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# THE FETAL BEHAVIOURAL STATES: AN ULTRASONIC STUDY

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## SUMMARY

In order to accurately detect the fetal behavioural state, we simultaneously measured fetal heart rate and multiple fetal activities in 27 healthy pregnant women at 38 to 40 weeks of gestation.

We ultrasonically identified gross body movements, breathing movements and micturition. Analysis of fetal heart rate allowed us to distinguish two different patterns of fetal behaviour: active and quiet phases. The frequency distribution of the analysed fetal events was significantly different in these two phases. These data suggest that a complete biophysical profile of the fetus is effective in differentiating behavioural states and may improve the predictive accuracy of fetal heart rate analysis alone.

KEY WORDS Fetal heart rate Fetal movements Fetal behaviour

## INTRODUCTION

The use of cardiotocography has made it possible to monitor the well-being of the fetus in real time by recording fetal heart rate (FHR). To this end the 'non-stress test' (NST) has been developed to estimate fetal well-being under basic conditions. Various methods for reading the NST have been proposed, but usually a test with FHR between 120–160 beats per min (bpm), variability of FHR greater than 10 bpm, more than three accelerations (FAD) in 20 min and presence of fetal movements (FM) is considered reactive (Evertson *et al.*, 1979).

Recent studies have shown that the human fetus at term rhythmically alternates quiet and active phases throughout the day (Timor-Trisch *et al.*, 1978). Active phases constitute the highest percent duration throughout the day. They correspond to a cardiotocographic tracing of the reactive type, characterized by a variability of FHR greater than 10 bpm, presence of FAD and FM and lasting about 60 min. The quiet phases instead occupy a smaller per cent duration throughout the day, calculated as 25 per cent. They have a characteristic cardiotocographic pattern with FAD and FM absent, reduced variability, lower than 10 bpm and lasting about 20 min, but may reach up to 40 min under physiological conditions (Visser *et al.*, 1982; Nijhuis *et al.*, 1982). This kind of tracing was either not detected in the past because of the brief duration of the NST (20–30 min) and the relative rarity of this phenomenon, or considered suspect (non-reactive) and treated with stimuli of various kinds (manual, sound, oxytocic). This could explain the percent-

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age of false positive results attributed to the NST which for some authors are as high as 75 per cent (Evertson *et al.*, 1979).

Studies lasting for the entire 24 h (Junge, 1980; Visser *et al.*, 1982; Arduini *et al.*, 1984) have made it possible to show how under physiological conditions the fetus alternates spontaneously between quiet and active phases and how external stimuli are inefficient in distinguishing the quiet phase from the onset of fetal suffering (Visser *et al.*, 1983). Moreover, neurophysiological studies have through correlative investigations on animal fetuses (Ioffe *et al.*, 1980; Ruckenbush, 1972) and newborn infants (Prechtl, 1974; Junge, 1980) clarified the behavioural significance of these phases. The quiet phase corresponds to the 'quiet sleep' (QS) of the newborn child or non-REM of the adult. The active phase corresponds both the waking state and the 'active sleep' (AS) or REM. These two states cannot be differentiated in the fetus merely by cardiotocography.

The functions of this alternation of phases are more obscure, but the hypothesis can be put forward that the somatic and perhaps psychic events of the fetus are organized around these phases (Sterman and Hoppenbrowers, 1971; Corner, 1980).

The echographic examination, besides being used for the assessment of fetal growth, has in obstetrics also undergone a dynamic development in the quantitative and qualitative analysis of fetal breathing and somatic movements (Wilds, 1978; Ianniruberto and Tejani, 1981).

The aim of this study is to combine cardiotocographic and echographical methods in order to obtain a more accurate diagnosis of the fetal condition and correlate some fetal events with quiet and active phases.

## MATERIALS AND METHODS

Twenty-seven healthy pregnant women between 38 and 40 weeks of gestation were studied. The mean gestational age was $38{\cdot}99 \pm 0{\cdot}6$ weeks. The patients had never taken drugs able to alter FHR and were non-smokers.

After informed consent had been obtained an ultrasound examination was performed to confirm gestational age and normal fetal growth.

The patients then rested in a lateral recumbent position in a quiet room exposed to normal daylight. They underwent simultaneous cardiotocographic and echographic examinations in the afternoon at different times after lunch.

A Hewlett-Packard 8040 cardiotocograph with an external ultrasound transducer was used for recording the FHR.

An Aloka SSD-250 and an Aloka SSD-210F real time scanners with 3·5 multifocused linear transducers were used for examination of fetal head and body respectively.

As published by us elsewhere (Romanini *et al.*, 1983), we have analysed by cardiotocograph 1-min epochs which were considered active if the following criteria were satisfied:

—presence of FAD (at least 15 bpm for 15 s)
—variability of FHR greater than 10 bpm
—presence of FM noticed by the patient
—presence of gross FM observed by echography.

Epochs were considered quiet if the following criteria were satisfied:

—absence of FAD

—variability of FHR lower than 10 bpm

—absence of FM noticed by the patient

—absence of FM observed by echography.

Three of the four parameters were considered sufficient for classification into one of the two phases. Epochs which did not fall into these two categories were classified transitory.

Besides gross fetal movements three parameters were estimated by ultrasonic examination:

—fetal eye movements (FEM)

—fetal breathing movements (FBM)

—micturition.

The analysis of FEM was based on the motility of the fetal lens (Bots *et al.*, 1981). The technique for viewing the lens was the following: once the fetal head was visualized there was a scanning tending to show one or both the orbital cavities. The lens was evidenced as a small echogenic ring within the orbital cavity (Figure 1). Movements were easily detected. FEM were classified as follows:

—rapid eye movements (REM) in the presence of rapid nystagmus-like movements of the lens with a frequency greater than six movements every minute.

—intermittent eye movements (IEM) in the presence of slow movements with a frequency less than six movements every minute.

—absent in the absence of movements of the lens.

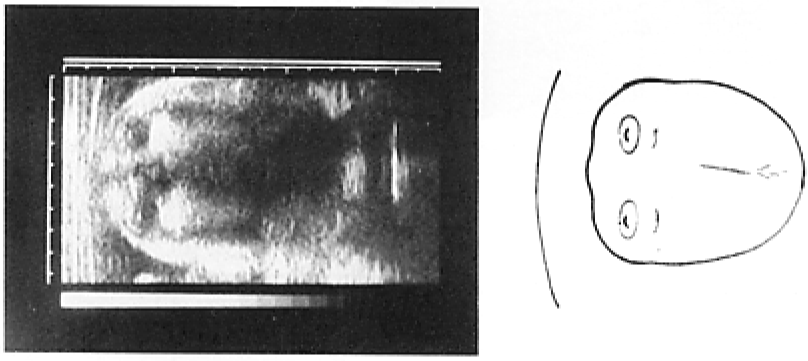

Figure 1. Ultrasound scan demonstrating both orbital cavities containing the lens

FBM were recorded by transverse or longitudinal scanning of the fetal chest (Figure 2). The FBM were simply evaluated as present or absent, without further differentiation as to the type of movement.

Bladder dimensions were obtained by scanning the fetal pelvis tending to show the longitudinal and transverse sections of the fetal bladder in its greatest dimension. Bladder volume was evaluated using the formula previously reported by Campbell *et al.* (1973) (Figure 3).

Statistical analysis was effected by the Student's *t*-test and the chi-square test.

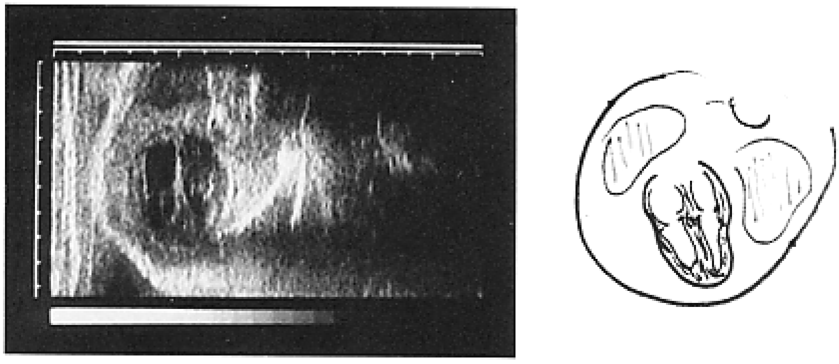

Figure 2. Transversal scan of fetal chest

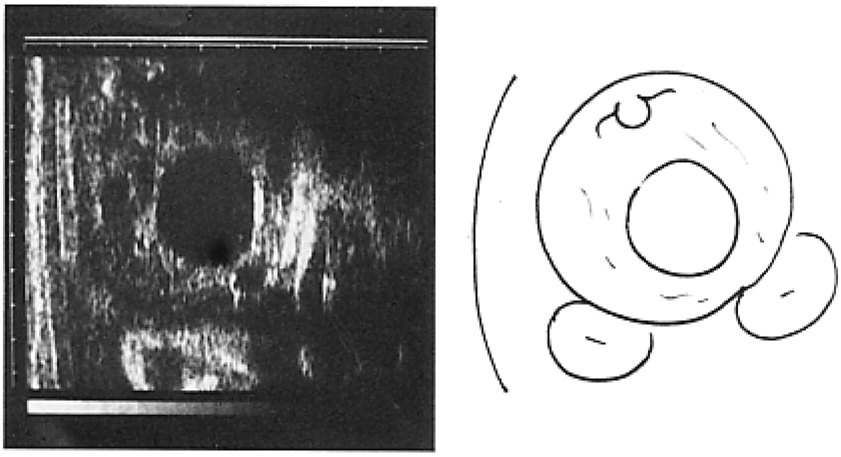

Figure 3. Transversal scan of fetal pelvis demonstrating the fetal bladder

## RESULTS

The mean duration of recording was 60·92 ± 8·3 min. From the data in the literature (Visser *et al.*, 1981a) and as previously reported by us (Romanini *et al.*, 1983), this duration is to be considered sufficient for recognition of the quiet-active cycle. We finished a recording only when we clearly detected phases of both quiet and activity.

The mean per cent duration of the active phase, considering all recordings, was 71·48 ± 13·1 per cent. The quiet phase lasted 25·81 ± 13·2 per cent and in 2·3 ± 0·9 per cent the epoch was considered transitory.

As seen in Table 1, these data do not differ statistically (Student's *t*-test) from those obtained on a sample of 29 healthy pregnant women of the same gestational age reported elsewhere (Romanini *et al.*, 1983).

From Table 2 it can be seen that during the active phase there is a prevalence of REM type of movements (87·2 per cent) with respect to the quiet phase in which they are never observed and where the absence of eye movements prevails (92·3 per cent). In about 2·3 per cent of active phases and 1·6 per cent of quiet phases

Table 1. Comparison of per cent mean duration ($\pm$S.D.) of quiet and active phases

| Activity % | Quiet % | Transitory % | Case no. |
|---|---|---|---|
| $71 \cdot 48 \pm 13 \cdot 1$ | $25 \cdot 81 \pm 13 \cdot 2$ | $2 \cdot 3 \pm 0 \cdot 9$ | 27 |
| $71 \cdot 35 \pm 16 \cdot 0$ | $28 \cdot 63 \pm 14 \cdot 5$ | n.d. | 29* |
| n.s. | n.s. | — | *p* |

*Romanini *et al.* (1983).

Table 2. Distribution of FEM in the active and quiet phases

| | Fetal eye movements | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | REM | | IEM | | Absent | | Failure | |
| | No. | % | No. | % | No. | % | No. | % |
| Activity | 512 | 87·2 | 42 | 7·2 | 20 | 3·3 | 14 | 2·3 |
| Quiet | 0 | 0 | 13 | 6·1 | 199 | 92·3 | 4 | 1·3 |

Chi-square = 643·33, $p \leqslant 0 \cdot 001$.

it was impossible to visualize the orbital cavity with the lens and evaluate the presence and type of FEM. The difference to the incidence of FEM in the quiet and active phases was evaluated by the chi-square test using a $3 \times 2$ contingency table ($p \leqslant 0 \cdot 001$).

Table 3. Distribution of FBM in the active and quiet phases

| | Fetal breathing movements | | | |
|---|---|---|---|---|
| | Present | | Absent | |
| | No. | % | No. | % |
| Activity | 249 | 42·3 | 339 | 57·7 |
| Quiet | 17 | 7·6 | 199 | 92·2 |

Chi-square = 83·26, $p \leqslant 0 \cdot 001$.

Table 3 shows the incidence of FBM in the quiet and active phases. It can be seen that in the active phase they are more frequent (42·3 per cent), but they are also present in the quiet phase. Again using the chi-square test the difference was shown to be significant ($p \leqslant 0 \cdot 001$).

Dividing the patients according to time after lunch, two groups were obtained:

(a) 10 patients (37 per cent of the sample) for whom recording was begun less than 150 min after lunch;

(b) 17 patients (63 per cent of the sample) for whom recording was begun more than 150 min after lunch.

Table 4 shows that FBM were more frequent in group (a), but the difference between active and quiet phases was still significant ($p \leqslant 0 \cdot 001$).

Table 4. Distribution of FBM in the two groups of patients in the active and quiet phases

| | Fetal breathing movements | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Group (a) | | | | Group (b) | | | | | |
| | Present | | Absent | | Present | | Absent | | | |
| | No. | % | No. | % | No. | % | No. | % | $\chi^2$ | $p \leqslant$ |
| Activity | 150 | 69·1 | 67 | 30·9 | 105 | 28·4 | 266 | 71·6 | 91·24 | 0·001 |
| Quiet | 15 | 18·9 | 64 | 81·1 | 2 | 1·4 | 135 | 98·6 | 18·88 | 0·001 |
| $\chi^2$ | 56·9 | | | | 41·75 | | | | | |
| $p \leqslant$ | 0·001 | | | | 0·001 | | | | | |

Table 5 shows that micturition was more frequent in the active than in the quiet phase ($p \leqslant 0·001$). Moreover, it was noted in 18 patients (66 per cent of the sample) that micturition began during the change from the quiet to the active phase. In 1·9 per cent of the active phases and 1·1 per cent of the quiet phases there was no optimal measurement.

Table 5. Modification of bladder volume in the active and quiet phases

| | Bladder volume | | | | | |
|---|---|---|---|---|---|---|
| | Decrease* | | Increase | | Failure | |
| | No. | % | No. | % | No. | % |
| Activity | 436 | 74·2 | 136 | 23·1 | 16 | 2·7 |
| Quiet | 22 | 10·2 | 190 | 88·0 | 4 | 1·8 |

Chi-square = 273·37, $p \leqslant 0·001$.
*Micturition

## CONCLUSIONS

These data confirm the existence of active and quiet phases of the fetus. The study of eye movements, essential in the infant and adult to establish the behavioural state, can also permit a more accurate diagnosis of fetal state. The high percentage (87·2 per cent) of REM observed in the active phase suggests the prevalence of active sleep with respect to waking state in the human fetus. The active epochs in which there are IEM, which in this study represent 7·2 per cent, might correspond to the waking state. These data are comparable with those obtained by Rockenbush (1972) and Ioffe *et al.* (1980) in the fetal lamb and by Prechtl (1974) in the newborn infant in which the waking state is around 5–10 per cent.

The quiet phases mainly show an absence of FEM (92·3 per cent) similar to the state of quiet sleep.

More complex is the question of FBM, the genesis of which involves neurophysiological and metabolic causes. In the active phases FBM are more frequent than in the quiet phases, but prevail percentage-wise close to meals because of the inducing effect of glucose (Bocking *et al.*, 1982).

In our observations, the FBM also occur in the quiet phases, but almost exclusively very close to meals. It can therefore be hypothesized that in the quiet phase the metabolic mechanism prevails in the genesis of FBM, while in the active phase the metabolic and neurophysiological mechanisms are working together given the correspondence between the number of FMBM and time after lunch (Carmichael *et al.*, 1984).

As already reported in the literature (Visser *et al.*, 1981b), the existence of a micturition rhythm is confirmed. It is rather interesting to note that in a high percentage of cases (66·6 per cent) micturition occurs during the change from a quiet to an active phase. This is a phenomenon which, is however, present also after birth though it disappears with growth, remaining with only the pathological enuresis.

It can therefore be concluded that dynamic biophysical activities in the fetus are not random phenomena, but part of a complex mechanism of integration. The development of the central nervous system permits a harmonious correlation between these events.

The combined use of echography and cardiotocography seems therefore to be a useful tool for obtaining a better insight into the physiology of the fetus and its deviations from the norm.

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