Interhemispheric Comparison of Globus Pallidus Interna and Cortical Local Field Potentials During Movement and Rest.

Nicholas Au Yong MD, PhD; Mahsa Malekmohammadi PhD candidate; Nader Pouratian MD PhD
David Geffen School of Medicine at UCLA
Neurosurgical Brain Mapping & Restoration Lab, Department of Neurosurgery

Introduction

Neurophysiological studies following Deep Brain Stimulation (DBS) electrode placement for subjects with Parkinson's Disease (PD) have largely focused on cortical and subcortical local field potentials (LFPs) within a single hemisphere. Such studies have demonstrated abnormal expression of beta "akinectic" (10–35 Hz) and gamma "prokinetic" (35–100 Hz) band oscillations within ipsilateral cortical and subcortical circuits (Ref. 1). In this study, interhemispheric comparison of beta and gamma band LFP modulation between bilateral globus pallidus interna (GPi) and right frontoparietal motor/premotor cortical LFPs was carried out during left hand self- paced grasping and rest.

Methods

Intraoperative LFPs were recorded from DBS electrodes bilaterally in the GPi and an electrocorticographic (ECog) strip overlying the right motor/premotor cortices in 9 subjects diagnosed with PD or dystonia (Ref. 2). Left hand activity was also captured via a sensor-embedded glove. GPi LFPs were obtained from the DBS lead's four ring electrode contacts (Medtronic, Model 3387, length 1.5mm, inter-contact distance 1.5mm) at their target coordinates for therapeutic stimulation. Unilateral LFP recordings in the Motor Cortex of the right hemisphere were obtained using a subdural ECoG strip (platinum-iridium 4 mm contacts with 1 cm spacing, AdTech Medical) with eight electrode contacts. Signal acquisition with a sampling rate of 2400 Hz was performed using BCI2000 v6.2 connected to an amplifier (g.Tec, g.USBamp 2.0) which, in turn, was connected to the DBS and ECog electrodes. Multi-taper power spectra and coherence estimates were analyzed between bilateral GPi and right cortical LFPs during periods of left hand grasping and rest.

Results

1. Beta power decreases in bilateral GPi and frontoparietal cortices during movement.

- Subjects exhibited prominent beta oscillations in bilateral GPi and contralateral cortex during periods of rest (Fig. 1).
- Average beta power within the contralateral GPi and frontoparietal cortex were 152.11 and 135.75 percent larger ($p<0.05$) respectively during periods of rest as compared to movement (Fig. 2 A&B).
- Average beta power within the ipsilateral GPi was moderately larger (28.51 percent; $p<0.05$) during periods of rest as compared to movement (Fig. 2C).

2. Gamma power increases in bilateral GPi and frontoparietal cortices during movement.

- Gamma oscillations within bilateral GPi and cortex were enhanced during periods of movement as compared to rest (Fig. 1)
- On average, gamma power within the contralateral GPi and frontopareital cortex increased 6.7 and 9.23 percent ($p<0.05$) respectively during periods of movement as compared to rest (Fig. 2 A&B).
- A smaller increase in the ipsilateral GPi gamma power (3.88 percent, $p<0.05$) is seen during periods of movement.

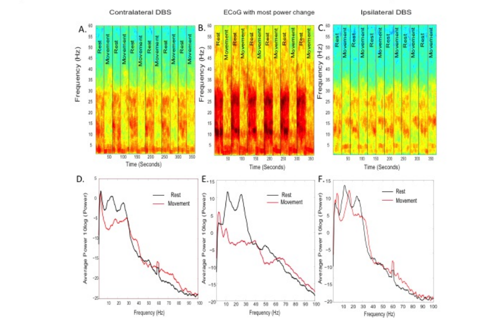
3. Movement-related modulation of beta oscillations within the contralateral GPi and frontoparietal cortex seen in PD subjects are not evident in dystonia.

- In LFPs recorded from one dystonia subject, beta oscillations in the contralateral GPi and frontoparietal cortex are persistent without modulation throughout the entire recorded session, but greatly diminished within the ipsilateral GPi (Fig 3).

4. There are no significant interhemispheric differences ($p>0.05$) in the beta and gamma coherence between bilateral GPi during movement and rest.

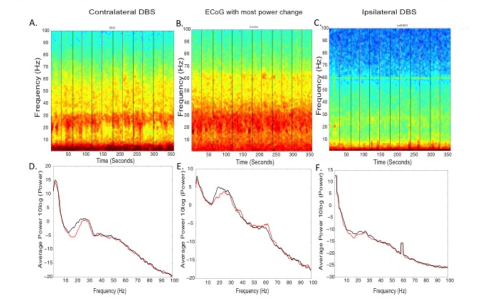
5. Contralateral pallidocortical beta coherence decreases (from 0.39 to 0.30, $p<0.05$) during periods of movement activity (Fig. 4)

Fig. 1 Movement-Related LFP Oscillations in Bilateral GPi and Contralateral Frontoparietal Cortex in PD.



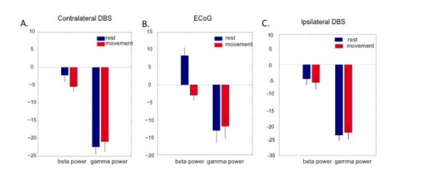
Examplary LFP spectrogram (0-60 Hz) from a single PD subject recorded within the A) contralateral GPi B) contralateral frontoparietal cortex and C) ipsilateral GPi during periods of left hand movement and rest, indicated by vertical lines. Corresponding LFP spectrum (0-100 Hz) from D) contralateral GPi E) contralateral frontoparietal cortex and F) ipsilateral GPi during periods of left hand movement (red trace) and rest (black trace).

Fig 3. LFP activity from Bilateral GPi and Contralateral Frontoparietal Cortex in a Dystonia Subject



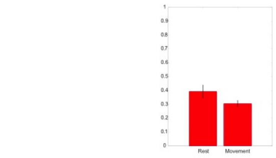
LFP spectrogram (0-60 Hz) from a single dystonia subject recorded within the A) contralateral GPi B) contralateral frontoparietal cortex and C) ipsilateral GPi during periods of left hand movement and rest, indicated by vertical lines. Corresponding LFP spectrum (0-100 Hz) from D) contralateral GPi E) contralateral frontoparietal cortex and F) ipsilateral GPi during periods of left hand movement (red trace) and rest (black trace).

Fig 2. Beta and Gamma Power Differences Between Periods of Movement and Rest



Mean and standard deviation of beta and gamma power during movement (red bar) and rest (blue bar) within the A) contralateral GPi B) contralateral frontoparietal cortex and C)ipsilateral GPi from PD subjects.

Fig. 4 Contralateral Corticopallidal Coherence During Rest and Movement



Mean and standard deviation of contralateral corticopallidal coherence during rest (left bar) and movement (right bar).

Conclusions

"Akinetic" beta oscillations were prominent in bilateral GPi and contralateral cortex during periods of rest.
Beta oscillations in the contralateral GPi and cortex were highly attenuated during phases of movement, but only moderately suppressed in the ipsilateral GPi.
"Prokinetic" gamma oscillations were prominent during periods of movement in bilateral GPi and contralateral frontoparietal cortex.
In contrast to PD, contralateral GPi and cortical beta oscillations in dystonia were persistent throughout the entire recorded session and markedly diminished within the ipsilateral GPi; possibly a neurophysiological signature of this disease.

Learning Objectives

By the conclusion of this session, participants should be able to: 1) Identify movement-related modulation of GPi and cortical LFP sub-bands and 2) Appreciate interhemispheric similarities and differences in LFP modulation.

References

1. Hammond, C., Bergman, H. & Brown, P. Pathological synchronization in Parkinson's disease: networks, models and treatments. Trends in Neurosciences 30, 357–364 (2007).
2. Tsiokos, C., Hu, X. & Pouratian, N. 200-300Hz movement modulated oscillations in the internal globus pallidus of patients with Parkinson's Disease. Neurobiology of Disease 54, 464–474 (2013).