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Relation of fetal blood gases and data from computer-assisted analysis of fetal heart rate patterns in small for gestation fetuses

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Summary. Fetal heart rate (FHR) monitoring and computer-assisted analysis were performed immediately before cordocentesis in 25 severely small-for-gestational age fetuses. There were significant associations between FHR variation and both umbilical vein blood Po_2 (r=0.66) and pH (r=0·69). However, the wide scatter of values around the regression lines prevented accurate prediction of fetal blood gases from FHR patterns. Nevertheless, FHR variation <20 ms was always associated with severe fetal hypoxaemia and acidaemia.

Although fetal heart rate (FHR) monitoring is widely used in the assessment of fetal well-being, there is considerable intra- and inter-observer variation in the interpretation of the various patterns (Trimbos & Keirse 1978; Lotgering *et al.* 1982). Computerized analysis has been introduced with the aim of providing reproducible results. Smith *et al.* (1988) have demonstrated a significant association between FHR variation and umbilical cord blood Po_2 in samples obtained at elective caesarean section within 24 h of FHR monitoring (Dawes *et al.* 1985; Smith *et al.* 1988). However, the results of such studies might have been influenced by the delay between FHR analysis and blood sampling as well as the possible effects on blood gas data of maternal pre-oxygenation, anaesthesia or surgery.

With the introduction of cordocentesis it has become possible to examine the relation between FHR patterns and umbilical cord blood gases *in utero* (Nicolaides *et al.* 1986).

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Subjects and methods

The FHR was monitored immediately before cordocentesis in 25 pregnant women who were referred to our unit for further investigations at 28–39 (mean 31·5) weeks gestation because of suspected severe intrauterine growth retardation. Gestational age was determined by Naegele's rule. The fetal abdominal circumference was 2·3–8·7 SD (mean 5·6 SD) below the normal mean for gestation of our reference range. Amniotic fluid volume was assessed subjectively by ultrasonography and was normal in seven and reduced in 18; in 9 of the latter there was oligohydramnios. Subsequently, the birthweight of all infants was found to be below the 5th centile for sex and gestation (Fig. 1; Yudkin *et al.* 1987). All fetuses included in this study were chromosomally and morphologically normal. All women gave informed consent and the project was approved by the hospital ethics committee.

FHR recordings were made for 60 minutes

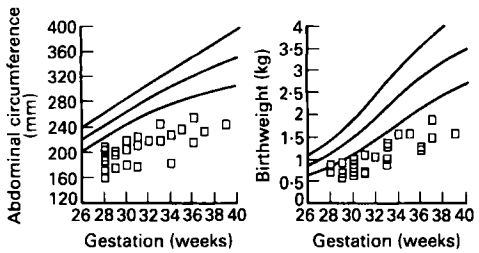

Fig. 1. Abdominal circumference of 25 SGA fetuses plotted on our reference range (mean, 95th and 5th centiles) for gestation (left). The birthweight is plotted on the reference range (mean, 95th and 5th centiles) for gestation from Yudkin *et al.* (1987) (right).

with the women in a semi-recumbent position (Hewlett Packard 8041A Cardiotocograph, Boblingen, West Germany). The System 8000 computer program (Sonicaid Ltd, Chichester) was used for analysis of the FHR traces. FHR variation was measured by averaging the one-minute ranges of pulse intervals about the baseline (mean minute range in ms) and the number of accelerations (amplitude >10 beats/min and duration ≥15 s) and decelerations (amplitude >20 beats/min and duration ≥30 s) was calculated. When large decelerations and accelerations were absent, smaller decelerations (≥10 beats/min, >60s) were also identified. Since in 95–97% of normal third trimester fetuses the FHR variation is >30 ms, this value was taken to be the lower limit of normality for our study (Dawes *et al.* 1985).

Cordocentesis was performed as an outpatient procedure without maternal fasting, sedation or fetal paralysis (Nicolaides *et al.* 1986). The cord vessel sampled was identified as artery or vein by the ultrasonic detection of the turbulence produced after the intravascular injection of normal

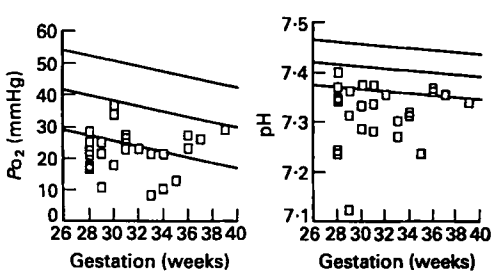

Fig. 2. Umbilical vein (UV) blood Po_2 (left) and pH (right) of 25 SGA fetuses plotted on our reference ranges (mean, 95th and 5th centiles) for gestation.

saline (400 μl). In this study, only pregnancies in which the umbilical vein was sampled were included. Fetal blood (200 μl) was aspirated into heparinized syringes and blood gas measurements used a Radiometer ABL 330 analyzer (Copenhagen, Denmark). The fetal temperature was assumed to be 37°C (Soothill *et al.* 1987).

Since in normal pregnancy the umbilical vein blood Po_2 and pH decrease with gestation (Nicolaides *et al.* 1989a), the results for the small for gestational age (SGA) fetuses were expressed as the number of SD by which the measured values differed from the appropriate normal mean for gestation (delta Po_2 and delta pH respectively in SDs). Regression analysis and unpaired Student's *t*-test were used to determine the significance of the relation between FHR variables and delta Po_2, or delta pH.

Results

In this group of 25 SGA features, the mean Po_2 was 2·0 SD (range 0·2–3·7 SD) and the mean pH 3·4 SD (range 0·7–10·7 SD) below the respective normal mean for gestation (Fig. 2). In 20 (80%) of the fetuses the Po_2 and/or pH were below the 5th centile for gestation. FHR variation was significantly associated with both delta Po_2 (n=25, r=0·66, p<0·05; Fig. 3) and delta pH (r=0·69, p<0·05; Fig. 4).

Accelerations were absent in four (16%) of the FHR traces and both the mean delta Po_2 (−3·42 SD) and the mean delta pH (−6·12 SD) of this group of fetuses were significantly lower than in the 21 fetuses with accelerations (mean delta Po_2=−1·69 SD, t=−4·21, P<0·001 and mean delta pH=−2·85 SD, t=−3·27, P<0·01).

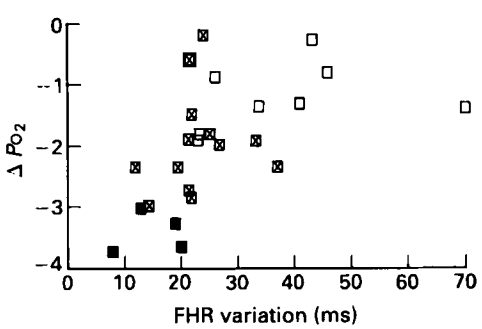

Fig. 3. Relation of fetal heart rate (FHR) variation and umbilical vein blood Δ Po_2 in 25 SGA fetuses. □=decelerations absent + accelerations present; ⧈=decelerations + accelerations present; ■=decelerations present + accelerations absent.

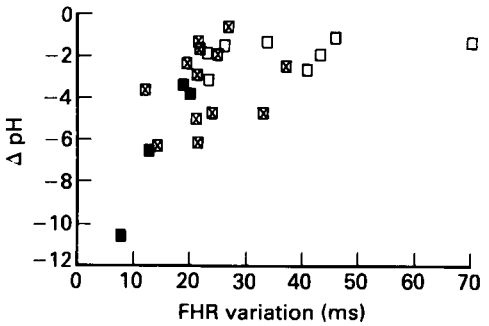

Fig. 4. Relation of fetal heart rate variation and umbilical vein blood Δ pH in 25 SGA fetuses. □=decelerations absent + accelerations present; ⊠=decelerations + accelerations present; ■=decelerations present + accelerations absent.

Large decelerations were present in 12 (48%) of the FHR traces and the mean delta pH of this group of fetuses was significantly lower than in the group without decelerations (mean difference=−1·82 SD, t=2·13, P<0·05); the mean delta Po_2 was not significantly different in the two groups (mean difference=−0·60 SD, t=−1·56). When small decelerations were included both the mean delta Po_2 and mean delta pH were found to be significantly lower in the 17 fetuses with decelerations than in the eight without (delta Po_2: mean difference=−1·08 SD, t=−2·92, P<0·01; delta pH: mean difference=−2·14 SD, t=−2·39, P<0·05.

In the six fetuses with FHR variation <20 ms, both the Po_2 and pH were below the 5th centile of the respective normal ranges; in all of them there were decelerations. In 10 of the 12 (83%) fetuses with variation 20–30 ms, the Po_2 and/or pH were below the 5th centile. In four of the seven (57%) fetuses with variation >30 ms, the Po_2 and/or pH were below the 5th centile, two of these fetuses had decelerations. For variation <30 ms, the presence or absence of decelerations or accelerations did not improve the prediction of blood gas results.

Discussion

In this group of severely growth retarded fetuses, 80% were hypoxaemic or acidaemic or both. Fetuses with either reduced FHR variation, decelerations or absence of accelerations were significantly more hypoxaemic and acidaemic than those with no FHR abnormalities. These findings are compatible with previous studies where FHR patterns were analysed visually and the results were related to pregnancy outcome or blood gas values in labour, at birth or at cordocentesis (Visser & Huisjes 1977; Nicolaides *et al.* 1989b; Visser *et al.* 1990). In this study the FHR patterns were not examined in relation to pregnancy outcome because the time and mode of delivery were largely based on blood gas results at cordocentesis.

Computerized analysis has made it possible to quantify FHR patterns accurately (Henson *et al.* 1983; Dawes *et al.* 1985). In the present study there were significant associations between FHR variation and umbilical vein blood Po_2 or pH (Figs. 3 and 4). The association between FHR variation and blood Po_2 is similar to that reported by Smith *et al.* (1988) who studied samples obtained from the umbilical cord at elective caesarean section. In contrast, neither Smith *et al.* (1988) nor Henson *et al.* (1983) found a significant association between FHR variation and umbilical artery pH in samples obtained at caesarean section in a heterogeneous group of high risk pregnancies (Henson *et al.* 1983; Smith *et al.* 1988). Indeed, these authors suggested that the reduced FHR variation in compromized fetuses is not the direct result of acidaemia but of hypoxaemia or some other factor associated with growth retardation. The most likely explanation for this apparent discrepancy in results is the fetal blood vessel sampled. Although umbilical artery blood may indeed be more representative of the 'fetal condition' (Henson *et al.* 1983), the activity of peripheral chemoreceptors, possible cardiac centres in the brain and the heart itself are more likely to be influenced by the composition of umbilical vein than artery blood. An additional explanation is the difference in the definition of acidaemia. Smith *et al.* (1988) and Henson *et al.* (1983) considered acidaemia to be present if the pH was below a certain fixed value irrespective of gestation whereas in the present study acidaemia was defined as a pH value below the fifth centile of a normal range that changes with gestation.

Computer-assisted analysis of FHR patterns provided reproducible numerical data that were related to indices of fetal oxygenation. FHR variation <20 ms was always associated with severe hypoxaemia and acidaemia whereas variation >30 ms was suggestive of normal blood gas results when decelerations were absent. However, when FHR variations were between 20 and 30 ms, the large scatter in values did not enable

accurate prediction of fetal Po_2 or pH, even when presence or absence of decelerations and accelerations was taken into account.

The 'scatter' of values around the regression lines describing the relations between FHR patterns and Po_2 or pH (Figs. 3 and 4) could be a consequence of the independent or additional effects of the deranged endocrinology and metabolism found in growth retarded fetuses (Robinson *et al.* 1979; Nicolaides *et al.* 1989c). Furthermore, the scatter in values may be due to the biological variation both in responsiveness to intrauterine stress and in inherent FHR patterns. Support for the latter is provided by Smith *et al.* (1987) who examined a group of normal fetuses with low FHR variation and demonstrated that perinatal outcome was normal despite persistence of low variation throughout the third trimester of pregnancy.

Our data suggest that in SGA fetuses, FHR variation <20 ms reflects severe hypoxaemia and acidaemia. But, the clinical significance of FHR variation >20 ms can only be determined by further assessment, such as sequential FHR monitoring, which may identify further responses to deteriorating intrauterine conditions (Snijders *et al.* 1989). Alternatively, other non-invasive tests, or cordocentesis are needed.

Acknowledgments

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