Relationships between MRI anatomy and electrophysiological spontaneous recordings in the subthalamic region during stereotactic surgery for Severe Idiopathic Parkinson’s disease.

Jérôme COSTE ¹,⁴; Séverine SIADOUX ²; Philippe DEROST ³; Frank DURIF ³; Jean GABRILLARGUES ²; Simone HEMM ⁵ and Jean-Jacques LEMAIRE ¹,⁵.

¹ Service de Neurochirurgie A, ² Service de Radiologie A, ³ Service de Neurologie, CHU de Clermont Ferrand, Université d’Auvergne

⁴ Laboratoire de Neurobiologie de la Douleur Trigéminale (INSERM E216)

⁵ Equipe de Recherche en Imagerie Médicale (Erim INSERM-ERI 14)
Question

Accuracy of the « electrophysiological mapping » to identify the structures during DBS ?

→ to confront electrophysiology with imaging based anatomy

Anatomical mapping

Electrophysiological mapping

STN
Material and Methods

Relationships between MRI anatomy and electrophysiological spontaneous recordings in the subthalamic region during stereotactic surgery for Severe Idiopathic Parkinson’s disease.
Direct targeting

1. Surrounding of the structures in the subthalamic area:

- SubThalamic Nucleus
- Substantia Nigra
- Rubral putamen
- Zona Incerta
- Red Nucleus
- Peri Rubral Area
- Forel’s Field (H1, H2)
- Para Ventricular Area
- Mamillo-Thalamic Bundle

2. Choice of two trajectories per side, separated by 2mm
Exploration electrode

- Stimulation: 1.2mm
- Impedance: 0.3 – 1.0 MΩ
- Recording: 0.50mm, 25µm, 100µm
Recording protocol

- systematic recording (10mm, 0.5mm step)
- of spontaneous activity
- without searching to isolate neurons
- on 2 trajectories simultaneously (Central and 2mm Anterior)
- during 30 seconds / position

• on-line description
• off-line analysis
<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Waveform</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Isolated discharge</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Low irregular activity</td>
<td></td>
<td>2A</td>
</tr>
<tr>
<td>Irregular activity</td>
<td></td>
<td>2B</td>
</tr>
<tr>
<td>High irregular activity</td>
<td></td>
<td>2C</td>
</tr>
<tr>
<td>Rhythmic activity</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Burst activity</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>High burst activity</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>Tonic activity</td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

On-line classification during surgery

STN DBS procedure
Off-line analyses

Pre processing (threshold) → Classification (PCA) → Analysis

[Graph showing time (sec) on the x-axis and frequency (Hz) on the y-axis, with a peak around 25 Hz at 20 sec.]
Stimulation

- Stimulation (10mm, 1mm step)
- 130 Hz, 0.06 msec
- intensity from 200 µA to 4 mA

- Threshold leading to a maximal clinical improvement
- Threshold leading to an adverse effect

- Stimulation = key point for DBS electrode placement
10 parkinsonians (mean age 62 yo)

38 trajectories (19 STN)
796 systematic recordings
336 neurons

Mean improvement on the motor score with stimulation ON (part III of UPDRS): 63.6%, p ≤ 0.001
Results

Relationships between MRI anatomy and electrophysiological spontaneous recordings in the subthalamic region during stereotactic surgery for Severe Idiopathic Parkinson’s disease.
On line classification

![Bar chart showing activity levels in different structures](chart.png)

- **Low activity**
- **High activity**

**Structures**
- Zona incerta
- ForelH2
- STNlat
- STNinter
- STNmed
- SN

**Percentage**
- 0%
- 50%
- 100%
Qualitative analysis

Neurons mean frequency

(Hz)

Zona incerta  ForelH2  STNlat  STNinter  STNmed  SN

Structures
Qualitative analysis

Number of bursts / min

Structures

- Zona incerta
- Forel H2
- STNlat
- STNinter
- STNmed
- SN
Quantitative analysis

Number of recordings with neuronal activity

Structures

- Zona incerta
- ForelH2
- STNlat
- STNinter
- STNmed
- SN

Number of recordings:
- Zona incerta: 15
- ForelH2: 20
- STNlat: 40
- STNinter: 25
- STNmed: 15
- SN: 30
Quantitative analysis

Number of recordings with neuronal activity/number of recordings

![Bar chart showing the number of recordings with neuronal activity for STNlat, STNinter, and STNmed.]
Relationships between MRI anatomy and electrophysiological spontaneous recordings in the subthalamic region during stereotactic surgery for Severe Idiopathic Parkinson’s disease.

Discussion
Result of the study: 17.64 2.24 Hz

<table>
<thead>
<tr>
<th>Study</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnin, Neuroscience 2000</td>
<td>41</td>
</tr>
<tr>
<td>Rodriguez-Oroz, Brain 2001</td>
<td>33.12</td>
</tr>
<tr>
<td>Benazzouz, Mov Disord 2002</td>
<td>42.30</td>
</tr>
<tr>
<td>Theodosopoulos, Mov Disord 2003</td>
<td>34</td>
</tr>
</tbody>
</table>

- Systematic recording is not isolation of neurons: this approach does not allow to optimize signal/noise ratio.
• Quite good relationships between MRI anatomy and electrophysiological spontaneous recordings in the subthalamic region during stereotactic surgery for Severe Idiopathic Parkinson’s disease:
  - on line classification: majority of low activity in white matter
  - neuronal mean frequency: continuous increase from ZI to SN
  - burst activity: in STN and SN
  - nb of recordings with spontaneous neuronal activity: lateral STN

• Others evaluations are required: evoked neuronal activity…

• But, per-operative clinical assessment with acute stimulation remains the key point for DBS electrode placement.
• Anatomical boundaries and unitary recordings seem to be linked.

• We found a slightly high number of spontaneously active neurons in the lateral STN which is also known as a good surgical target for DBS in severe PD.
I wish to thank all the members of the multidisciplinary team for movement disorder surgery and the associated research teams.

Thank you for your attention.