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The additional lateralizing and localizing value of the postictal EEG in frontal lobe epilepsy

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HIGHLIGHTS

- Our study revealed that 47/96 (49%) postictal periods contained lateralizing or localizing information.
- In 14/38 (39%) patients, at least one seizure with an unhelpful ictal EEG was followed by postictal EEG features with new lateralizing information.
- In frontal lobe epilepsy, close examination of the postictal EEG can offer additional information to identify a potentially resectable epileptogenic zone.

ABSTRACT

Objective: The aim of this study was to describe the additional lateralizing and localizing value of the postictal EEG in frontal lobe epilepsy (FLE). The ictal EEG in FLE is frequently challenging to localize.
Methods: We identified patients investigated for epilepsy surgery with unilateral FLE based on consistent semiology, a clear lesion and/or with frontal onset on intracranial EEG. A one hour section of postictal EEG was analyzed by two raters for new or activated EEG features and it was assessed whether these features offered additional information when compared to the ictal EEG. Postictal features assessed included asymmetrical return of the posterior dominant rhythm and potentiated lateralized or regional frontal slowing, spikes or sharp waves.
Results: Thirty-eight patients were included who had a combined total of ninety-six seizures. 47/96 (49%) postictal periods contained correctly lateralizing or localizing information. The sensitivity for asymmetrical return of the posterior dominant rhythm was 24%. The sensitivity for regional frontal slow and frontal spikes was 23% and 20% respectively. Further analysis showed that in 14/38 (39%) patients, at least one seizure with an unhelpful ictal EEG was followed by postictal EEG features that added new localizing or lateralizing information. A subgroup of 11 patients who were $\geqslant$1 year seizure-free (ILAE class 1) and thus classified as having a 'gold-standard' FLE diagnosis were analyzed separately and it was found that 14/30 of their seizures (47%) had extra postictal information.
Conclusions: The new postictal information was always concordant with the ultimate diagnosis, except for asymmetric postictal return of background activity ipsilateral to the epileptogenic zone in three patients.
Significance: This study shows that a close examination of the postictal EEG can offer additional information which can contribute to the identification of a potentially resectable epileptogenic zone.
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1. Introduction

The ictal and interictal EEG in frontal lobe epilepsy (FLE) is challenging and unreliable. The ictal EEG is localizing in less than one third of patients (Laskowitz et al., 1995) and may otherwise be

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generalised, obscured by muscle and movement artefact or mislocalise to the temporal lobe or opposite hemisphere (Bagla and Skidmore, 2011). The interictal epileptiform abnormalities in FLE can be bilateral, multilobar or generalized (Laskowitz et al., 1995). Studies have shown that the postictal EEG can provide additional information reflecting the seizure onset zone (So and Blume, 2010; Kaibara and Blume, 1988). In FLE, the value of localizing or lateralizing features in the postictal EEG could be particularly high in the context of the challenging features of these epilepsies described above. However, no large study has explored the value of the postictal EEG in this patient group, although studies have explored its utility in temporal lobe epilepsy (TLE) (Jan et al., 2001; Kaibara and Blume, 1988; Gotman and Koffler, 1989). Jan et al. (2001) showed that, in a pre-surgical population, 64% of focal TL seizures were followed by postictal lateralized polymorphic delta activity. This postictal feature, when present, was able to predict side of surgery with 96% accuracy, with reviewers blinded to the ictal EEG or clinical details. However, although outcome data was presented, the data was not analyzed separately for the subpopulation of patients who became seizure-free. In one study (Kaibara and Blume, 1988) postictal regional delta activity was seen in 57% of all seizures recorded. Postictal EEG depression was bilateral in half of the seizures, but always persisted longer on the side of seizure origin. Thus, lateralization of postictal disturbance was ipsilateral to the side of seizure onset in all 35 cases studied. Twenty-five percent of seizures were followed by activation of spikes over the lobe of onset. In 86% of these patients' postictal slowing was also 'parasagittal'. The seizure onset zone in this study was defined based on ictal EEG changes while there is no reference to concordant semiology or lesion.

A single study of 9 patients with FLE examined a ten minute postictal period and found regional activation of spikes in 1/9 patients (Bautista et al., 1998). However, as the average time interval for the EEG to return to baseline after FL seizures is 35 min (Arkilo et al., 2013), assessing a longer period may provide further information.

This study was concerned with assessment of the post-ictal EEG in a well-defined FLE cohort to determine whether any changes observed add localizing or lateralizing value compared to the ictal EEG. If this were the case, the contribution of the postictal phase may add valuable information to enhance confidence in lateralizing and localizing challenging frontal lobe epilepsies.

2. Methods

The telemetry database at the National Hospital for Neurology, a quaternary referral centre, was searched from 1st January 2008 to 21st December 2012. We included pre-surgical patients with unilateral FLE based on consistent semiology and either a clear FL lesion and/or with intracranial proven frontal onset. All patients had been discussed in the pre-surgical multi-disciplinary team meeting and their imaging, neuropsychometry and other data were found to be concordant with the lobar classification of their epilepsy.

Up to five seizures were included for each patient with the longest seizures chosen first. Seizures had to be associated with objective clinical signs (loss of awareness and/or positive or negative motor signs). All seizures had to be followed by at least one hour of EEG without seizures. The last seizure of a cluster was included in some cases. Patients with previous craniotomy and a breach rhythm were included because the study only focused on additional postictal changes, when compared to the patient's EEG baseline. Seizures treated with a benzodiazepine were included in the analysis of all postictal features except for spike analysis because Diazepam significantly suppresses interictal spikes (Duncan, 1987).

Classification of the ictal EEG was based upon accepted criteria (Foldvary et al., 2001) with minor modifications:

1. Generalized/non-lateralized: activity involving multiple electrodes over both hemispheres equally; non-localisable and symmetrical bifronto-central patterns were also included in this category.
2. Lateralized: activity involving multiple electrodes over two or more lobes of a single hemisphere; frontotemporal patterns were included in this category.
3. Regional frontal: activity with a clear maximum in electrodes of one frontal lobe.

As this paper focuses on FLE, we added one additional category: regional vertex (i.e. non-lateralized) (Table 1). The addition of this 'regional vertex' category reflects the localizing (but not lateralizing) value of a focal ictal pattern at the vertex which would otherwise have had to fall within the less localizing category of 'bifrontocentral'. 'Regional vertex' is a descriptive terminology frequently used within our pre-surgical EEG telemetry reports.

Table 1
Demographic information.

Patients (n = 38)	
Age (mean)	36 years (range 17–59)
Gender	15 F; 23 M
Previous craniotomy	9/38
Lesion on MRI	32/38 FCD (17); DNET or other low grade tumor (8); vascular insult (4); cerebral contusion (1); cavernous haemangioma (1); abscess (1)
Intracranial investigation (proven unilateral FL onset)	27/38 (all 6 without a lesion and 21/32 with a lesion)
Seizures (n = 96)	
Seizures treated with a benzodiazepine	5
Clinical seizure type	Complex motor (31); tonic (25); automotor (17); GTCS (9); hypermotor (8); clonic (2); head versive (2); dialeptic (2)*
Clinical seizure duration (median and range)[a]	35 s (range 6–676)
EEG seizure duration (median and range)[a]	40 s (range 6–1800)
Ictal EEG in the 96 seizures	Regional frontal (31); lateralized (21); generalized (24); bifrontocentral with side emphasis (11); regional vertex (9)

[a] In the case of post-ictal analysis of the last seizure of a cluster, clinical and EEG seizure duration reflects the duration from the first to the last seizure of the cluster.

* Classified using semiological seizure classification (Lüders et al., 1999).

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