Clinical Neurophysiology 126 (2015) 257–267

Contents lists available at ScienceDirect

Clinical Neurophysiology

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

Prognostic value of intracranial seizure onset patterns for surgical outcome of the treatment of epilepsy

Diego Jiménez-Jiménez [a,b,c], Ramesh Nekkare [a], Lorena Flores [a], Katerina Chatzidimou [a], Istvan Bodi [d], Mrinalini Honavar [d,g], Nandini Mullatti [b], Robert D.C. Elwes [b], Richard P. Selway [e], Antonio Valentín [a,b,1], Gonzalo Alarcón [a,b,f,*,1]

[a] Department of Clinical Neuroscience, King's College London, Institute of Psychiatry, UK
[b] Department of Clinical Neurophysiology, King's College Hospital NHS Trust, London, UK
[c] Universidad San Francisco de Quito, School of Medicine, Quito, Ecuador
[d] Department of Neuropathology, King's College Hospital NHS Trust, London, UK
[e] Department of Neurosurgery, King's College Hospital NHS Trust, London, UK
[f] Departamento de Fisiología, Facultad de Medicina, Universidad Complutense, Madrid, Spain
[g] Serviço de Anatomia Patológica, Hospital Pedro Hispano, Matosinhos, Portugal

See Editorial, pages 221–222

ARTICLE INFO

Article history:
Accepted 2 June 2014
Available online 23 June 2014

Keywords:
Intracranial EEG
Invasive recordings
Seizure onset
Epilepsy surgery
Surgical outcome

HIGHLIGHTS

- Focal fast activity at onset was associated with favourable postsurgical outcome.
- Diffuse electrodecremental event at onset was associated with poor outcome.
- A preceding focal, widespread or bilateral epileptiform discharge was not associated with either favourable or poor outcome.

ABSTRACT

Objective: To investigate if intracranial EEG patterns at seizure onset can predict surgical outcome.
Methods: Ictal onset patterns from intracranial EEG were analysed in 373 electro-clinical seizures and subclinical seizures from 69 patients. Seizure onset patterns were classified as: (a) Diffuse electrodecremental (DEE); (b) Focal fast activity (FA); (c) Simultaneous onset of fast activity and diffuse electrodecremental event (FA-DEE); (d) Spikes; (e) Spike-wave activity; (f) Sharp waves; (g) Alpha activity; (h) Delta activity. Presence of preceding epileptiform discharge (PED) was also studied. Engel and ILAE surgical outcome scales were used.
Results: The mean follow-up period was 42.1 months (SD = 30.1). Fast activity was the most common seizure onset pattern seen (33%), followed by (FA-DEE) (20%), DEE (19%), spike-wave activity (12%), sharp-waves (6%), alpha activity (6%), delta activity (3%) and spikes (1%). Preceding epileptiform discharges were present in 75% of patients. FA was associated with favourable outcome ($p = 0.0083$) whereas DEE was associated with poor outcome ($p = 0.0025$). A widespread PED was not associated with poor outcome ($p = 0.9559$). There was no clear association between seizure onset pattern and specific pathology, except possibly between sharp/spike waves and mesial temporal sclerosis.

* Corresponding author at: Department of Clinical Neuroscience, Institute of Psychiatry, King's College London, P.O. Box 43, De Crespigny Park, London SE5 8AF, UK. Tel.: +44 207 848 5161; fax: +44 207 848 0988.
E-mail address: gonzalo.alarcon@kcl.ac.uk (G. Alarcón).
[1] Drs. A. Valentín and G. Alarcón are joint senior authors.

http://dx.doi.org/10.1016/j.clinph.2014.06.005

Conclusions: FA activity is associated with favourable outcome. DEE at onset was associated with poor surgical outcome. Widespread/bilateral PEDs were not associated with poor or good outcome.
Significance: FA appears to be the best marker for the epileptogenic zone. Surgery should be contemplated with caution if DEE is the first ictal change. However, a widespread/bilateral PED at onset is common and should not discourage surgery.

1. Introduction

Resective surgery can achieve seizure freedom in 40% to 70% of patients with drug-resistant epilepsy (Wiebe et al., 2001; de Tisi et al., 2011; Kumar et al., 2013). Successful outcome of surgery depends on accurate identification of the epileptogenic zone (Engel et al., 1993; Luders et al., 2006; Jette and Wiebe, 2013). At present, a variety of non-invasive techniques are initially used to identify the epileptogenic zone, including interictal and ictal scalp electroencephalography (Adachi et al., 1998; Alarcon et al., 2001, 2012b), neuroimaging (Koutroumanidis et al., 2004; Duncan, 2010) and neuropsychology (Akanuma et al., 2003). However, in approximately 25% of patients assessed for surgery, non-invasive techniques are non-localising or non-concordant, and assessment with intracranial electrodes may be necessary to identify the epileptogenic zone (Alarcon et al., 2006).

The EEG recorded with intracranial electrodes shows larger amplitude and less muscle artefacts than the scalp EEG. In addition, intracranial recordings show a wider variety of interictal and ictal abnormalities than the scalp EEG (Fernandez Torre et al., 1999b; Kissani et al., 2001) not necessarily restricted to the ictal onset zone (Alarcon et al., 1995; Fernandez Torre et al., 1999a; Kissani et al., 2001). Interictal slowing of the background activity occur at or around the area of seizure onset in around 80% of patients assessed with chronic intracranial recordings (Valentin et al., 2014). In 40–100% of patients, spontaneous interictal epileptiform discharges occur independently at the seizure onset zone and elsewhere, including contralateral cortex (Alarcon et al., 1994; Fernandez Torre et al., 1999b).

Despite the presence of interictal abnormalities, the interpretation of chronic intracranial recordings still heavily relies on the identification of the ictal onset zone, i.e., the area where seizures start on intracranial recordings. A difficulty arises from the fact that the onset of focal seizures can be associated with a variety of EEG patterns, which are not necessarily focal in distribution (Alarcon et al., 1995). Approximately two thirds of focal seizures start with a run of focal fast activity, sharp waves, spikes or slow waves lasting for a few seconds (Alarcon et al., 1995). However, in one third of seizures, focal changes are preceded by more widespread patterns, such as a diffuse attenuation of the background activity (diffuse electrodecremental event or DEE) (Alarcon et al., 1995). In many human recordings, these sustained ictal changes are immediately preceded by a single epileptiform discharge (preceding epileptiform discharge, or PED), which can show a widespread or bilateral distribution and is associated with a prominent slow wave. A similar phenomenon described as "leading spike" has been reported in 15 children with epileptic spasms (Asano et al., 2005). Although PEDs are transitory phenomena resembling interictal activity, their association with seizures is obvious, as they consistently occur immediately preceding the onset of the more sustained ictal patterns described above. The physiological and clinical significance of such widespread changes at seizure onset in focal epilepsy are unclear.

To simplify wording throughout the paper, the ictal onset patterns which typically last for several seconds (DEE and runs of focal fast activity, sharp waves, spikes or slow waves) will be generically designated as "sustained ictal onset patterns" (SIOP). PEDs can precede any type of SIOP and consequently will be analysed separately. The term "seizure onset patterns" will include SIOPs and PEDs.

To the best of our knowledge, the prognostic significance of PEDs has not been reported in focal epilepsies. Its removal is associated with favourable outcome in infantile spasms (Asano et al., 2005). Several authors have studied the value of intracranial SIOPs to predict surgical outcome (Lieb et al., 1986; Spencer et al., 1992; Alarcon et al., 1995; Jung et al., 1999; Kutsy et al., 1999; Lee et al., 2000; Zaatreh et al., 2003; Wetjen et al., 2009; Holtkamp et al., 2012; Dolezalova et al., 2013). These studies suggest that the presence of focal fast activity at seizure onset appears to be associated with seizure relief after resective surgery. However, the prognostic value of the more widespread SIOPs is unclear. DEE is one of the most common SIOP, occurring in as many as 60% of patients assessed with intracranial electrodes (Alarcon et al., 1995; Zaatreh et al., 2003; Perucca et al., 2013) and is the first SIOP in about a third of seizures recorded with intracranial electrodes (Alarcon et al., 1995). Early studies on a very limited number of cases suggested that the presence of DEE does not significantly affect surgical outcome (Alarcon et al., 1995). Unfortunately, larger studies on the prognostic value of ictal onset patterns have not usually included DEE in their analysis (Spencer et al., 1992; Lee et al., 2000; Wetjen et al., 2009; Holtkamp et al., 2012; Park et al., 2012). One publication suggested that the presence of DEE may be associated with poor surgical outcome in temporal lobe epilepsy (Dolezalova et al., 2013), and one abstract has reported that the same may occur in extratemporal epilepsy (Zaatreh et al., 2003).

In the present work, we study the prognostic value with regard to seizure control and pathology of the following intracranial seizure onset patterns: PED, DEE, runs of focal fast activity (FA), spikes, sharp waves, alpha or slow activity. We report a series of 69 consecutive patients undergoing resective surgery for the treatment of epilepsy, the largest study published to date, including temporal and extratemporal patients. We also analyse the prognostic significance of widespread and bilateral PEDs. Preliminary results have been published in abstract form (Jimenez-Jimenez et al., 2013).

2. Methods

2.1. Patients

The study initially included all 74 patients who underwent cortical resective surgery for the treatment of epilepsy after assessment with intracranial electrodes implanted at King's College Hospital between 08th of November 1999 and the 23th of December 2010 and had postsurgical follow-up of 12 months or longer. The following patients were excluded: (a) Patients who had no seizures during telemetry (1 patient), (b) Patients who underwent hemispherectomy for the treatment of Rasmussen Disease (1