Antepartal analysis of fetal heart rate variability by abdominal electrocardiography

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1 Introduction

Antepartal analysis of fetal heart rate variability (FHRV) has been shown to be of value in predicting fetal distress in labor [8]. Abdominal fetal electrocardiogram (aFECG) is used as a trigger signal in the statistical analysis of intervals and the differences between them [7]. The indices of variability thus obtained have a good correlation with indices calculated simultaneously from direct FECG [6, 12]. Interval index (II) describes the long-term variability and differential index (DI) the short-term variability in this analysis. The main disadvantage of this analysis system is a fairly high failure rate of aFECG during the third trimester of pregnancy. Gestational age, the electrode position and the maternal position have been shown to affect the recordability of aFECG [1, 2, 3, 4, 9, 11]. On the other hand, maternal obesity, placental location and the state of the membranes have been shown not to have any effect on the quality of aFECG [1, 3, 9]. The aim of this study was to investigate how often FHRV analysis made by aFECG succeeds and what is the role of certain methodological factors in the recording procedure.

2 Patients and methods

FHRV analyses were performed by a previously described method using an on-line microprocessor system [7]. The analysis was regarded as a failure when less than 30% of the intervals detected were accepted in the analysis. Student's paired t-test (one-sided) was used to measure the significance of the results.

The following methodological factors and patients were investigated:

2.1 The success rate of FHRV analysis.
The effect of gestational age on the success rate of FHRV analysis was studied by attempting a five-minute FHRV analysis in 80 normal and 554 high risk pregnancies at different stages of gestation. Distribution of the antepartal diagnoses is shown in Tab. I.

Tab. I. Distribution of the antepartal diagnoses in the data of antepartal analyses of fetal heart rate variability in high risk pregnancies.

Toxemia of pregnancy and essential hypertension	186
Suspected intrauterine growth retardation	99
Diabetes mellitus	82
Blood group incompatibility	26
Cholestasis of pregnancy	77
Postmaturity	84
Total	554

2.2 Maternal position in FHRV analysis.
The maternal supine vs. 90-degree lateral position was studied relating to the success rate and to the variability indices in 30 pregnancies. A five-minute analysis was first attempted in the supine position immediately followed by a 90-degree lateral position. The maternal supine and 15-degree lateral positions were similarly compared in 30 pregnancies.

2.3 Dry or moist electrodes? The success rate of FHRV analysis with dry and with moist electrodes was studied in 143 pregnancies. FHRV analysis was first attempted with dry electrodes. In case of failure the electrodes were moistened with tap water. If the analysis again failed, electrode paste was applied.

2.4 The rejection logic in FHRV analysis. In this analysis system, II is calculated from the standard deviation of intervals and DI from standard deviation of interval differences. Rejection logic is used to exclude erroneous intervals and interval differences created by noise in aFECG. The idea of using a narrow rejection limit lies in the presumption, that the interval differences thus included are most probably created by the fetus. The effect of maximum rejection limit for interval differences of five vs. ten beats per minute (bpm) on the variability indices and on the percentage of accepted intervals was studied in 19 pregnancies. Two subsequent five-minute periods of aFECG were analysed and compared. The first was analysed with a rejection limit of five bpm and the second with a rejection limit of ten bpm.

2.5 The effect of sample time on variability indices. The period of aFECG from which FHRV analysis is calculated is called sample time [5]. The clinical studies on antepartal FHRV made by our group have been performed using a sample time of five minutes [8]. The effect of sample time on variability indices was studied in 76 pregnancies. First an analysis was performed of a one-minute sample of aFECG immediately followed by a five-minute sample. A similar comparison was made of five-minute and 20-minute analyses.

3 Results

3.1 The success rate of FHRV analysis at different stages of gestation is shown in Fig. 1. A total of 1291 attempts in 80 normal and 554 abnormal pregnancies are included.

3.2 FHRV failed totally 14 times in the 90-degree lateral position after having succeeded in the supine position. In the supine position FHRV analysis failed only once after having succeeded in the 90-degree lateral position. II did not change significantly (t-ratio = - 1.01, p < 0.2) when the

maternal position was changed from the supine to the lateral or vice versa, while DI was significantly higher in the lateral position (t-ratio = - 1.79, p < 0.05). The percentage of accepted intervals had no significant change in this test (t-ratio = 0.11, p < 0.47).

FHRV analysis failed totally four times in the 15-degree lateral tilt after having succeeded in the supine position, and six times in the supine position after having succeeded in the 15-degree lateral tilt. The changes in II (t-ratio = 0.11, p < 0.47), DI (t-ratio = - 1.17, p < 0.15) and the percentage of accepted intervals (t-ratio = 0.16, p < 0.45) when shifting from the supine position to the 15-degree lateral tilt or vice versa were not significant.
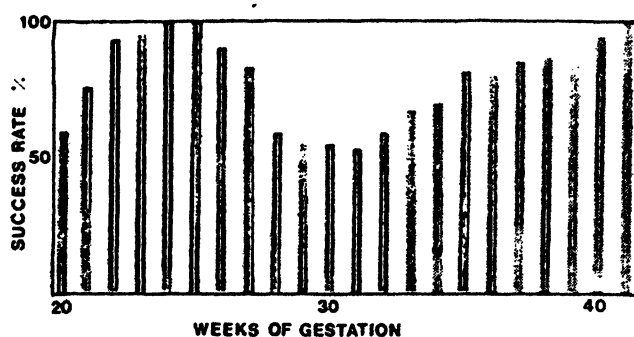

Fig. 1. The success rate of the serial antepartal analysis of fetal heart rate variability at different stages of gestation in cases of 78 normal and 551 high risk pregnancies. The analysis was regarded as a failure when less than 30 per cent of intervals recorded by abdominal fetal electrocardiography were accepted in the analysis.

3.3 FHRV analysis succeeded 48 times out of 143 attempts with dry electrodes (34%). Moistening of the skin with tap water was successful in 42 of the 95 cases which failed with dry skin. Application of electrode paste on the skin in the remaining cases of failure (53 cases) brought about 24 additional successful analyses. The final success rate was 80%.

3.4 The maximum rejection limit of five bpm vs. ten bpm had a significant effect on the percentage of accepted intervals (t-ratio = - 2.96, p < 0.005) and DI (t-ratio = - 2.61, p < 0.01) but no significant effect on II (t-ratio = - 1.61, p < 0.1).

3.5 No significant correlation was observed between IIs measured using five-minute and 20-min-

ute samples of aFECG (Fig. 2). A highly significant correlation was found between DIs measured using five-minute and 20-minute samples (r = 0.82, p < 0.001) (Fig. 3) and using one-minute and five-minute samples (r = 0.81, p < 0.001) (Fig. 4) of aFECG.

4 Discussion

4.1 In our system of FHRV analysis, an "on-line" display of the percentage of accepted interval differences is available.

At the end of the analysis this percentage describes the relative amount of interval differences included in the analysis from the whole number of interval differences during this period.

FHRV analysis was regarded as a failure when less than 30% of the interval differences were accepted in the analysis. We have clinical experience that the corresponding cardiograms are also visually difficult to interpret. With the thus defined limit of success, the success rate of FHRV analysis (Fig. 1) closely resembles the amplitude curve of abdominal R-wave presented by BOLTE [2]. The fairly high failure rate of aFECG around the 31st week of gestation has been attributed to abundant vernix caseosa on the fetal skin, which might have an insulating effect. If this is true, there should be considerable differences between individual amounts of vernix, since in our normal material there were a couple of pregnancies in which the FHRV analysis failed during eight subsequent weeks, until spontaneous labor, and some other pregnancies in which FHRV analysis was success-
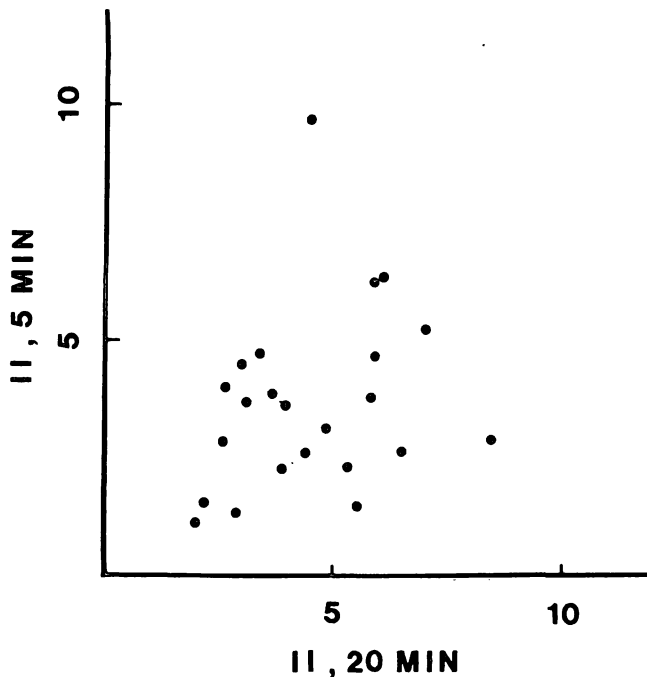

Fig. 2. Correlation between the interval indices (II) measured using five-minute and 20-minute samples of abdominal fetal electrocardiogram. The correlation is not significant (r = 0.22, N = 23).
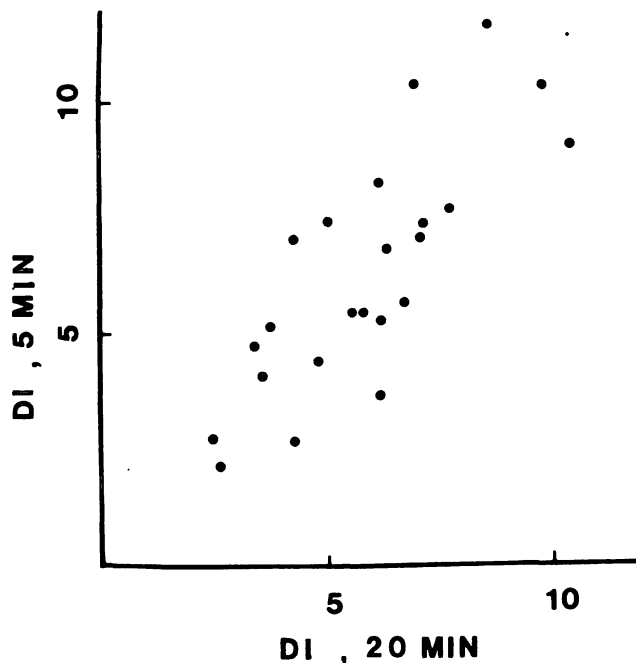

Fig. 3. Correlation between the differential indices (DI) measured using five-minute and 20-minute samples of abdominal fetal electrocardiogram. The correlation is highly significant (r = 0.81, y = 0.63 + 0.97x, p < 0.001, N = 23).
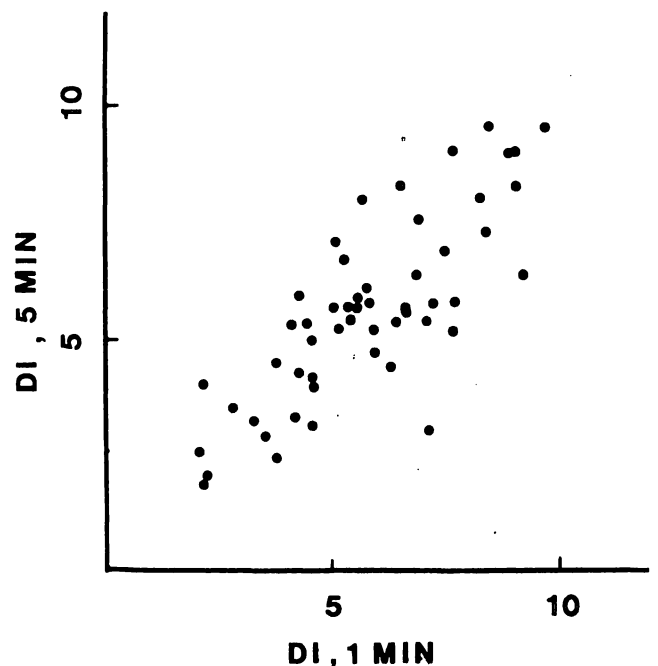

Fig. 4. Correlation between the differential indices (DI) measured using one-minute and five-minute samples of abdominal fetal electrocardiogram. The correlation is highly significant (r = 0.82, y = 0.98 + 0.83x, p < 0.001, N = 53).

ful up to 15 times during the entire second and third trimesters of pregnancy. The possible insulating effect of vernix caseosa should be investigated on a quantitative basis in respect to signal size.

4.2 The maternal 90-degree lateral tilt position was clearly less favorable than the supine position (regarding the FHRV analysis) success rate. Moreover, DIs measured in the lateral position showed a certain difference to those measured in the supine position. The 90-degree lateral position should not be used except possibly in cases where the FHRV analysis fails in the supine position and in the 15-degree lateral tilt.

The supine and the 15-degree lateral tilt positions seem to be equal respecting the success rate of FHRV analysis and the variability indices. No clinically manifest supine syndrome was observed during the five-minute analyses, but to avoid such a possibility, we prefer to start with a 15-degree lateral tilt and if it fails, we try the supine position.

The reason for the high failure rate of FHRV analysis in 90 degree lateral tilt is not known. A possible explanation is a higher degree of vibration and electrical noise of the cup electrodes in this position.

4.3 It has been claimed that ECG can be recorded with moist electrodes or even with dry electrodes [10] instead of electrode paste, which is commonly used. This study shows that the best success rate of aFECG is obtained when electrode paste is applied to maternal skin.

4.4 The maximum beat-to-beat interval difference accepted in the FHRV analysis was five bpm. This means that, when aFECG is used as a trigger signal, only those differences which are five bpm or less are included in the calculation of II and DI. Using this limit, about 85 per cent of RR interval differences of a resting fetus are included. Using another limit, ten bpm, which we use in processing direct FECG, about 99 per cent of differences of the resting fetus are included. The present study shows that this limit is very important. Only those indices which have been measured with the same rejection logic should be compared.

4.5 This study confirms an earlier observation that DI can be measured from short samples of aFECG [5], since the correlation of DIs from different periods is good. II, on the other hand, has a great variation according to the arousal level of the fetus and it should be measured from longer samples.

Summary

The success rate and some methodological factors influencing the antepartal analysis of fetal heart rate variability (FHRV) by abdominal electrocardiography (aFECG) were studied in 80 normal and 554 high risk pregnancies. The success rate of FHRV analysis was found to be dependent on the gestational age with virtually 100% success at 22 to 25 weeks and at 40 to 41 weeks of gestation. The lowest rate of success, 50% was found around the 30th week of gestation (Fig. 1). The fifteen-degree lateral tilt and the supine position of the mother were found to be equal respecting the success rate and the test results, while the 90-degree lateral tilt was found to be less favorable for the analysis. FHRV analysis suc- ceeded more often with electrode paste than it did with tap water moistening or with dry electrodes. The rejection limit of maximum interval differences in FHRV analysis was found to be an important factor influencing the test results. The variability indices should be compared only if they have been measured with the same rejection logic. Differential index, or short-term variability, can be measured from short samples of aFECG, having a good correlation between DIs measured using 1-minute, 5-minute and 20-minute samples (Figs. 3, 4). On the other hand, interval index measuring the long-term variability should be measured using longer samples of aFECG.

Keywords: Antepartal, electrocardiography, fetal heart, heart rate variability.

Zusammenfassung

Antepartale Analyse fetaler Herzfrequenzänderungen mit Hilfe der abdominalen Elektrokardiographie

Wir untersuchten die Erfolgsquote und einige methodologische Faktoren, die eine antepartale Analyse fetaler Herzfrequenzänderungen (FHRV), abgeleitet über die abdominale Elektrokardiographie (aFECG), beeinflussen.

Das Untersuchungskollektiv bestand aus 80 normalen und 554 Risikoschwangerschaften. Die Erfolgsquote einer FHRV-Analyse ist in starkem Maße vom Schwangerschaftsalter abhängig: zwischen der 22. und 25. Schwangerschaftswoche sowie um die 40. und 41. Woche war die Ableitung in nahezu 100% der Fälle möglich. Die nied-

rigste Erfolgsquote (50%) fand sich um die 30. Schwangerschaftswoche (Fig. 1). Eine geringe Seitenlagerung um 15° sowie die Rückenlagerung waren gleichzeitig in Bezug auf die Erfolgsquote und die Untersuchungsergebnisse, während sich eine vollständige Seitenlage (um 90°) als ungünstig erwies. Die Ableitung gelang häufiger und besser, wenn wir eine Elektrodenpaste benutzten, als mit nur befeuchteten oder gar trockenen Elektroden. Ein wichtiger, die Analyse beeinflussender Faktor war die Ausschlußgrenze bei maximalen Intervallunterschieden.

Variabilitätsindices sollten nur miteinander verglichen werden, wenn ihnen dasselbe Ausschlußverfahren zugrunde liegt. Der Differentialindex, oder auch Kurzzeitvariabilität genannt, kann aus kurzen Ableitungen der aFECG berechnet werden, denn es besteht eine gute Korrelation zwischen den gemessenen Differentialindices nach einer Minute bzw. nach 5 und 20 Minuten (Abb. 3, 4). Auf der anderen Seite sollte der Intervallindex, der die Langzeitvariabilität wiedergibt, aus länger andauernden Ableitungen bestimmt werden.

Schlüsselwörter: Antepartale Herzfrequenzänderungen, Elektrokardiographie, fetales Herz.

Résumé

Etude de l'instabilité du rythme cardiaque foetal pendant la grossesse à partir de l'électrocardiogramme enregistré par voie abdominale
Les auteurs ont étudié au cours de 80 grossesses normales et de 554 grossesses à hauts risques le pourcentage de succès d'enregistrement de l'électrocardiogramme foetal par voie abdominale (E.C.G FA) et certains éléments de méthodologie qui influencent l'analyse de l'instabilité du rythme cardiaque foetal (IRCF) en dehors de l'accouchement. Le pourcentage de succès de l'enregistrement de l'E.CG.FA dépend de l'âge gestationnel, avec pratiquement 100% de succès entre 22 et 25 semaines et entre 40 et 41 semaines de gestation. C'est autour de la 30ème semaine que le pourcentage de succès est le plus faible 50% (fig. 1). Le décubitus dorsal de la mère ou le léger décubitus latéral (15°) sont équivalents quant aux pourcentages de succès et aux résultats de l'examen; alors que le décubitus

latéral complet (90°) est moins favorable pour l'enregistrement. L'analyse de l'IRCF a plus de chance de succès en utilisant des électrodes enduites de pâte conductrice qu'avec des électrodes humidifiées à l'eau, ou sèches. Il a été mis en évidence que la limite de rejet des différences d'intervalle maximum dans l'analyse de l'IRCF est un facteur important, influençant les résultats de l'examen. Les indices d'instabilité ne peuvent être comparés que si ils ont été déterminés avec la même logique de rejet.
On peut mesurer l'index différentiel ou l'instabilité à court terme, à partir de courtes portions de l'ECGFA, avec une bonne corrélation entre les I.D. calculés à partir d'échantillons d'un, de cinq ou de 20 minutes (fig 3 et 4). Par ailleurs, l'index d'intervalle, appréciant l'instabilité à long terme doit être déterminé à partir d'échantillons plus importants de l'ECGFA.

Mots-clés: Coeur foetal, électrocardiogramme, instabilité du rythme cardiaque pendant la grossesse.

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