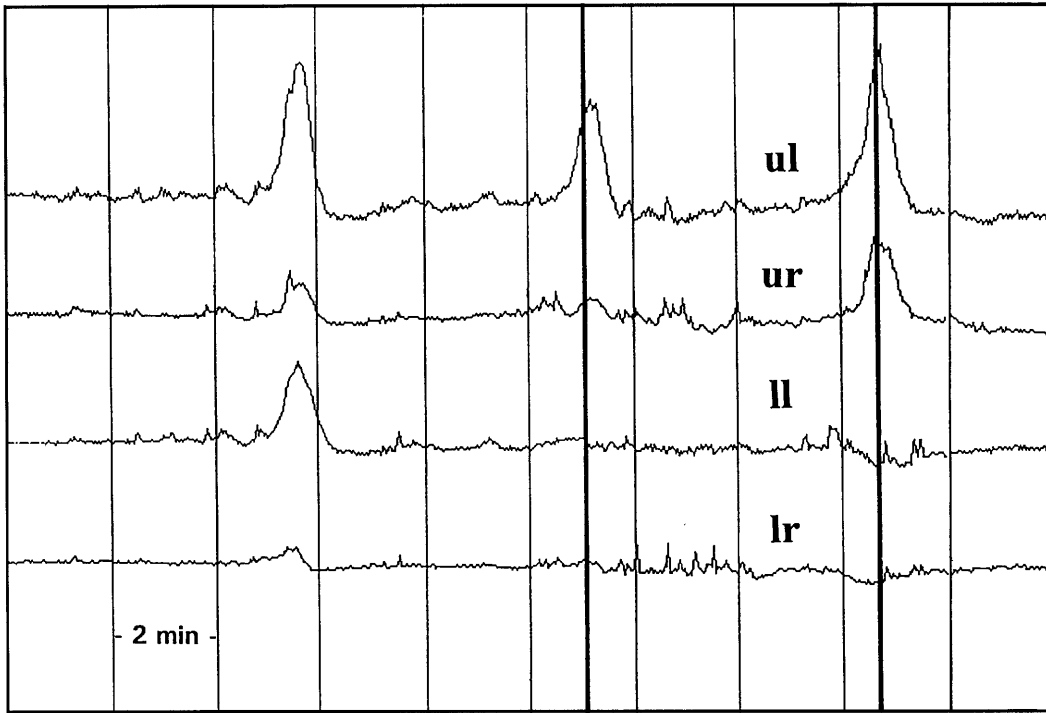


Figure 2. Example of a four-channel-tocography showing a great variety of participating transducers. (ul = upper left, ur = upper right, ll = lower left, lr = lower right; the vertical lines indicate contractions perceived by the patient). The first contraction is global, the second and the third are local contractions.

ery for all weeks of gestation compared to women with origin of labor elsewhere (figure 4).

3.4 Combined evaluation of origin of labor and center of dominance

In 8 patients, a predominant origin of labor in the upper right segment combined with a constant center of dominance was found. The median ges-

tational age of these patients at delivery was 255 days, indicating preterm delivery. Eighteen patients had neither a reproducible center of domi-

Table III. Number of patients in both groups with constant and variable center of dominance.

Gestational age (days)	CD1 = CD2 (n)	CD1 ≠ CD2 (n)
<271.5 (Group A)	16	6
>271.5 (Group B)	8	14

CD1/2 = Center of dominance in the first/second measurement; n = number of patients; p = 0.015.

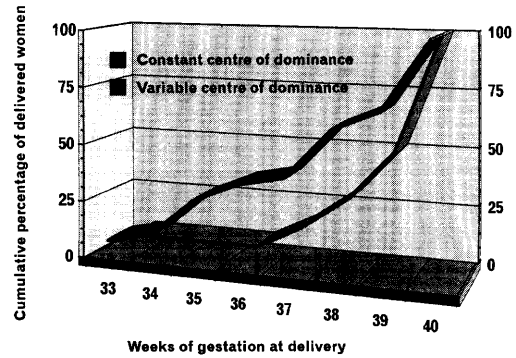


Figure 3. Cumulated percentage of delivered women with constant (black line) and variable (grey line) center of dominance with reference to gestational age at delivery.

Table IV. Number of patients in both groups with predominant origin of labor in the upper right region versus number of patients with predominant origin of labor elsewhere.

Gestational age (days)	OL = ur (n)	OL ≠ ur (n)
<271.5 (Group A)	8	17
>271.5 (Group B)	2	23

OL = Origin of labor; ur = upper right; n = number of patients; $p = 0.034$.

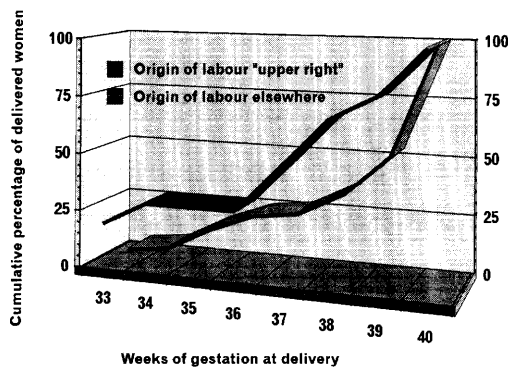


Figure 4. Cumulated percentage of delivered women with origin of labor in the right fundal region (black line) or elsewhere (grey line) with reference to gestational age at delivery.

nance nor an origin of labor in the upper right segment. Their medium duration of pregnancy was 275 days, which is 20 days longer than in women fulfilling both criteria ($p = 0.012$). This observation is not related to time of registration which is 29 vs 30 weeks of gestation.

4 Discussion

Four-channel tocography could predict preterm labor more accurately. The analysis of the four-channel registration provides additional parameters that are not detected by conventional single-channel tocography.

The individuals examined represent the unselected group of patients admitted to the hospital for preterm labor. The great variety of Bishop Scores at admission to hospital and gestational ages at delivery mirror the uncertainty of obstetri-

cians in making this diagnosis. The quality of one channel tocography and four channel tocography deteriorate in obese women. If signals could be measured, our investigation was designed to qualify not to quantify uterine contractions. Quantities are dependent on individual variations.

A center of labor dominance could be identified by evaluating the individual amplitudes of uterine contractions of each patient. It should be pointed out that the comparison of the relative intensities was exclusively performed for each individual woman and each individual measurement. A constant center of dominance in repeated measurements indicates a coordination of uterine activity, possibly resulting in preterm delivery. This hypothesis is supported by the shorter duration of pregnancy in patients showing a reproducible center of dominance.

REYNOLDS [7] and CALDEYRO-BARCIA and co-workers [2] investigated the temporal and spatial course of labor. They demonstrated that the coordination of contractions was as important as their intensity in producing labor progress. Accordingly, they described the "triple descending gradient" with the origin of contractions, highest intensity and longest duration in the fundal region, as the physiological form of uterine motility during labor [1]. WOLFS and ROTTINGHUIS [9] observed a shift of the origin of labor to the upper uterine segments during progressive labor.

Further authors emphasized the importance of a fundal origin of labor [2, 5, 7]. Up to now no differentiation between left and right segments has been made. In a preceding study during delivery, we found that a predominant origin of labor in the upper right fundus was correlated with a higher rate of spontaneous birth. In contrast, a predominant origin of labor elsewhere was associated with a higher rate of operative deliveries because of arrest of labor progress [8]. The present study also shows the increased effectiveness of contractions with right fundal origin in preterm labor.

At present data-analysis is performed "off line". In order to allow routine testing with direct clinical consequences, an automatic evaluation program using self-learning systems on the basis of neuronal networks is being developed. More data

are being collected during uncomplicated pregnancies and near term.

It can be stated that the four-channel tocography leads to a better understanding of the differentiated process of uterine contractility. It can distinguish between local and global contractions. It demonstrates, two phenomena for the first time a shorter duration of pregnancy, which are associ-

ated with the reproducibility of a certain center of dominance and a predominant origin of labor in the right fundal region. Therefore, the four-channel tocography would become a useful tool to differentiate contractions leading to preterm delivery and, thus, to avoid unnecessary hospitalization and tocolytic therapy.

Abstract

In order to know more about preterm labor the objective of our investigation was to look for a correlation between the spatial and temporal pattern of uterine contractions and the duration of pregnancy.

50 patients with preterm labor between 21 and 35 weeks of gestation underwent repeated measurements using four-channel tocography in which the pressure of contractions was registered simultaneously on the left and right sides at the fundus and the lower segment of the uterus. Half of all recorded signals were locally restricted (typical labor pattern in only one or two registration tracks). The following two phenomena were sig-

nificantly associated with a shorter duration of pregnancy:

1. the reproducibility of a center of dominance (defined as the locus of registration with the highest sum of amplitudes), and
2. a predominant origin of labor in the right fundal region of the uterus.

Four-channel tocography indicates whether preterm labor is likely to lead to preterm delivery. It may therefore help the obstetrician in deciding whether to use tocolytic therapy.

Keywords: External tocography, four-channel tocography, preterm labor.

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