

Functional Connections of Limbic Network in SEEG Operated Patients.

Rei Enatsu; Demitre Serletis MD, PhD, FRCSC; Juan Bulacio; Yuichi Kubota; Zhe Piao; John Mosher; Richard Burgess; Dileep Nair MD; Jorge Alvaro Gonzalez-Martinez MD PhD

Epilepsy Center, Department of Neurology, Department of Neurosurgery, Cleveland Clinic Foundation, Cleveland, OH, USA

Introduction

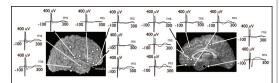
Papez proposed the memory and emotion associated network, which is termed limbic network. However, in vivo human limbic network has not been established. We investigate the connectivity of human limbic system using cortico-cortical evoked potential (CCEP), which reveals the brain networks.

Methods Patients

This retrospective analysis included 28 patients with medically intractable focal epilepsy who underwent stereoelectroencephalogram electrode implantation and CCEP.

CCEP analysis

Alternating 1 Hz electrical stimuli were delivered to the parts of limbic system [anterior and posterior hippocampus, amygdala, parahippocampal gyrus (PHG), anterior and posterior cingulate gyrus (ACG, PCG), medial and lateral orbitofrontal cortex(OF)]. A total of 40 -60 stimuli were averaged in each trial to obtain CCEP responses. CCEP distributions were evaluated by calculating the root mean square (RMS) of CCEP responses(1 ms slide, 15 ms to 300 ms).



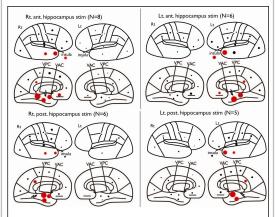
Examples of CCEP waveforms in the right anterior hippocampal stimulation.

Results

In order to illustrate the distribution of each activity, a circle map was employed based on the median value of RMS of all patients, in which the diameter of the circle at each electrode represented the value of RMS of CCEP activities.

Hippocampal stimulation

Anterior hippocampal stimulation elicited prominent CCEP responses (RMS >50) in ipsilateral medial and lateral temporal structures, PCG, medial OF and insula. On the other hand, posterior hippocampal stimulation induced CCEP responses in the ipsilateral medial, lateral temporal structures and PCG.



Circle maps of the median RMS of CCEPs in the anterior hippocampal stimulation.

Amygdala stimulation

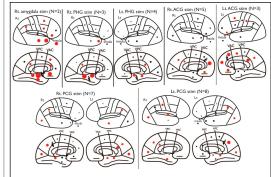
Amygdala stimulation induced CCEP responses in broad areas including the ipsilateral medial and lateral temporal structures, medial and lateral frontal areas, cingulate gyrus, insula and inferior parietal lobule.

Parahippocampal gyrus stimulation

In PHG stimulation, CCEPs were obtained in medial temporal structures and PCG.

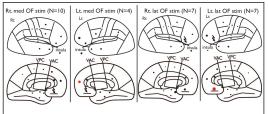
Cingulate stimulation

In ACG stimulations, CCEP responses were recorded from the ipsilateral medial frontal and medial parietal areas. In addition, left ACG stimulation induced broader CCEPs in additional areas, that included preSMA, SMA, lateral OF and dorsolateral PM, as compared to right ACG stimulation. PCG stimulation elicited bilateral CCEP responses in the medial temporo-parieto-occipital and lateral parieto-occipital areas.

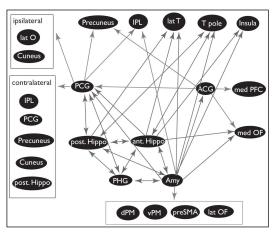


Circle maps in the amygdala, PHG and cingulate stimulation.

Orbitofrontal stimulation Medial and lateral OF stimulation induced responses in the adjacent cortices.



Circle maps in the OF stimulation.



Discussion

1. The anterior and posterior hippocampus had differential efferent connection patterns.

2. The amygdala showed the most extensive connections, which may reflect integrative information processing between

prefrontal/temporal association cortices and the hypothalamus.

3. ACG had connections to the ipsilateral medial fronto-parietal areas and more development of the network in the dominant hemisphere.

4. There was strong intra- and interhemispheric connections from PCG to the bilateral temporo-parietooccipital areas in our results.

5. OF stimulation induced responses only in the adjacent cortices, likely due to the restricted field of electrical stimulation in our study.

Conclusions

This finding supports the assertion that the limbic system has anatomical connectivity including intrinsic reverberating circuits and extrinsic output.