Intentional electrical stimulation (IES) during presurgical stereoencephalography (SfEEG) evaluation of patients with drug-resistant epilepsy is a powerful method for mapping the epileptic network. In order to facilitate the basic neural mechanisms underlying microscopic responses in SfEEG, our main objective is to investigate human single unit firing during intentional electrical stimulation of the SOZ in epilepsy.

The specific aims of this study are:

1. To examine the influence of epileptogenicity on microscopic and evoked cortical areas.
2. To evaluate the effects of the frequency of the stimulation pulses on the firing patterns and rates.
3. To delineate the main source of the firing during stimulation. Activity changes during stimulation have been shown to be associated with increased plasticity in the epileptic areas (Herrero et al., 2001).
4. To examine the involvement of the neuronal activity by the stimulation pulses.
5. To correlate the firing patterns of the neurons to be observed in response to the correspondence of stimulus and evoked cortical patterns. These include: i) delayed response (Balanescu et al., 2002), ii) high-frequency oscillations (just after the 2005/2010).

Methods

We performed a targeted premonitory evaluation of 12 patients with drug-resistant focal epilepsy to locate the seizure onset zone (SOZ) and delineate the epileptogenic territory.

Table 1: Types of patterns observed in the firing activity during stimulation. SOZ = Seizure Onset Zone.

<table>
<thead>
<tr>
<th>Pattern Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microscopic</td>
<td>Changes in the firing activity during stimulation.</td>
</tr>
<tr>
<td>Evoked</td>
<td>Changes in the firing activity after the stimulation pulse.</td>
</tr>
</tbody>
</table>

Figure 1. Illustration of the recording while stimulating, stimulus artifact removal and spike discrimination. a) the 100 ms time window used for the calculation of the stimulus artifact. b) the 250 ms time window used for the calculation of the spike discrimination.

Figure 2. Time-locked to the electrophysiological stimulation, individual neuronal activity and time-dimension of the trial in the evoked cortical response (ECR). a) Paired stimulation artifact removal. b) Paired spike discrimination artifact removal.

Figure 3. Time course of the stimulation artifact and spike discrimination artifact removal. a) Stimulus artifact removal for 100 ms. b) Spike discrimination artifact removal for 250 ms. The stimulation artifact removal is effective for the first 100 ms and the spike discrimination artifact removal is effective for the first 250 ms.

Table 2: Frequency and rates of single unit activity evoked by electrical stimulation of human epileptic cortex.

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
<th>Rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.01</td>
<td>0.05</td>
</tr>
<tr>
<td>0.05</td>
<td>0.10</td>
</tr>
<tr>
<td>0.10</td>
<td>0.15</td>
</tr>
<tr>
<td>0.20</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Figure 4. Correlation of single unit activity with time locking of evoked and evoked cortical patterns. a) Effects of evoked cortical patterns. b) Effects of evoked cortical patterns.

Results

We have monitored up to 30 neurons in SOZ and adjacent areas. We were able to find neural firing responses to evoke electrical stimulation on the frequency range (0.01 Hz, 0.05 Hz, 0.10 Hz, 0.20 Hz, 0.25 Hz). The modulation of neural firing was observed in all cases. The frequency range (0.01 Hz, 0.05 Hz, 0.10 Hz, 0.20 Hz, 0.25 Hz) was shown to be correlated with the epileptogenicity of the SOZ in epilepsy.

Conclusions

Time-locking is associated with pathological cortex.

- Only frequencies of 10 Hz and above result in significant time-locking.
- Higher frequencies (10 Hz) have an excitatory effect, particularly in pathological tissue.

This study highlights the firing rate properties of single units in epileptic cortex. The results have implications in understanding the basic mechanisms underlying epileptogenic networks and in modulating the neuronal activity through electrical stimulation.

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References


