Background electroencephalographic (EEG) activities of very preterm infants born at less than 27 weeks gestation: a study on the degree of continuity

M Hayakawa, A Okumura, F Hayakawa, K Watanabe, M Ohshiro, Y Kato, R Takahashi, N Tauchi

Abstract

Aims—To clarify the features of the background electroencephalographic (EEG) activities in clinically well preterm infants born at less than 27 weeks gestation and to outline their chronological changes with increasing postconceptional age (PCA).

Methods—EEGs of clinically well premature infants born at less than 27 weeks gestation were recorded during the early postnatal period. The infants were separated into three groups according to their PCA at the time of EEG recording (21–22 weeks PCA, 23–24 weeks PCA, and 25–26 weeks PCA). The mean and maximum duration of interburst intervals (IBIs), the mean duration of bursts, and the percentage of continuous and discontinuous patterns in each PCA group were evaluated.

Results—There were three infants at 21–22 weeks PCA, seven at 23–24 weeks PCA, and five at 25–26 weeks PCA. Eighteen EEG recordings were obtained. The mean and maximum IBI duration decreased with increasing PCA. The percentage of continuous patterns increased with increasing PCA. Conversely, the percentage of discontinuous patterns decreased with increasing PCA.

Conclusions—In premature infants born at less than 27 weeks gestation, the characteristics of the background EEG activities were similar to those of older premature infants. These changes reflect the development of the central nervous system in this period.

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Keywords: electroencephalogram; central nervous system; development; prematurity; extremely low birthweight infants; neonatal intensive care unit

During the last few decades, advances in neonatal intensive care have resulted in a decrease in neonatal mortality and a dramatic increase in the survival rate of extremely low birthweight infants. However, severe neurological sequelae are common because of the vulnerability of the immature central nervous system. Although various techniques such as cranial ultrasonography are used for neurological evaluation, electroencephalography (EEG) is one of the most useful tools for predicting neurological outcome in preterm and term infants.

Several authors have studied EEGs in premature infants. We can recognise two distinct patterns, continuous and discontinuous. The continuity of EEG activities changes considerably with maturation of the brain. In immature infants, discontinuous patterns occur in a large part of the tracing.

Although several studies on EEG findings of premature infants have been published, most were concerned only with those born at more than 27 weeks gestation. The aim of this study was to clarify the features of background EEG activities in clinically well preterm infants born at less than 27 weeks gestation in terms of continuity and to outline their developmental changes with increasing postconceptional age (PCA).

Patients and methods

The subjects were preterm infants born at less than 27 weeks gestation, who were admitted to the neonatal intensive care unit of Ogaki Municipal Hospital from June 1997 to October 1998. Infants were selected who met all of the following criteria: normal neurological examination and cranial ultrasound at least until 24 hours after the last EEG recordings; no evidence of asphyxia (pH > 7.25 in initial blood gas analysis); no congenital anomalies; stable respiratory and circulatory state. Gestational age was determined from the date of the mother’s last menstrual period and confirmed by the New Ballard Score. The latter was used if the mother’s last menstrual period was unknown or if the gestational age estimated from the last menstrual period was discordant with physical examination data.

EEG recordings were performed at the infants’ bed side using a Nihon-Koden instrument. Eight bipolar conduction electrodes were placed according to the modified 10–20 international system adjusted to the smaller head size of preterm infants (AF3-C3, C3-O1, AF4-C4, C4-O2, AF3-T3, T3-O1, AF4-T4, T4-O2). Paper speed was 30 mm/second, with a time constant of 0.3 second. Amplitudes were 10 µV/mm. A high frequency filter was set at 60 Hz. EEGs were recorded for more than 30 minutes in order to include both continuous and discontinuous patterns.

EEG findings were divided into three categories according to the following criteria (fig 1). (1) Continuous patterns: EEG activity mainly consisting of delta waves > 100 µV that were continuously recognised for more than 20
Calibrations are 100 µV and 1 second.

(A) Continuous pattern; (B) discontinuous pattern; (C) undifferentiated pattern.

Figure 1 Electroencephalographic (EEG) findings for a very preterm infant (gestational age 23 weeks 6 days; postconceptional age 24 weeks 0 days; birth weight 564 g).

Figure 1 Electroencephalographic (EEG) findings for a very preterm infant (gestational age 23 weeks 6 days; postconceptional age 24 weeks 0 days; birth weight 564 g).

Table 1 Characteristics of the three groups of preterm infants at time of EEG recordings

<table>
<thead>
<tr>
<th>PCA (weeks)</th>
<th>No of EEGs</th>
<th>Recording age (days)</th>
<th>Systolic BP (mm Hg)</th>
<th>Diastolic BP (mm Hg)</th>
<th>pH</th>
<th>BE (mmol/l)</th>
<th>SpO2 (%)</th>
</tr>
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<tbody>
<tr>
<td>21–22</td>
<td>5</td>
<td>1.0 (0–3)</td>
<td>37.2 (24–42)</td>
<td>22.2 (15–39)</td>
<td>7.41 (7.35–7.46)</td>
<td>−4.5 (−10.2–−1.1)</td>
<td>96.2 (95–97)</td>
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<td>23–24</td>
<td>7</td>
<td>2.4 (0–9)</td>
<td>49.0 (45–57)</td>
<td>29.3 (23–36)</td>
<td>7.38 (7.34–7.45)</td>
<td>−2.0 (−3.0–0.7)</td>
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<tr>
<td>25–26</td>
<td>6</td>
<td>2.0 (0–8)</td>
<td>53.2 (41–62)</td>
<td>33.0 (24–44)</td>
<td>7.38 (7.35–7.41)</td>
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<td>Total</td>
<td>18</td>
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<td>47.1 (24–62)</td>
<td>28.6 (15–44)</td>
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Values are means (range). PCA, Postconceptional age; BP, blood pressure; BE, base excess.

Results

Fifteen infants participated in this study. Their mean gestational age was 24.1 (21.1–26.3) weeks and mean birth weight 638.7 (415–940) g. Eighteen EEG recordings were obtained.

Table 1 shows the clinical characteristics at the time of EEG recording. The mean postnatal age at the time of the EEG recording was 1.9 (0–9) days. Mean systolic and diastolic blood pressures were 47.1 (24–62) and 28.6 (15–44) mm Hg respectively. Mean pH was 7.39 (7.34–7.46) and mean base excess was −2.9 (−10.2 to 0.7) mmol/l. Mean SpO2 was 96.6 (90–100)%. None of patients received sedative or narcotic agents.

Mean IBI duration decreased as PCA increased (fig 2A). The mean IBI duration was 25.8 (14.1–46.3) seconds at 21–22 weeks PCA, 18.4 (11.1–25.2) seconds at 23–24 weeks PCA, and 12.7 (10.3–16.3) seconds at 25–26 weeks PCA. There was a significant difference only between 21–22 weeks PCA and 25–26 weeks PCA (p < 0.05).

The maximum IBI duration also showed a decreasing trend from 21 to 26 weeks PCA (fig 2B). The maximum IBI duration was 126.0 (67–218) seconds at 21–22 weeks PCA and 86.6 (43–136) seconds at 23–24 weeks PCA. At 25–26 weeks PCA, the maximum IBI duration was 44.2 (19–76) seconds. A significant difference was seen only between 21–22 weeks PCA and 25–26 weeks PCA (p < 0.05).

The mean burst duration during discontinuous patterns increased as PCA increased (fig 3). Burst durations were 4.3 (3.4–5.1) seconds at 21–22 weeks PCA, 5.0 (3.9–7.4) seconds at 23–24 weeks PCA and 5.8 (4.9–7.2) seconds at 25–26 weeks PCA. There was a significant difference only between 21–22 weeks PCA and 25–26 weeks PCA (p < 0.05).

The percentage of continuous patterns at each PCA increased as PCA increased (fig 4A). The percentage of continuous patterns at 21–22 weeks PCA, 23–24 weeks PCA, and 25–26 weeks PCA were 5.5 (0.0–17.3), 23.8 (1.3–46.4), and 48.5 (27.3–73.2) respectively.

**Table 1** Characteristics of the three groups of preterm infants at time of EEG recordings

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Values are means (range). PCA, Postconceptional age; BP, blood pressure; BE, base excess.
The results were significantly different between 21–22 weeks PCA and 25–26 weeks PCA (p < 0.01). In contrast with the continuous patterns, the percentage of discontinuous patterns decreased as PCA increased (fig 4B). The percentage of discontinuous patterns at 21–22 weeks PCA, 23–24 weeks PCA, 25–26 weeks PCA were 69.0 (30.4–96.1), 53.8 (32.8–76.8), and 48.4 (18.9–49.0) respectively. The results were significantly different between 21–22 weeks PCA and 25–26 weeks PCA (p < 0.05).

Six of these 15 infants died after the recordings. The causes of death were pneumothorax in two, necrotising enterocolitis in two, intestinal perforation in one, and pyothorax in one. One infant was blind due to retinopathy of prematurity and another had subglottis stenosis. Although neurodevelopmental outcome was not sufficiently evaluated because three infants were younger than one year of corrected age at their last follow up, six infants had no neurological sequelae.

**Discussion**

This study illustrates the characteristics and developmental changes in background EEG activities in very premature infants in terms of continuity. The mean and maximum IBI duration decreased as PCA increased, whereas the burst duration and continuity increased with increasing PCA. These findings are consistent with the maturational changes in background EEGs in infants born after 27 weeks gestational age.11–16

The presence of discontinuous patterns is a prominent feature of EEGs of preterm infants. IBI is an easily distinguishable component of EEG activity. Several reports have focused on IBI duration and its maturational change.14 16 23 Mean IBI duration has been reported to decrease as PCA increases. Connell et al.,17 using continuous four channel EEG monitoring, reported that mean IBI duration fell from 14 to 8 seconds between 26 and 37 weeks. Anderson et al.16 showed that mean IBI decreased from 12 to 7 seconds between 27 and 32 weeks. A similar trend is observed in the
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showed that it was independent of PCA.16 17
PCA in our study, whereas previous studies
increased in agreement with previous studies,
fore the maximum IBI decreased as PCA
and 44.2 seconds at 25–26 weeks PCA. There-
weeks PCA, 86 seconds at 23–24 weeks PCA,
the maximum IBI was 126.0 seconds at 21–22
between 27 and 32 weeks. In the present study,
the maximum IBI was 126.0 seconds at 21–22
weeks PCA, 86 seconds at 23–24 weeks PCA,
and 44.2 seconds at 25–26 weeks PCA. There-
ence was longer than that of older preterm
But several authors have reported that continu-
and discontinuous patterns decreased with increasing PCA.18 19
Eyre et al20 reported that the duration of bursts
was between two and five seconds. Anderson
et al21 reported that the duration of bursts during discon-
patterns was four to five seconds on average at any PCA. However, sufficient
statistical analysis was not performed in these
In contrast with previous studies, our
study showed that the mean burst duration was 4.3 seconds at 21–22 weeks PCA, 5.0 seconds
at 23–24 weeks PCA, and 5.8 seconds at 25–26
weeks PCA. Burst duration was significantly
longer in infants at 21–22 weeks PCA than in
infants at 25–26 weeks PCA.

Several authors have reported that continuous
patterns increased and discontinuous patterns decreased with increasing PCA. Anderson
et al20 showed that the percentage of discontinuous patterns was 62 at 27–28 weeks
PCA, 53 at 29–30 weeks PCA, and 45 at 31–32
weeks PCA. Goto et al22 reported that continuous
patterns increased from 1.2 to 7.1% and discontinuous patterns decreased from 66.6 to
36.7% from 26 to 30 weeks PCA. In our study,
maturational alteration of the percentage of continuous and discontinuous patterns in very
preterm infants was consistent with previous
reports on more mature preterm infants. How-
over, the percentage of continuous patterns in
this study was larger and that of discontinuous patterns was smaller than that of more mature
preterm infants in these studies. These differ-
ences may be attributable to the difference in
the definition of continuous and discontinuous patterns. Goto et al22 reported sequential
changes in continuity of EEG activities using low amplification and a compressed time scale.
Some low voltage EEG activities, which are
detectable in our study, may have been missed.
Furthermore, they used only two cerebral
channels located in the bilateral frontal and
central regions. EEG activities from other
regions were not detected by their monitoring
system. This resulted in longer discontinuous
patterns in their study. We were able to identify
continuous and discontinuous patterns more
precisely because we used a higher amplifica-
tion rate and faster paper speed.

There are two limitations to our study.
Firstly, the definition of a normal very preterm
infant is difficult because prematurity itself is
not physiological. A preterm infant cannot be
confirmed as truly healthy during the early
neonatal period until normal growth and
psychomotor development are achieved. The
prognosis of very preterm infants is poor
despite recent advances in neonatal intensive
care.23 This is especially true for those born at
less than 24 weeks gestation. Therefore we
cannot decide whether the infants who partici-
pated in this study were truly well. We consider
that they were healthy and their brain function
satisfactory because we carefully selected very
preterm infants whose respiratory and cardio-
circulatory conditions were stable and cranial
ultrasonographic findings were normal. There-
erefore we believe that EEGs of healthy preterm
infants were evaluated in this study. Another
limitation is the small number of patients. Severe complications such as intracranial
haemorrhage and respiratory or cardiac failure
are common among very preterm infants. It is
difficult to record EEGs of very preterm infants while they are clinically well. Further multicen-
tre studies will be necessary to determine pre-
cisely the physiological EEG findings of very
preterm infants.

The central nervous system of very preterm
infants is vulnerable because of its prematurity.
The main causes of neurological sequelae are
intraventricular haemorrhage and periventric-
ular leucomalacia. Previous studies have
shown that EEG is useful in predicting neuro-
logical outcome of preterm infants.16–21 De-
creased continuity of EEG activities is known
to be related to neurological outcome in
preterm infants. This indicates that the con-
tinuity of EEG activities is sensitive to the brain, although chronic
brain injuries cannot be assessed with this vari-
able.22 An assessment of EEG continuity will
provide valuable information on brain func-
tion. This study shows some important features
of background EEG of clinically well very pre-
term infants born at less than 27 weeks
gestational age. Further studies that include
impaired infants are needed to establish the

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Key messages
At less than 27 weeks gestational age, the characteristics of background EEG activi-
ties were found to be as follows:
• the mean and maximum IBI duration decreased with increasing PCA
• the percentage of continuous patterns increased with increasing PCA
• the percentage of discontinuous patterns increased as PCA increased
diagnostic and prognostic value of EEG in very preterm infants.