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Correlation between regular mouthing movements and heart rate patterns during non-rapid eye movement periods in normal human fetuses between 32 and 40 weeks of gestation

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ABSTRACT

Background: Regular mouthing movements (RMMs) are observed during fetal non-rapid eye movement (NREM) periods.
Aim: To determine the correlation between RMM and fetal heart rate (FHR) patterns during NREM periods.
Study design: Fetal eye and mouth movements and FHR patterns were observed and recorded.
Subjects: 50 normal singleton pregnancies between 32 and 40 weeks of gestation.
Outcome measures: Changes in the power spectrum ratio of 3-minute blocks of RMM clusters, FHR with RMM clusters (HR+), and FHR without RMM clusters (HR−) were calculated at a frequency band of 0.02 Hz among 3 gestational age groups: group 1, 32–34 weeks gestation; group 2, 35–37 weeks gestation; group 3, 38–40 weeks gestation. We calculated the percentage of cases showing dominant peak ratios of RMM and HR+ in the same frequency band, the maximum correlation coefficient, and its lag time.
Results: In group 3, the dominant peaks of both RM and HR+ were present at the same frequency band, 0.06–0.08 Hz; this was not seen in the other groups' relative power spectral patterns. The percentage of cases showing dominant peaks of RMM and HR+ in the same frequency band increased with advancing gestational age. The maximum correlation coefficient in groups 1 (0.28 ± 0.11) and 3 (0.45 ± 0.14) differed significantly ($p<0.05$).
Conclusions: The correlation between RMM and FHR patterns became stronger, and their rhythmicity was similar, from 38 to 40 gestational weeks, suggesting that a common center starts to govern both patterns at approximately 38 weeks gestation.

1. Introduction

With advances in ultrasonography, it is now possible to observe various types of fetal movements and the developmental process of these individual movements across gestational ages [1]. Fetal mouthing movements such as jaw opening, yawning, sucking, and swallowing first appear between 10 and 12 weeks gestation [2]. Regular mouthing movements (RMMs) are small movements of the mouth and chin, occurring in clusters [3]. Horimoto et al. reported that fetuses between 32 and 34 weeks gestation showed a high incidence of RMM, and that RMM went on to coincide with the non-rapid eye movement (NREM) period from 35 gestational weeks to 40 weeks [4]. Similarly, RMM is reported to occur only during quiet sleep (QS) of newborn human infants [5–7]. RMM is thought to be related to the development of brain functions associated with sleep [8]. Continuing with this train of thought, maturation of the correlation between QS and RMM in infants, and NREM periods and RMM in fetuses, is believed to reflect developmental aspects of the central nervous system (CNS), making RMM a possible evaluation index for fetal brain function. We previously reported that evaluation of specific fetal behavioral patterns, including RMM during NREM periods after 35 weeks gestation, can be useful for determining fetal neurological function and therefore possibly for identifying postnatal neurological impairments [9].

NREM periods are well-known to correspond with quiet phases in the fetal heart rate (FHR) pattern, defined as periods of decreased fetal heart rate variability near term [10,11]. It has been reported that sinusoidal-like fetal heart-rate patterns occur in association with fetal sucking [12,13]. van Woerden et al. reported that the power spectra of heart rate data in RMM periods showed a peak, coinciding with the frequency of clusters of mouthing movements, at 38–40 weeks gestation; this peak was absent in the power spectra of periods without these movements [3].

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To the best of our knowledge, no study has investigated rhythmicity in RMM and FHR patterns in fetuses before 38 weeks gestation; likewise, no study has investigated the correlation between RMM and FHR patterns. In this study, we investigated the changes in rhythmicity of FHR and RMM patterns with gestational age and the correlation between these patterns during NREM periods in normal human fetuses between 32 and 40 weeks gestation.

2. Materials and methods

2.1. Fetal population

The study population comprised 50 normal singleton pregnancies between 32 and 40 weeks of gestation. All pregnancies were uncomplicated, with no medications prescribed except for iron and vitamin supplements. Gestational ages were calculated from the last menstrual period and confirmed with serial ultrasonographic measurements of the crown-rump length during the first trimester. All mothers were non-smokers without any history of alcohol abuse. We selected only cases with a cephalic presentation at the time of observation. Clinical characteristics are shown in Table 1 (10 patients were excluded from this table, as they did not exhibit RMM during observed NREM periods). All patients were cared for and delivered at the Maternity and Prenatal Care Unit, Kyushu University Hospital. All patients had uneventful deliveries of healthy newborn babies with no abnormal neurological findings at 1 month of age. We obtained institutional review board approval and the informed consent of all mothers.

2.2. Data acquisition

The mothers were initially placed in the semi-recumbent position on a bed in a quiet room, and were able to change their position freely. Recordings were conducted between 9 AM and 6 PM, with a break of at least 2 h after a meal. Fetal movements and FHR patterns were observed simultaneously for approximately 60 min. Fetal eye and mouth movements were observed using real-time ultrasonography (Voluson E8 Expert; GE Healthcare, Kretz, Zipf, Austria) with a 2.0–8.0 MHz convex transducer, and stored on a DVD recorder; the recorded period included both onset and ending points of 1 NREM period. For the ultrasonographic observation of fetal eye and mouth movements, the standard plane was determined to be a nearly frontal section of the fetal face from the lips to the lens margin, with the fetal lens detected as a ring-like, round echo. If obtaining this standard plane proved difficult, a parasagittal view showing the fetal lens and the lips was used. FHR tracings were recorded using cardiotocographic equipment (Model MT-5700; Toitu, Tokyo, Japan) with a Doppler ultrasound transducer of 1.1 MHz, and FHR values were stored on a personal computer (Versa Pro VJ16A/ED-1; NEC, Tokyo, Japan).

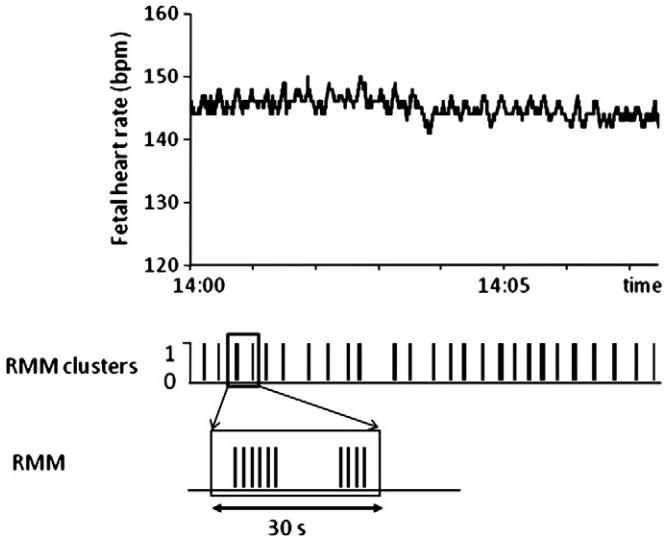

Fig. 1. Original time series data of fetal heart rate (FHR) and regular mouthing movement (RMM) obtained from a fetus at 38 weeks gestation. The horizontal axis indicates the elapsed time of recording. The vertical axis indicates FHR (upper) and RMM clusters (lower). Within 1 cluster, RMM appears at regular intervals.

2.3. Data processing

Data were processed and analyzed on an individual basis. As data were replayed for each case, the total observation period was divided into 1-min units. Each unit was evaluated for the presence of NREM periods or rapid-eye movement periods based on the absence or presence of fetal eye movements. RMM, which was only seen in NREM periods, was observed as repetitive bursts of continual mouthing, with pauses between the bursts. We defined the period of 1 burst as a RMM cluster (Figs. 1, 2).

The time series data of RMM consisted of the numeral 1 or 0, depending on the presence or absence of a RMM cluster. For example, we assigned the numeral “1” to a period with a RMM cluster and “0” to a period without RMM clusters, with a sampling rate of 0.25 s.

2.4. Data selection

We divided NREM periods into 3-min segments (3-min blocks). We selected for analysis 3-min blocks that met the criteria listed below. These 3-min blocks were assigned the categories of RMM clusters, FHR with RMM clusters (HR+), and FHR without RMM clusters (HR−). The total number of 3-min blocks is shown in Table 2.

Criteria:

1. Fetal body movements are absent.
2. FHR accelerations and decelerations are absent.
3. FHR baseline variability is less than 10 beats/min (bpm) [10].

Table 1
Characteristics of the 40 fetuses.

	Total	Group 1	Group 2	Group 3
Case (n)	40	13	14	13
Gestational age at delivery (weeks)	39.4 (36–41)	39.6 (36–41)	37.9 (36–41)	40.1(38–41)
Birth weight (g)	3120 (2360–4150)	3175 (2360–3810)	3040 (2435–3435)	3125 (2720–4150)
Sex (male/female; n)	22/18	7/6	10/4	5/8
Apgar score				
1 min	9 (7–9)	8 (8–9)	9 (7–9)	9 (7–9)
5 min	9 (8–10)	9 (8–9)	9 (8–10)	9 (9–10)
pH of umbilical artery	7.32 (7.19–7.43)	7.32 (7.23–7.43)	7.32 (7.19–7.39)	7.29 (7.19–7.38)

Median data are shown with ranges.