Is the Hemodynamic Response to Scalp Interictal Epileptic Discharges the Onset Zone of Intracerebral Interictal Discharges?

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Presenter Disclosure

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• The brain region where interictal epileptic discharges (IEDs) are present in patients with focal epilepsy (the irritative zone), is often widespread and thus considered a poor marker of the epileptogenic zone.
• The fact that IEDs are often recorded at multiple brain regions with barely distinguishable latency suggested that IEDs could propagate rapidly across the cortex.
• Despite their observation that good surgical outcome was associated with removal of the brain regions where IEDs were originated, Jasper and Penfield noted the apparent impossibility to differentiate reliably the original IEDs (red spikes) and the propagated IEDs (green spikes).¹

¹ Penfield W, Jasper H. Epilepsy and the functional anatomy of the human brain. 1954
• EEG-fMRI of scalp IEDs is a non-invasive tool resulting in hemodynamic responses that can contribute to localize the generator of epileptic activity.
  • A few studies with small number of patients had found some correspondence between EEG-fMRI hemodynamic response and intracerebral IED but did not derived the general principle of correspondence.
  • Indeed, we have demonstrated that the maximum BOLD response often localizes the seizure onset zone defined by SEEG.
  • Removal of the maximum BOLD response was also correlated with good surgical outcome.

FULL-LENGTH ORIGINAL RESEARCH

Electroencephalography/functional magnetic resonance imaging responses help predict surgical outcome in focal epilepsy

Dongmei An, MD is a research fellow at Montreal Neurological Institute.


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We hypothesize that the maximum hemodynamic response to scalp IEDs reflects the region in which these widespread IEDs originated. We sought to determine if IED recorded close to the maximum EEG-fMRI hemodynamic response indeed correspond to the earliest IED during a widespread intracranial IED.

Objectives

Subjects/Materials

All patients with focal epilepsy that participated in EEG-fMRI studies (April 2006 - July 2017) and then underwent SEEG implantation
N=68

Patients excluded
• No IED during EEG-fMRI, N=18
• Technical issues, N=7
• No post-implantation imaging, N=3

Patients included
N=41

Each patient can have multiple studies

Studies
N=79

Studies excluded
• Closest channel located > 10 mm, N=41
• No significant BOLD response, N=12

Studies included
N=26

Each study can have up to two maxima

Maximum BOLD response analyzed
N=28
Methods
- To obtain averaged traces and latency

100-120 IEDs

Main channel

Channel $N-2$

Channel $N-1$

Channel $N$

Averaged traces of each channel

Latency

Amplitude ($\mu$V)

Time (ms)

Results

Example of interictal epileptic discharge (IED) recorded closest to the maximum hemodynamic response being the earliest.
Results

Example of interictal epileptic discharge (IED) recorded closest to the maximum hemodynamic response among the earliest.
Results

Latency between the IED of the first channel and the
(1) IED of the main channel;
(2) IED of any random channel

\[ \text{Main channel} \quad P = 0.00037 \]

\[ \text{Any random channel} \]

\[ P = 0.000048 \]

Permutation test (1 million repetitions)
Results

Distance between the BOLD maxima and location of (1) the main channel; (2) any random channel

Distance from BOLD maxima

- Main channel: 6.25 mm
- Any random channel: 29.6 mm
Results

Latency of an intracerebral IED is correlated to the distance between the location of its recording channel and the BOLD maximum.

The closer the channel is located to a BOLD maximum, the earlier the IED.
1. Widespread IEDs occur as the result of an IED originating in a small region and propagating within 20 to 50 ms over wide regions.

2. EEG-fMRI is a non-invasive tool that points to this region of IED origin, which we call the spike onset zone.
   - The IEDs recorded close to the EEG-fMRI maximum hemodynamic response are more likely to precede the IEDs recorded in remote locations.
   - The IED delay in a particular channel is correlated with distance of its location to the maximum response.

3. The spike onset zone found by EEG-fMRI is the neuronal source or origin of an IED.
   - It is different from the source obtained by EEG/MEG analysis of the instantaneous electrical field.
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