Diffusion-weighted magnetic resonance imaging is a feasible method to study cerebral signal processing during transcutaneous vagus nerve stimulation (t-VNS)

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Introduction

In order to address disadvantages of state-of-the-art vagus nerve stimulation (VNS) devices, a non-invasive transcutaneous vagus nerve stimulation (t-VNS) method was recently introduced. BOLD fMRI has previously demonstrated specific activations of higher order relay nuclei of vagal afferent pathways while undergoing t-VNS. This work studied the feasibility of using diffusion-weighted imaging (DWI) to study towards the mode-of-action of t-VNS.

Questions which were addressed:
- Are fMRI activated areas reasonable seed points for DWI tracking?
- Is multi diffusion weighted imaging a useful tool to show links between subcortical activations and higher cortical areas during t-VNS?

Methods

Subjects and stimulation
- 12 subjects - 11 males, 1 female (27.1 ± 5.1 years, mean ± SD)
- electrical stimulation of: N. Vagus, N. mentalis and N. trigeminus
- individual threshold determination for each stimulation site and subject

Experimental protocol

Anatomical setup:
- Application of electrical, non-painful stimuli to:
  a) N. vagus at the inner side of the tragus
  b) N. facialis close to the stylomastoid foramen
  c) origin of the N. mentalis above the mental foramen

fMRI - experimental setup:
- Application of transcutaneously electrical stimuli in a block design with 4 stimulus periods of 30 sec and alternating rest periods of 60 sec

fMRI data evaluation and further DTI analysis
- Standard pre-processing of the fMRI-EPI data
- Coregistration of fMRI-data to individual 3D-MPRAGE data and further transformation to Talairach-space
- GLM multi study with z-transformation and high statistical significance of activated clusters by p < 0.005
- Anatomical assignment of activated areas by averaged brain analysis with "Talairach Daemon" and with standard anatomical atlases
- Further details are presented in poster 346.1

For DTI-tracking a standard diffusion weighted data set of "BrainVoyager QX®" was used.

Transformation of DTI-data to Talairach-space and matching with transformed MPRAGE-data

Activated clusters of the fMRI analysis was used as seed-points for fiber tracking
- Tracking started at selected ROIs (table 1) of the t-VNS-experiment

Discussion of results

Left and right Thalamus:
BOLD-activations of the right and left thalamus could be tracked as thalamo-cortical projections to the gyral frontalis superior and to prefrontal cortex. A commissure between right and left thalamus and a projection to the ipsilateral cerebellar hemisphere was found.

Conclusions

In order to address disadvantages of state-of-the-art vagus nerve stimulation (VNS) devices, a non-invasive transcutaneous vagus nerve stimulation (t-VNS) method was recently introduced. BOLD fMRI of the left pontine tegmentum / regio locus coeruleus leads to ipsilateral nuclei of the thalamus and the prefrontal cortex and S1-cortex.

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