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Original research article

Reorganization of language centers in patients with brain tumors located in eloquent speech areas – A pre- and postoperative preliminary fMRI study

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ARTICLE INFO

Article history:
Received 2 August 2016
Accepted 6 July 2017
Available online xxx

Keywords:
Language
Functional magnetic resonance imaging
Brain mapping

ABSTRACT

Introduction: The aim of this study was to determine in pre- and postsurgical fMRI studies the rearrangement of the Broca's and Wernicke's areas and the lateralization index for these areas in patients with brain tumors located near speech centers. Impact of the surgical treatment on the brain plasticity was evaluated.

Materials and methods: Pre- and postoperative fMRI examinations were performed in 10 patients with low grade glial, left-sided brain tumors located close to the Broca's (5 patients) or Wernicke's area (5 patients). BOLD signal was recorded in regions of interest: Broca's and Wernicke's areas, and their anatomic right-sided homologues.

Results: In the preoperative fMRI study the left Broca's area was activated in all cases. The right Broca's area was activated in all the patients with no speech disorders. In the postoperative fMRI the activation of both Broca's areas increased in two cases. In other two cases activation of one of the Broca's area increased along with the decrease in the contralateral hemisphere.

In all patients with temporal lobe tumors, the right Wernicke's area was activated in the pre- and postsurgical fMRI. After the operation, in two patients with speech disorder, the activation of both Broca's areas decreased and the activation of one of the Wernicke's areas increased.

Conclusions: In the cases of tumors localized near the left Broca's area, a transfer of the function to the healthy hemisphere seems to take place. Resection of tumors located near Broca's or Wernicke's areas may lead to relocation of the brain language centers.

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http://dx.doi.org/10.1016/j.pjnns.2017.07.010

Please cite this article in press as: Gębska-Kośla K, et al. Reorganization of language centers in patients with brain tumors located in eloquent speech areas – A pre- and postoperative preliminary fMRI study. Neurol Neurochir Pol (2017), http://dx.doi.org/10.1016/j.pjnns.2017.07.010

1. Introduction

Treatment of the brain tumors localized near language areas remains a real challenge. Surgical excision of these tumors frequently leads to the irreversible speech impairment. The electrical cortical mapping (ECM) is still accepted as a gold standard of intraoperative localization the language centers. However, it is invasive and time-consuming [1–4]. Moreover, some behavioral responses triggered during surgery do not provide relation between electrical stimulation and the function of the stimulated area [5].

In an attempt to overcome these limitations, functional magnetic resonance (fMRI) becomes a tool of increasing importance enabling safe presurgical determination of both speech centers' position and language lateralization. It can answer the question whether and how speech areas are displaced due to the presence of a tumor. FMRI studies provide better understanding of brain plasticity and may predict clinical and functional outcome of the surgery. Nevertheless, the quoted sensitivity and specificity of fMRI compared to electrical stimulation is 66% and 90% respectively. That is why fMRI protocols are not yet used alone to make critical surgical decisions [6–9].

The present study was undertaken in right-handed patients with low grade glial tumors, in an attempt to determine by means of fMRI examinations the functional reorganization of Broca's and Wernicke's areas before and after surgery

2. Materials and methods

2.1. Patients

The study protocol was approved by the local Commission of Bioethics: Decision no. RNN/123/09/KE. Ten patients with primary brain tumors were enrolled into the study – 5 men and 5 women, aged 22–55 years (median 35.5) according to the following criteria: (1) tumor located near the Broca's or Wernicke's area of the left hemisphere (2) right handedness of patients (3) neuropsychological status of patients allowing for planned, standardized procedures of fMRI. The right-handedness was defined on the base of the inventory test.

The patients were divided into two groups – one group consisted of 5 patients with tumors located in the frontal lobe and the other group of 5 patients with temporal lobe tumors. The distance between the eloquent brain areas and the tumor border was measured on the morphological, three-dimensional T1-weighted sequences with a mask based on functional activation. In all cases the distance was less than 2 cm.

The patients were operated on at the Department of Neurosurgery in 2010–2014 with intraoperative brain mapping performed in all the cases. All the patients underwent total or subtotal resection of the tumors. Histopathology showed 4 high grade gliomas, HGG: (three WHO IV and one WHO III) and 6 low-grade gliomas, LGG (5 WHO II and one WHO I). In each patient speech was assessed twice by the clinical neuropsychologist – before the preoperative and before postoperative fMRI. The patients data are summarized in Table 1.

Each patient had a preoperative and a postoperative fMRI performed at least 3 months after the operation.

2.2. FMRI study

2.2.1. MRI scanner

fMRI study was performed in all the patients using a 1.5 T scanner (Siemens, Avanto). Morphological, three-dimensional T1-weighted sequences were obtained according to the following protocol: FOV = 256 × 256 mm, matrix = 512 × 512, TR = 8.8 ms, TE = 4.8 ms, TA = 5′07. Each volume acquired contained 160 slices of 1 mm thick. The functional examination included echoplanar imaging (EPI) sequences: TR = 3000 ms, TE = 50 ms, FOV = 1680 × 1680 mm, matrix 64 × 64, TA = 5′11, thirty-eight 3 mm thick slices.

2.2.2. Data analysis

The analysis of the data was conducted using the statistical program SPM 2, running in MATLAB (http://www.fil.ion.ucl.ac.uk/spm/). Data were analyzed for $p = 0.05$.

All the patients had been informed about the exact course of the study 30 min in advance before it started. The used paradigm was word generation (WG). The study was divided into five blocks, each containing 10 acquisitions. Pattern of stimulation proceeded in ABABABABAB block diagram, where A was the rest (control), and B represented stimuli. The patients were ordered to pronounce in periods of stimulation non-repetitive male and female names, for example: Kate,

Table 1 – Characterization of the patients group including gender, age and tumor localization, size, histopathological type of the tumor and WHO grade.

Patient	Gender	Age (years)	Tumor localization	Tumor size (cm^3)	Histopatological type of the tumor	WHO grade
KwJ	F	36	Frontal lobe	2.63	Astrocytoma pilocyticum	L
SzK	M	22	Frontal lobe	10.95	Astrocytoma pilocyticum	L
DeB	F	23	Frontal lobe	66.78	Ependymoma	L
SiA	F	32	Frontal lobe	16.63	Astrocytoma fibrillare	L
KaM	F	31	Frontal lobe	23.8	Astrocytoma fibrillare	L
KwS	M	55	Temporal-parietal border	37.42	Glioblastoma	H
BlK	M	38	Temporal lobe	23.21	Oligodendroglioma	L
MiK	M	44	Temporal lobe	24.68	Glioblastoma	H
NiS	M	47	Temporal-occipital border	21.77	Glioblastoma	H
RoM	F	35	Temporal lobe	6.8	Glioma mixtum anaplasticum	H

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