Epilepsy Research (2010) **90**, 228—233

journal homepage: www.elsevier.com/locate/epilepsyres

The slow-wave component of the interictal epileptiform EEG discharges

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Received 25 January 2010; received in revised form 27 April 2010; accepted 3 May 2010
Available online 31 May 2010

KEYWORDS
EEG;
Epileptiform discharges;
Slow-wave component

Summary The interictal epileptiform discharges (IEDs) consist of a fast component (FC; spike or sharp-wave) followed by a slow-wave component (SC). Our purpose was to assess the intra-individual variance, the diagnostic significance and the effect of sleep on the SC. Ninety-nine EEG recordings from 50 consecutive patients with IEDs were analysed. We measured the duration (ms) of the SC (SC-duration), while the amplitude of the SC was divided by the amplitude of the FC yielding a normalized value (SC/FC amplitude-ratio). Intra-individual, intra- and inter-recording coefficients of variation (CV) were calculated for the SC-duration and SC/FC amplitude-ratio. The correlation with the diagnosis, and the effect of sleep was analysed. The SC-duration and the SC/FC amplitude-ratio had low CV (<27%). The SC-duration was not correlated with the diagnosis. The SC/FC amplitude-ratio was significantly higher in the patients with generalized epilepsies as compared with the localization-related ones, and it was higher in the patients with idiopathic epilepsies as compared with the symptomatic ones. These predictors were independent. The SC/FC amplitude-ratio of the patients with idiopathic epilepsy increased significantly during sleep. We conclude that the SC-duration and SC/FC amplitude-ratio are stable parameters. The amplitude of the SC in relation to the fast component is larger in patients with generalized and idiopathic epilepsies, suggesting higher degree of cortical inhibition in these patients, possibly corresponding to specific protective mechanisms.

Introduction

The interictal epileptiform discharges (IEDs) have a multiphasic character: the fast component (FC; spike or sharp-wave) is trailed by a negative slow-wave component (SC) in most instances (Niedermeyer, 2005).

SC has been attributed to inhibitory phenomena. Studies with intracranial electric brain stimulation in humans have

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0920-1211/$ — see front matter
doi:10.1016/j.eplepsyres.2010.05.005

Table 1 Number of patients in the diagnostic groups.

Group	Number of patients
1. Localization-related epilepsies and syndromes	23
1.1 Idiopathic	6
1.2 Symptomatic	17
2. Generalized epilepsies and syndromes	25
2.1 Idiopathic	6
2.2 Cryptogenic or symptomatic	13
2.3. Symptomatic	6
3. Epilepsies and syndromes undetermined whether focal or generalized	2

demonstrated that there is an increased discharge threshold after interictal spikes (Wilson and Engel, 1993; Wilson et al., 1998; De Curtis et al., 2005). Decrease in the high frequency intracerebral EEG activity (100—500 Hz) during the SC recorded with scalp electrodes has been recently demonstrated suggesting an inhibitory phenomenon during this phase (Urrestarazu et al., 2006). In vitro studies have shown a profound hyperpolarization following spikes caused by intrinsic and synaptic mechanisms (Lebovitz, 1979; Gutnick et al., 1982; Hwa et al., 1991).

The frequency of the bursts of generalized spike- and slow-wave complexes has a well-established clinical significance: classical, 3 Hz bursts are recorded in patients with childhood absence epilepsy; higher (>4 Hz) frequencies are found in patients with juvenile myoclonic epilepsy (JME), while lower frequencies (below 2.5 Hz) are recorded in patients with Lennox—Gastaut Syndrome (Niedermeyer, 2005). However, the parameters of the SC of IEDs (single spikes/sharp-waves) received little clinical attention. It has been suggested that in patients with benign focal epilepsy of childhood the amplitude of the FC exceeds the amplitude of the SC (Noachtar et al., 1999; Lüders and Noachtar, 2001).

In an attempt to elucidate the clinical significance of the SC we measured two parameters: the duration (SC-duration; ms) and the amplitude (μV). The absolute value of the amplitude varies considerably even within the same recording, therefore we attempted to calculate a normalized value, which can easily be determined also in clinical practice. We choose the ratio between the amplitude of the SC and the preceding FC (SC/FC amplitude-ratio) because this could reflect the proportion of the excitatory and inhibitory phenomena during an IED, and because it was previously suggested that this ratio could have diagnostic significance (Noachtar et al., 1999; Lüders and Noachtar, 2001).

To assess the stability of these parameters we determined the intra-individual variance (both intra- and inter-recording). Then we searched for a diagnostic correlation for the SC-duration and for the SC/FC amplitude-ratio. Previous studies suggested a strong modulation of the IEDs during sleep (Halász et al., 2002; Kotagal and Yardi, 2008; Guaranha et al., 2009). Therefore we assessed whether these SC parameters change significantly during sleep. We analysed 99 EEG recordings from 50 consecutive patients with interictal epileptiform single-discharges.

Many automated systems for the detection, characterisation and quantification of the IED have been developed and evaluated (Gotman, 1986; Ktonas, 1987; Wilson and Emerson, 2002; Larsson et al., 2009). However when assessing the accuracy of these methods, most studies use the visual analysis of the EEG recordings by trained experts as gold standard. Therefore we opted for the visual analysis method in our study.

Methods

Patients

Data from 50 consecutive patients (25 males, 25 females) aged between 1 and 70 years (mean 19.6) with IEDs trailed by SCs were included in the study. We analysed all the previous EEGs recorded in our laboratory from these patients, provided they contained IEDs. In total we analysed data from 99 recordings. Eleven patients only had 1 recording, 9 patients had 2 recordings, and 30 patients had 3 or more recordings. Thirteen patients had 2 independent foci, 10 patients had 3 independent foci and 6 patients had 4 or more foci. Each focus was analysed separately. For the patients with generalized epilepsy, the SC was determined in the channel with the largest signal. In 26 patients the same focus could be analysed separately for the awake-relaxed state and for sleep (non-REM sleep, stages: N1—N2). Thus we analysed the slow-waves in 226 conditions totally. For each of these conditions, up to 20 IEDs were measured. Patients were classified into the major groups of the classification of epilepsies and epileptic syndromes (Table 1) (Commission on Classification and Terminology of the International League Against Epilepsy, 1989).

EEG recordings and measurements

EEGs were recorded with a Nicolet-One apparatus, using a standard 25 electrode setting (including 6 electrodes in the inferior temporal chain) with a sampling frequency of 256 Hz. The anti-aliasing filter was set at 134 Hz. Signals were digitally filtered: 0.5—70 Hz.

EEG recordings were visually reviewed in order to detect and classify the IEDs, which were categorized according to their localization and the level of arousal (awake vs. sleep) at which they occurred. SC parameters for each category were measured in Common Average montage, in the channel where the signal was the largest. We did not opt for a bipolar montage, because we wanted to avoid contamination of the signal by the active, neighbouring electrode (Scherg et al., 2002).

SC parameters were measured visually using cursors on the electronic display. For all measurements a sensitivity of 3 μV/mm and a paper-speed of 60 mm/s were used. The resolution of the monitor was 34 pixels/cm. This resolution yielded 204 pixels for 1 s of recording. The SC-duration was measured from the positive turn between the fast and the slow component, until the following positive turn (Fig. 1A). The amplitudes (μV) of the FC and SC were measured from the largest positive to the largest negative peak — to compensate