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Computer-Assisted Analysis of Fetal Heart Rate Patterns at 20–41 Weeks' Gestation[1]

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Key Words. Fetal heart rate · Fetal physiology · Fetal well-being · Computer analysis

Abstract. Fetal heart rate (FHR) monitoring and computer-assisted analysis of FHR patterns were used to study 190 normal pregnancies on one occasion at 20–41 weeks' gestation. The mean baseline FHR decreased, while the overall FHR variation, number of accelerations and time spent in high variation increased with gestation. The time spent in low variation did not change significantly with gestation. These data indicate that, in the interpretation of FHR patterns from high-risk pregnancies, it is necessary to make adjustments for gestational age.

Introduction

Fetal heart rate (FHR) monitoring is the most widely accepted method for assessment of fetal well-being. Recently, computerized methods for FHR analysis have been introduced to overcome the problem of the substantial intra- and interobserver variability in the visual interpretation of FHR patterns [1–6]. However, studies using computerized numerical analysis have primarily focused on the third trimester of pregnancy. Improvements in perinatal care and survival rates of the very premature infant have now made it necessary to extend FHR monitoring to the second trimester of pregnancy. The aim of the present study was to establish reference ranges from 20–41 weeks' gestation for numerical data from computer-assisted analysis of FHR patterns, as a basis for the interpretation of FHR patterns from compromized fetuses.

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Patients and Methods

FHR monitoring was performed in 205 healthy women with singleton pregnancies at 20–41 weeks' gestation. The study was cross-sectional and the patients were recruited from our routine antenatal clinic. Gestational age was calculated from the mother's last menstrual period and confirmed by ultrasonographic measurement of the fetal biparietal diameter at 16–20 weeks amenorrhoea. Subsequently, 15 patients were excluded from analysis because they delivered before 37 weeks' gestation, developed pre-eclampsia, had antepartum haemorrhage or the birthweight of their infant was below the 10th centile for sex and gestation [7].

FHR was recorded for 60 min with the mother in a semirecumbent position (Hewlett-Packard 8040A cardiotocograph, Boblingen, FRG). Good-quality FHR records (signal loss < 20% at < 25 weeks' and < 10% at ≥ 25 weeks' gestation) were assured by either the mother or a research fellow adjusting the position of the transducer when necessary. The System 8000 (Oxford Sonicaid Ltd., West Sussex, UK) was used for on-line computer-assisted analysis of the FHR patterns.

In the first analysis, a baseline was fitted and the overall heart rate variation was calculated by averaging 1-min ranges in pulse intervals about the baseline (mean minute range in milliseconds). An increase in FHR by > 10 beats per minute (bpm) for > 15 s was identified as an acceleration and a decrease of ≥ 10 bpm for > 60 s or 20 bpm for ≥ 30 s was recorded as a deceleration. Episodes of high (HV) or low variation (LV) were marked when 5 of 6 sequential minutes had a minute range of > 32 or < 30 ms, respectively.

A second analysis was performed if in the first 25 min of recording the overall variation was < 25 ms. In this analysis records were examined for the presence of small decelerations (> 10 bpm and > 15 s) and episodes of LV and HV were identified with thresholds of > 24 and < 22 ms, respectively [5, 6].

Reference ranges with gestation were derived using regression analysis after the data were tested for normality and, if necessary, made Gaussian by logarithmic transformation.

Results

FHR baseline varied from 114 to 164 bpm and decreased with gestation from a mean of 149 bpm at 20 weeks to 134 bpm at term (fig. 1; n = 190, r = –0.537, p < 0.0001, constant = 163, slope = –0.741, SD = 7.5). Accelerations were identified in 178 (94%) cases; all 12 FHR patterns without accelerations were from fetuses of < 30 weeks' gestation (n = 93). One big deceleration was identified in 13 (7%) records at gestations ranging from 20 to 37 weeks and small decelerations were detected in 2 of the 32 records which underwent second analysis (fig. 2).

Overall FHR variation varied from 21.3 to 87.2 ms (fig. 1), and HV episodes were identified after first or second analysis in 158 (83%) and 24 (13%) cases, respectively

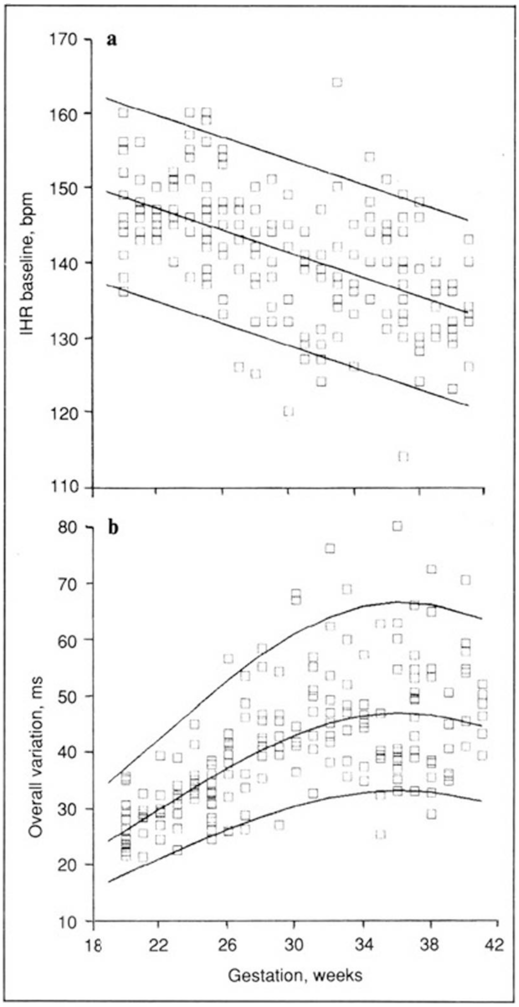

Fig. 1. Individual values and reference range (mean, 5th and 95th centiles) of FHR baseline (**a**) and overall variation (**b**) with gestation in 190 normal pregnancies.

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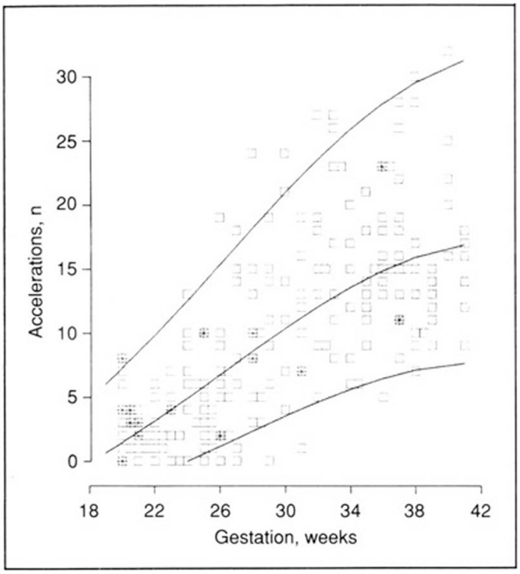
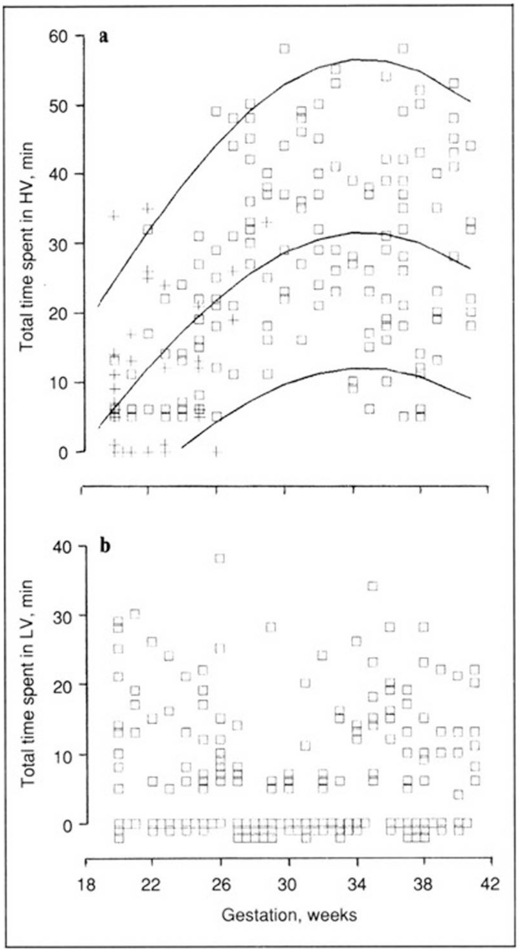


Fig. 2. Individual values and reference range (mean, 5th and 95th centiles) of accelerations (☐) with gestation in 190 normal pregnancies. In 15 cases there were decelerations (⊠).

Fig. 3. Individual values and reference range with gestation (mean, 5th and 95th centiles) of total time spent in HV (**a**) identified with thresholds of 32 (☐) or 24 (+) ms, respectively. The total time spent in LV (**b**) did not change with gestation.



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(fig. 3). LV episodes were present in 116 (61%) records (fig. 3).

The data on the number of accelerations (fig. 2), overall FHR variation (fig. 1) and total time spent in HV (fig. 3) were made Gaussian by $\log_{10}$ transformation. All three variables increased significantly with gestation (GA) in weeks [$\log_{10}$ (Accelerations) = 0.04 + 0.06 × GA – 0.0007 × GA^2, SD = 5, n = 190, r = 0.75, $p < 0.01$; $\log_{10}$ (Variation) = 0.4 + 0.07 × GA – 0.001 × GA^2, SD = 9.3 ms, n = 190, r = 0.68, $p < 0.0001$, and $\log_{10}$ (total time HV) = 1.2 + 0.04 × 3 GA – 0.0006 × GA^2, SD = 13 min, n = 190, r = 0.58, $p < 0.0001$; table 1]. The total time spent in LV did not change significantly with gestation (fig. 3; mean = 8.4, range = 0–38 min).

Discussion

The baseline FHR decreases with gestation while the incidence of accelerations, overall variation and total time spent in HV

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Table 1. Reference ranges (5th, mean and 95th centiles) of overall variation (ms), number of accelerations and time spent in HV with gestation

Gestation weeks	n	Overall variation ms			Accelerations/h (> 10 bpm, > 15 s)			Time spent in HV min/h		
		5th	mean	95th	5th	mean	95th	5th	mean	95th
20–21	22	18	26	37	0	1	7	0	6	25
22–23	15	21	30	42	0	3	10	0	12	32
24–25	21	24	34	48	0	5	12	1	17	38
26–27	18	26	37	52	1	7	15	4	22	44
28–29	17	29	40	57	2	8	18	7	26	49
30–31	14	31	43	61	4	10	21	10	29	53
32–33	17	32	45	63	5	12	24	11	31	55
34–35	14	33	47	66	6	14	26	12	32	57
36–37	24	33	47	67	6	15	28	12	31	56
38–39	15	33	47	66	7	16	30	11	30	55
40–41	13	32	46	65	8	17	31	9	28	52

increase. These findings are compatible with data derived from visual FHR analysis [8–13] and indicate that in the interpretation of FHR patterns from high-risk pregnancies it is necessary to make adjustments for gestational age.

Isolated decelerations occur more frequently at early gestations, but are found up to 37 weeks. This indicates that the presence of a single deceleration is not necessarily indicative of fetal compromise.

At 20–30 weeks' gestation, the relatively low incidence of accelerations, with absence in 13% of recordings, demonstrates the limited value of traditional assessment of reactivity as an indicator of fetal well-being. However, within this gestational range there is a steep increase in overall FHR variation, and this parameter may provide a useful alternative to counting the number of accelerations in the assessment of fetal health.

From 30 weeks onwards, the scatter of values for the number of accelerations and overall variation is much wider than at 20–29 weeks. This finding can be attributed to progressive differentiation and lengthening of fetal rest and active episodes and thus, to increased incidence of FHR records in which either one of the behavioural states predominates [12].

Computerized numerical analysis of FHR patterns, by identifying episodes of HV and LV, provides indirect information on the presence of rest and active cycles of fetal behaviour. However, the time spent in HV increases with gestation, while the total duration of fetal activity, as detected by ultrasonographic examination, remains constant or decreases [11, 13]. This apparent discrepancy can be explained from the observation that the duration of fetal movements and the size of FHR accelerations, as well as the association between movements and accelerations, increase with gestation [13]. Indeed, 42 of the 93 FHR records at < 30 weeks' gestation did not show episodes in which

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FHR variation was > 32 ms. Nevertheless, a second analysis in which the threshold was reduced to 24 ms demonstrated the presence of high variation episodes in 57% (24 of 42) of the latter FHR traces.

The total time spent in LV does not change significantly with gestation and does not exceed 38 min per 60 min of recording. This is similar to the reported maximum duration of 40 min for rest cycles in normal fetuses at 37–40 weeks' gestation and indicates that the total time spent in rest remains constant despite increasing length of rest cycles with advancing gestation [3, 4, 14, 15].

This study provides reference ranges with gestation for numerical data from computer-assisted analysis of FHR patterns. We are currently investigating whether deviations in fetal oxygenation are associated with deviations in FHR parameters when corrected for gestation.

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