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Prognostic value of the second ictal intracranial pattern for the outcome of epilepsy surgery

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HIGHLIGHTS

- The prognostic value of ictal patterns depends on where they occur within the seizure.
- More widespread second ictal patterns are associated with poorer outcome.
- Delayed second ictal patterns ($\geqslant 10$ s) appear to be associated with good outcome in temporal lobe epilepsy.

ABSTRACT

Objective: To investigate the prognostic value of the second ictal pattern (SIP) that follows the first ictal pattern (FIP) seen at seizure onset in order to predict seizure control after epilepsy surgery.
Methods: SIPs were analysed in 344 electro-clinical and subclinical seizures recorded with intracranial electrodes in 63 patients. SIPs were classified as (a) electrodecremental event (EDE); (b) fast activity (FA); (c) runs of spikes; (d) spike-wave activity; (e) sharp waves; (f) alpha activity; (g) delta activity and (h) theta activity. Engel surgical outcome scale was used.
Results: The mean follow-up period was 42.1 months (SD = 30.1). EDE was the most common SIP seen (41%), followed by FA (19%), spike-wave activity (18%), alpha activity (8%), sharp-wave activity (8%), delta activity (3%), runs of spikes (2%) and theta activity (2%). EDE as SIP was associated with favourable outcome when compared with FA ($p = 0.0044$) whereas FA was associated with poor outcome when compared with any other pattern ($p = 0.0389$). FA as SIP tends to occur after EDE (75%) whereas EDE tends to evolve from a FIP containing FA (77%). SIP extent was focal in 46% of patients, lobar in 24%, multilobar in 14% and bilateral in 16%. There is a gradual decrease in the proportion of Engel grade I with the extent of SIP. Focal and delayed (in temporal lobe epilepsy) SIPs appear to be associated with better outcome.
Conclusions: As SIP, EDE was associated with favourable surgical outcome whereas FA was associated with poor outcome, probably because outcome is dominated by FIP.
Significance: EDE as SIP should not discourage surgery. However, FA as SIP should be contemplated with caution. SIP focality and latency can have prognostic value in epilepsy surgery.

1. Introduction

Approximately 50% of patients undergoing ressective surgery for the treatment of epilepsy continue suffering from seizures after surgery (Kumar et al., 2013) despite the variety of techniques

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available to identify the epileptogenic zone preoperatively, including interictal and ictal scalp electroencephalography (Adachi et al., 1998; Alarcon et al., 2001), neuropsychology (Akanuma et al., 2003) and neuroimaging (Koutroumanidis et al., 2004; Duncan, 2010).

Approximately 30% of patients assessed for surgery require assessment with intracranial electrodes for the identification of the epileptogenic zone (Alarcon et al., 2006; Kumar et al., 2013). Although intracranial recordings can show a wide variety of interictal abnormalities (Alarcon et al., 1994, 1995, 2012; Fernandez Torre et al., 1999a,b; Kutsy et al., 1999; Kissani et al., 2001; Flanagan et al., 2009) with various degrees of localising value (Valentin et al., 2014), ictal findings are still the gold standard in the interpretation of the intracranial recordings.

The onset of focal seizures can be associated with a variety of sustained, evolving EEG patterns which may show different prognostic values for predicting seizure freedom after surgery (Alarcon et al., 1995; Jung et al., 1999; Holtkamp et al., 2012; Dolezalova et al., 2013; Jimenez-Jimenez et al., 2015b). As the first ictal pattern (FIP), focal fast activity (FA) is associated with favourable outcome whereas diffuse EEG flattening tends to be associated with poor seizure control. In temporal lobe epilepsy, the poor seizure control associated with such diffuse FIP is not explained by the presence of bilateral functional temporal connections (Jimenez-Jimenez et al., 2015a). Ictal activity is sustained, lasting for several seconds or minutes, with ictal patterns often evolving or spreading as the seizure propagates and recruits further cortex. The patterns arising are of various nature and often complex, with FA followed by diffuse EEG flattening or vice versa, or both occurring simultaneously (Jimenez-Jimenez et al., 2015b), or FA evolving over seconds, gradually decreasing in frequency and increasing in amplitude (rhythmic ictal transformation) (Alarcon et al., 2012). In scalp recordings, unilateral delayed rhythmic activity occurring seconds after seizure onset has a 79% lateralising value, even in the absence of a focal ictal onset on the scalp EEG (Alarcon et al., 2012). The latency of seizure propagation may also influence surgical outcome. In temporal lobe epilepsy, interhemispheric propagation time shorter than 5 s was associated with poor outcome whereas propagation times longer than 50 s were associated with good seizure control (Lieb et al., 1986).

The prognostic significance of specific ictal patterns occurring after FIP in intracranial recordings is largely unknown. Our hypothesis is that the second ictal pattern (SIP) is related to the mechanisms involved in seizure spreading and affects surgical prognosis. In the present work, we investigate the prognostic value of the nature, latency and extent of SIP occurring after the FIP seen at seizure onset.

2. Methodology

2.1. Patients

The study included all 63 patients who underwent assessment with intracranial electrodes prior resective surgery for the treatment of epilepsy at King's College Hospital from November 1999 to December 2010, who had a follow up period longer than 12 months.

The study excluded the patients who: (a) had no seizures during telemetry (1 patient), (b) underwent hemispherectomy for the treatment of Rasmussen Disease (1 patient), (c) were assessed for reoperation after failure of the first operation (3 patients), (d) presented only subclinical seizures with no SIP (1 patient).

Under UK regulations, no NHS Research Ethics Committee approval was required under section 6 of the Governance Arrangements for Research Ethics Committees (September 2011). The Neuroscience Audit Committee at King's College Hospital has approved this study.

2.2. Electrode placement

The type, number and location of the electrodes were determined by the suspected location of the ictal onset region, according to non-invasive evaluation: clinical history, scalp EEG recordings obtained with the Maudsley system (Fernandez Torre et al., 1999b; Alarcon et al., 2001; Kissani et al., 2001), neuropsychology (Akanuma et al., 2003) and neuroimaging. The selection criteria and implantation procedures have been described in detail elsewhere (Alarcon et al., 2006; Alarcon, 2012).

2.2.1. Subdural electrodes

Subdural electrodes consisted of strips and mats (AdTech Medical Instruments Corp., WI, USA). Each strip consisted of a single row of 4–8 platinum disk electrodes spaced at 10 mm between centres. The disks were embedded in a 0.7 mm thick polyurethane strip which overlapped the edges leaving a diameter of 2.3 mm exposed, and recessed approximately 0.1 mm from the surface plane. Mats contained rectangular arrays of 12, 16, 20, 32 or 64 similar platinum electrodes with 10 mm centre-to-centre distances within rows.

2.2.2. Intracerebral (depth) electrodes

Multicontact flexible bundles of depth electrodes (AdTech Medical Instruments Corp., WI, USA) were implanted stereotactically under MRI guidance. The electrode bundles contained 8 or 10 cylindrical 2.3 mm long platinum contacts separated by 5 mm between centres of adjacent electrodes of the same bundle.

The position of the electrodes was confirmed with post-implantation CT or MRI.

2.3. Electroencephalographic recordings

Recording of intracranial EEG started when the patient had recovered from electrode implantation, usually 24–48 h after surgery. Cable telemetry with up to 64 recording channels was used for data acquisition with simultaneous video monitoring. In 29 patients, the Telefactor Beehive-Beekeeper system (Astro-Med, RI, USA) was used. Data were digitized at 200 Hz and band pass filtered (high pass cut-off frequency at 0.3 Hz and low pass cut-off frequency at 70 Hz). The system input range was 2 mV and data were digitized with a 12 bit analog-to-digital converter (amplitude resolution of 0.488 μV). In the remaining 34 patients, a Medelec-Profile system was used (Medelec, Oxford Instruments, United Kingdom). Data were digitized at 256 Hz and band pass filtered (0.05–70 Hz). The input range was 10 mV and data were digitized with a 22 bit analog-to-digital converter (an amplitude resolution of 0.153 μV). Data were recorded as common reference to Pz or to an intracranial electrode, and displayed in a variety of montages including various scalp, intracranial and average common references to identify the most inactive reference for review in each patient. When common average reference was used, channels showing large spikes or artifacts or responses were removed from the average.

2.4. SIP analysis

The study included 344 seizures (336 clinical and 8 subclinical) recorded from all 63 patients. Visual analysis of the pruned ictal recordings was carried out to identify FIPs and SIPs. As FIP we consider the first sustained ictal change observed at the beginning of seizures recorded in at least one channel, i.e. the patterns previously designated as "sustained ictal onset patterns"