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Original article

A new electroencephalogram classification with reduced recording time in asphyxiated term infants

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Abstract

Background and objectives: Conventional electroencephalogram (cEEG) is a reliable predictor of outcome in term infants with hypoxic ischemic encephalopathy (HIE). Early therapeutic hypothermia initiated within 6 h after birth is a beneficial treatment in these infants. However, a classification system with reduced cEEG recording time to determine early intervention has not been reported. The aim of this study is to propose a new classification of depression on cEEG with reduced recording time in infants with HIE and to examine the correlation between the classification and short-term outcome. *Patients and methods:* We retrospectively investigated 20 term infants with HIE in whom cEEG was performed within 12 h after birth, and deaths or outcomes at 18 months of age were assessed. We determined grades 0–3 EEG depression in each 10-min epoch based on the most common EEG patterns of each 20 s epoch defined by our criteria. *Results:* Eighteen infants could be assessed by depression grade. The Spearman's rank correlation coefficient *Rs* between the maximum depression grade in 10-min epochs and three-grade outcomes was 0.68 ($P = 0.002$), and that between the minimum one and outcomes was 0.66 ($P = 0.003$). The area under the receiver operating characteristic curve of the maximum and minimum depression grades for predicting abnormal outcome were 0.885 and 0.869, respectively. *Conclusions:* We demonstrated a new cEEG depression classification with a recording time of at least 10 min in term infants with HIE and a good correlation with short-term outcome.

Keywords: Classification; Electroencephalogram; Hypoxic ischemic encephalopathy; Prediction; Term infant

1. Introduction

Hypoxic ischemic encephalopathy (HIE) is a major cause of death and neurological impairment in asphyxiated neonates [1]. Randomized clinical trials have demonstrated the benefit of therapeutic hypothermia commenced within 6 h after birth for reducing death or disability at 18 months of age [2–4]. In 2010, the American Heart Association, European Resuscitation Council, and International Liaison Committee on Resuscitation recommended therapeutic hypothermia in term or near-term infants with moderate to severe HIE [5].

Conventional electroencephalogram (cEEG) is a highly reliable predictor of outcome in term infants with HIE [6–9]. However, the previous cEEG classification criteria require a recording time of 45–120 min because assessments of sleep–wake cycles or cEEG patterns during all sleep stages are needed for most of these criteria.

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A classification system with reduced cEEG recording time in infants with HIE has not been reported. On the other hand, early initiation of appropriate interventions such as therapeutic hypothermia is important for a good prognosis in these infants. Therefore, clinicians must decide between a long-duration assessment of cEEG and earlier intervention of therapeutic hypothermia. Short-duration and precise evaluation of brain function in infants with HIE will aid in early determination and provision of appropriate interventions for a good prognosis.

Our hypothesis based on our experience is that it is possible to evaluate cEEG with reduced recording time of at least 10 min within 12 h after birth in term infants with HIE to predict short-term outcome at 18 months of age. The aim of this study was to develop criteria for classifying cEEG depression with reduced recording time in term infants with HIE and to clarify the correlation between the classification and short-term outcome.

2. Methods

2.1. Patients

We retrospectively investigated 20 consecutive term infants with HIE admitted to the neonatal intensive care units of Okazaki City Hospital ($N = 8$), Anjo Kosei Hospital ($N = 9$), Toyota Memorial Hospital ($N = 1$), Japanese Red Cross Nagoya Daiichi Hospital ($N = 1$), and Nagoya University Hospital ($N = 1$) between April 2004 and March 2010. These hospitals provide tertiary-level care for newborns. The infants fulfilled all of the following criteria: (1) $\geqslant$37 weeks gestation; (2) Apgar score $\leqslant$5 at 5 min after birth, pH $\leqslant$ 7.0 in umbilical-cord blood or a blood sample immediately after birth or base deficit $\geqslant$ 16 mmol/l in the same sample, or assisted ventilation for at least 5 min after birth; (3) clinical signs of moderate or severe encephalopathy as defined by Shankaran et al. [2]; (4) no congenital anomalies or inborn errors of metabolism; (5) cEEG performed within 12 h after birth; and (6) assessment of death or neurological outcome at 18 months of age. We collected the clinical data of all subjects from the medical charts.

2.2. cEEG recordings

cEEG was recorded polygraphically at the bedside for at least 10 min using a bipolar montage with at least eight surface Ag/AgCl cup electrodes (AF3–C3, C3–O1, AF4–C4, C4–O2, AF3–T3, T3–O1, AF4–T4, and T4–O2) according to the international 10–20 system. This was combined with an electrocardiogram and respiratory movement assessment by the NicoletOne Monitor nICU (Natus Medical, San Carlos, CA, USA) or Nihon Kohden EEG Neurofax (Nihon Kohden, Tokyo, Japan). The low-cutoff filter was fixed at 0.5 Hz, and the raw cEEG was displayed at 3 cm/s and 100 μV/10 mm. Impedance was <20 kΩ. The preparation time of set-up for recording was within 10–15 min in our hospitals. Written informed consent for the cEEG recordings was obtained from the parents of all patients. Approval of the institutional ethics committee at Okazaki City Hospital was obtained to conduct this study.

2.3. cEEG assessments

Representative cEEG patterns in the 20 s epochs are shown in Fig. 1. We evaluated cEEG patterns in each 20 s epoch throughout recording using criteria based on our previous report, with minor modifications, to determine the depression grade on cEEG [6,10]. The cEEG patterns were classified as follows: P, poor activity of 5–20 μV or inactivity of 0–5 μV; B, a burst–suppression pattern consisting of abnormal burst activity of >50 μV for <4 s interrupted by attenuated activity of 0–20 μV; D, discontinuous pattern consisting of >4 s physiological burst activity interrupted by attenuated activity of 0–20 μV; dA, depressed-alternating pattern consisting of physiological high-voltage slow bursts of 50–150 μV separated by low-voltage activity of 20–50 μV, but the duration of the bursts was <3 s or the duration of low-voltage activity >8 s; L, continuous low-voltage irregular activity of 20–50 μV; A, alternating pattern consisting of physiological high-voltage slow bursts of 50–150 μV for 4–8 s separated by low-voltage activity of 20–50 μV for <8 s; M, continuous medium-voltage activity of 30–100 μV; H, continuous high-voltage slow activity of 50–150 μV; S, seizure activity consisting of stereotyped, repetitive, and rhythmic activity lasting >10 s; N, noise or artifacts; U, unclassified pattern consisting of patterns other than the above. Minor modifications included addition of the new dA pattern and a more detailed definition of patterns B and D. If inter-hemispheric asymmetry or asynchrony was seen, we selected the former pattern, which was more depressed. The expert investigator (T. Kato) who alone evaluated the cEEG patterns was blinded to the clinical information. The inter- and intra-rater agreement on these patterns was assessed in 15 representative samples of 20 s epochs consisting of all patterns except for S, N, and U by three authors (T. Kato, T. Tsuji, and T. Kubota) who are experts at evaluating neonatal cEEG using κ statistics. Among 15 samples, disagreements between two raters were seen in two to three samples ($\kappa = 0.82$). The intra-rater agreement (T. Kato) was perfect in the 15 samples ($\kappa = 1$).

Thereafter, we extracted the most common pattern in the 20 s epochs in each 10-min record as the representative 10-min epoch pattern (Fig. 2). We evaluated all consecutive 10-min epochs whether in wakefulness or in sleep. If pattern S was seen in at least one 20 s epoch, then the representative pattern in this 10-min epoch