Preoperative mapping of the speech-eloquent areas with fMRI: comparison of different task designs

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Introduction

Mapping of brain speech areas is essential to resect brain tumors in those vicinity, since, in contrast to the classical concept of a constant localization, the position of these areas show large interindividual differences [1]. Moreover, the identification of the eloquent areas in patients can be impaired by cortical reorganization as well as by lack of anatomical landmarks, especially due to space-occupying lesions. Functional magnetic resonance imaging (fMRI) has proved to be a valid method to identify speech-eloquent regions [2]. Motion artifacts, limited compliance, and cognitive deficits however usually complicate the implementation of fMRI studies by patients, so that the task design should be short and simple. Aim of this study was to evaluate different paradigms to robustly localize Broca's and Wernicke's areas for clinical applications.

Material and Methods

Ten patients with supratentorial brain tumors were included in the study, after written informed consent approved by the local ethics committee. Three different paradigms were tested: 1) generation of an appropriate verb/adjective (VG), fitting to a given substantive (ex. 'window' – 'open'), 2) generation of words beginning with a given alphabetic character (WG), 3) enumeration of months (ME). A blocked-design protocol was used, consisting of 80 volumes, with 4 intervals (10 volumes) of paradigm execution alternated by 4 intervals (10 volumes) of rest. Images were acquired on a 1.5 T MR scanner (Symphony, Siemens Medical Solutions, Germany). Multiple T1-weighted anatomical scans were collected, including a whole-brain sagittal 3D data set (FLASH, 256x256x192, 1.0 mm slice thickness), and a set of sagittal slices corresponding to the locations of the functional scans. Functional images based on the BOLD contrast method were acquired with a T2*-weighted echoplanar sequence (EPI, 20 slices, 64x64 matrix, 22 cm FOV, 4 mm slice thickness, 1 mm gap, TR/TE=2600/50 ms). To minimize head movement artifacts a prospective motion correction (PACE, Siemens Medical Solutions) was used; in addition, the patients were asked to perform the task silently, avoiding mouth and tongue movement. The instructions were given acoustically through the headset intercom during the 800 ms interval between subsequent EPI scans. The functional image analysis and overlay procedures were performed using BrainVoyager® (Brain Innovation, Maastricht, The Netherlands). All image sets were corrected for linear trends, high frequency fluctuations, and motion; a spatial Gauss filtering (σ=8 mm) was applied. The first two volume scans of each series were discarded to eliminate T1 saturation effects. fMRI data were analyzed by correlating the measured MR-signal time course voxelwise with the supplied reference function using general linear model (GLM) after correcting each image set for the delay of the hemodynamic response. The volumes of the activated clusters were calculated for each patient. The center of gravity of the cluster was determined by choosing a relative small confidence range with high maximum and minimum value. Then, all voxels with in a confidence range 3.5-8.0 were included in the computation of the cluster volumes.

Results

All the patients understood quickly the instructions for task execution; no study needed to be interrupted due to patients unease. All the tested paradigms allow the localization of the Broca's area; however, the volume of the activation clusters showed a significant dependence on the executed task; the largest activation was observed by performing paradigm VG, the smallest by paradigm ME. The Wernicke's area could be localized by both paradigms VG and WG, but not by paradigm ME. The volume of the activated cluster was also in this case significantly higher when performing paradigm VG.

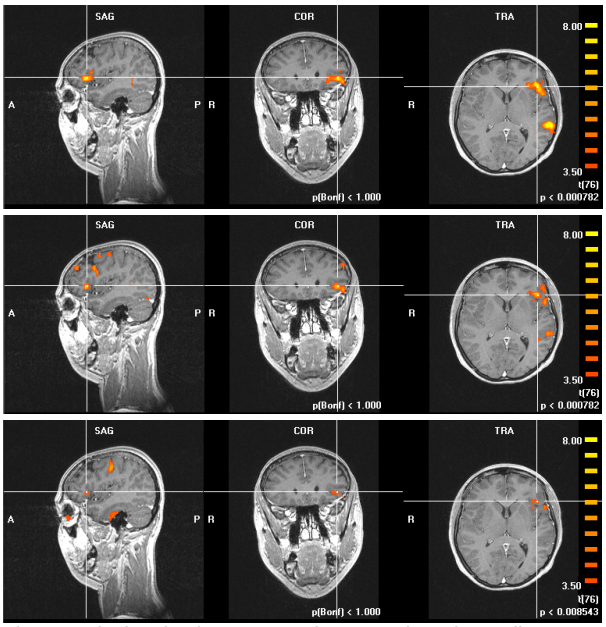

Fig 1: Typical activation patterns by execution of paradigms VG (upper panel), WG (middle panel), and ME (bottom panel).

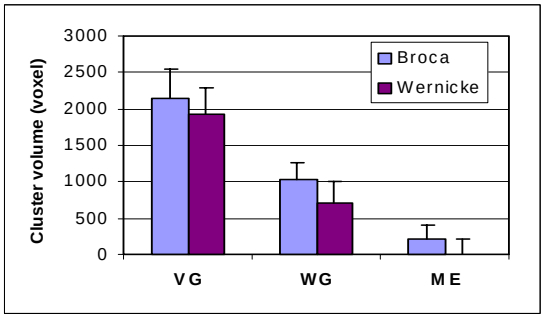

Fig. 2: Mean volumes of the activation clusters as a function of paradigm.

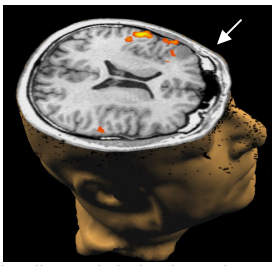

Fig. 3: Low grade glioma inferior frontal gyrus near Broca's area.

Discussion

All the three presented clinical fMRI protocols for the localization of the speech-eloquent areas can be implemented in a standard MR unit, and do not require special equipment. Between the tested task designs, the paradigm "verb generation" (VG) showed the best performance, allowing a robust visualization of both the Broca's and Wernicke's area. This paradigm can thus be recommended for the preoperative mapping of the cortical language representation in patients with brain tumors.

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[2] C Stippich, J Mohammed, B Kress, S Hähnel, J Günther, F Konrad, K Sartor, Neurosc. Lett 2003; 346:109-13.