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Combination of EEG and ECG for improved automatic neonatal seizure detection

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Abstract

Objective: Neonatal seizures are the most common central nervous system disorder in newborn infants. A system that could automatically detect the presence of seizures in neonates would be a significant advance facilitating timely medical intervention.
Methods: A novel method is proposed for the robust detection of neonatal seizures through the combination of simultaneously-recorded electroencephalogram (EEG) and electrocardiogram (ECG). A patient-specific and a patient-independent system are considered, employing statistical classifier models.
Results: Results for the signals combined are compared to results for each signal individually. For the patient-specific system, 617 of 633 (97.52%) expert-labelled seizures were correctly detected with a false detection rate of 13.18%. For the patient-independent system, 516 of 633 (81.44%) expert-labelled seizures were correctly detected with a false detection rate of 28.57%.
Conclusions: A novel algorithm for neonatal seizure detection is proposed. The combination of an ECG-based classifier system with a novel multi-channel EEG-based classifier system has led to improved seizure detection performance. The algorithm was evaluated using a large data-set containing ECG and multi-channel EEG of realistic duration and quality.
Significance: Analysis of simultaneously-recorded EEG and ECG represents a new approach in seizure detection research and the detection performance of the proposed system is a significant improvement on previous reported results for automated neonatal seizure detection.

Keywords: Neonatal seizure detection; EEG; ECG; EKG

1. Introduction

Seizures in the neonate require immediate medical attention and represent a distinctive sign of central nervous system dysfunction. There is increasing evidence that neonatal seizures have an adverse effect on neurodevelopmental outcome, and predispose to cognitive, behavioural, or epileptic complications in later life (Levene, 2002). Neonatal seizures occur in 6% of low birth-weight infants (Volpe, 2001) and in approximately 2% of all newborns admitted to a neonatal ICU (Scher et al., 1993a). Seizures in this age-group are often subtle, difficult to diagnose and may be clinically silent, particularly after antiepileptic drug treatment, making diagnosis by clinical observation alone very unreliable (Boylan et al., 2002). Electroencephalography (EEG) is the most reliable method available to detect the majority of neonatal seizures but interpretation requires special expertise that is not readily available in most neonatal intensive care units least so on a 24-h basis. A system that could automatically detect the presence of seizures in

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newborn babies would be a significant advance, facilitating timely medical intervention.

A number of studies have reported neonatal seizure detection methods based on the EEG (Liu et al., 1992; Gotman et al., 1997a; Celka and Colditz, 2002; Altenburg et al., 2003). Faul et al. (2005) provided a review and experimental comparison of three of the most commonly cited neonatal seizure detection algorithms. None performed sufficiently to be deemed suitable for use in the neonatal intensive care unit (ICU). Karayiannis et al. (2001) reported a video-based method for distinguishing myoclonic from focal clonic seizures and differentiating these types of seizures from normal infant behaviours. However, this approach does not provide a complete solution to the problem, as many neonatal seizures are not accompanied by this spectrum of body movements.

The importance of autonomic changes may be underestimated in neonatal seizure detection research. Neonatal seizures are often associated with changes in heart and respiration rate (Greene et al., 2006b). Significant changes in heart rate may alert the clinician to the possibility of seizures and instigate further investigation with EEG. These findings led to the development of a neonatal seizure detection system based exclusively on the electrocardiogram (ECG) (Greene et al., 2006a).

The aim of this study was to attempt to improve the neonatal seizure detection rate by combining simultaneously-acquired ECG and EEG data. To the best of our knowledge this is the first method to combine the ECG with the EEG for seizure detection.

2. Data-set

A data-set of 12 records from 10 term neonates containing 633 labelled seizure events, with mean seizure duration of 4.60 min, were recorded and analysed. The records had a mean duration of 12.84 h. Each record contained 7–12 channels of EEG and one channel of simultaneously-acquired ECG. Ten records, sampled at 256 Hz, were made in the neonatal intensive care units of the Unified Maternity Hospitals in Cork, Ireland, using the Viasys NicOne video-EEG system. The remaining recording, sampled at 200 Hz, was recorded at Kings College Hospital, London, on a Telefactor Beehive video-EEG system. A total of 154.1 h of EEG and ECG were analyzed.

The data-set used in this research is a resource of continuously-recorded digital video-EEG data and other physiological parameters in newborns with seizures in the first 3 days from birth. All newborns were full term (GA: 40–42 weeks) and had hypoxic ischaemic encephalopathy (HIE). All the data for each recording were included in the analysis regardless of record length or quality. Electrographic seizures were identified and annotated by an expert in neonatal EEG (GBB). Fig. 1 shows

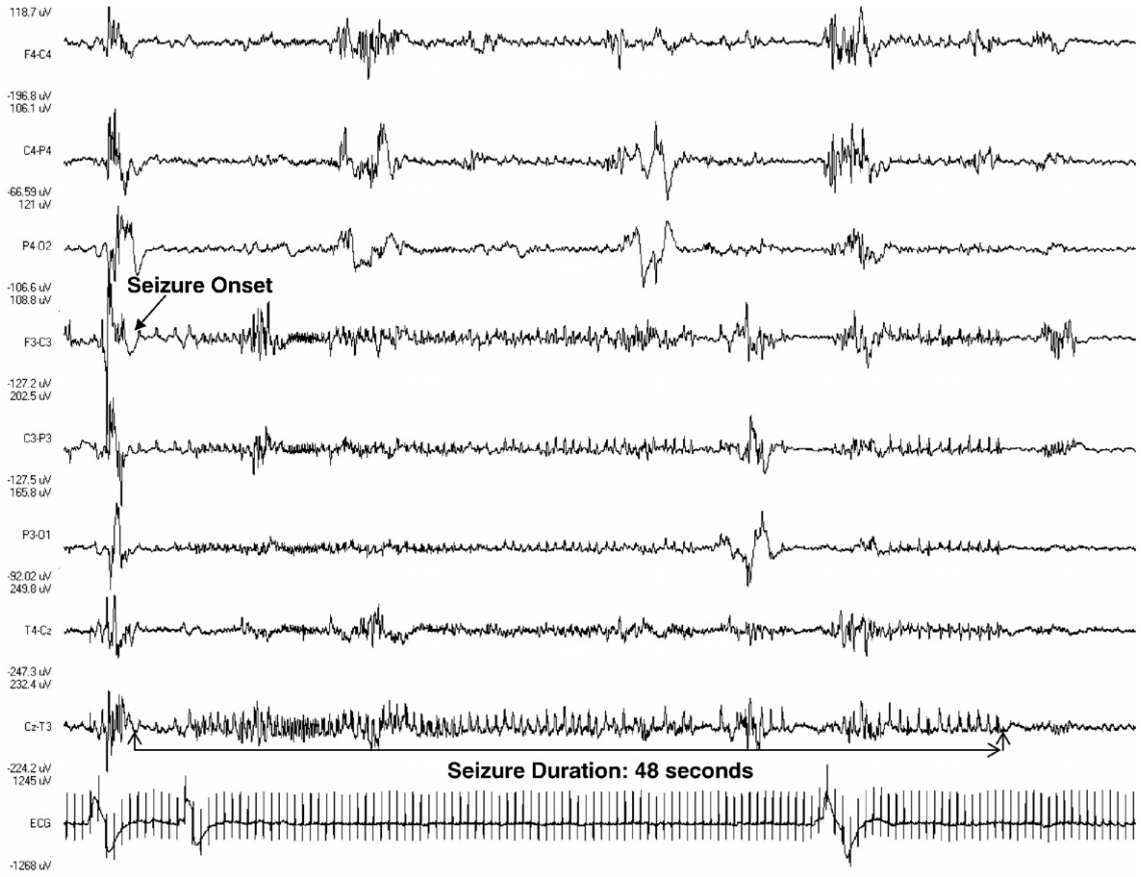

Fig. 1. Example of a multi-channel electrographic seizure. Seizure onset and duration are marked.