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FUNCTIONAL MAGNETIC RESONANCE IMAGING OF A BRAIN – EXAMPLE RESULTS OF EXAMINATION

The article describes a functional magnetic resonance imaging (fMRI) examination and the further data analysis. Inspiration to take an interest in fMRI diagnostics was its cognitive and clinical use which was observed by the author during the student practice at the Cracow University Hospital Department of Radiology (1.5 T SIGNA EXCITE 2 Echospeed MR System). The author of the paper participated in fMRI study of a patient diagnosed with right brain hemisphere tumour. In this case it was necessary to determine active regions responsible for limbs' movement. The obtained diagnostic data were the object of further analysis (digital processing). The images of an anatomical structure of patient's brain (in greyscale) with colourful active areas were obtained by analyzing images using specialized software NordicICE 2.3.1 and Functool 2.6.6. Looking at such images, it is possible for a doctor to determine the changes in the brain at the molecular level and to plan eventual neurosurgery.

1. INTRODUCTION

1.1. INSPIRATION

The inspiration to deal with the problem of functional magnetic resonance imaging was the fact that the author of the paper held her student internship at the Cracow University Hospital Department of Radiology. It was possible thanks to favour of professor Andrzej Urbanik M.D. PhD who is the head of The Department, and two medical physicists: MA Justyna Kozub and MA Paulina Karcz. The main field of interest during the internship were cognitive and clinical fMRI examinations. It was an opportunity for the paper's author to participate in many interesting examinations as an assistant as well as a patient.

1.2. SOME IMPORTANT THEORY

It is necessary to get to know the theory about fMRI examinations for better understanding of the whole process of obtaining and analyzing images of patient's brain. Neuroimaging enables proper pinpointing of active brain areas, which are connected to the particular processes in the brain. Nowadays it is the most widely used method of brain's activity imaging. It is also commonly used in the field of brain mapping due to its accuracy and wide availability.

1.3. HEMODYNAMIC RESPONSE

The strong correlation of local blood flow intensity and brain activity is the major principle of fMRI. The most important technique for fMRI study is blood-oxygen-level dependence (BOLD). It is connected to the MRI contrast of blood haemoglobin and its local ratio. The essential fact is that the oxygenated haemoglobin (oxyhaemoglobin) and the deoxygenated one (deoxyhaemoglobin) have different magnetic features. The first one is diamagnetic while the second one is paramagnetic, so that the registered signal is different for each of them. The local activity of brain causes local increases in blood flow and volume. The flow is told to increase about the 20-40%. Due to that fact, there is also the rise of

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the oxygen's level in some particular brain area and the ratio of oxyhaemoglibin to deoxyhaemoglobin changes. These are the reasons for local changes in the magnetic field which are seen as registered signal intensity changes.

1.4. BOLD TECHNIQUE

In fMRI study using BOLD technique patient is obliged to perform specific action which is responsible for activation of a particular brain area. Periods of activation interweave with periods of rest. The hemodynamic response is different in these situations so that the registered images show other features. The final fMRI image is obtained by image subtraction (pure insertion).

2. FMRI EXAMINATION

2.1. PURPOSE OF STUDY AND THE TEST STAND

The main aim of the study was to pinpoint key active areas in the brain of a patient who was going to a neurosurgery. The patient was a 53-years-old woman with previously diagnosed tumour in the right brain hemisphere. The tumour was initially diagnosed in the frontal lobe, close to two important regions which are responsible for motor activity of the left hand and left leg. Accordingly, during the examination the patient was supposed to perform two tasks: movement of the left hand (finger tapping) and movement of the left leg (toe tapping).

The fMRI examination was done in the Cracow University Hospital Department of Radiology. The 1.5 T SIGNA EXCITE 2 Echospeed MR system was used. The parameters of the gradient system in this tomography are: amplitude 33mT/m and slow rate 12OmT/m/ms.

2.2. COURSE OF THE EXAMINATION

The fMRI examination can be conceptually divided into two phases: initial phase and basic phase. The initial phase is equivalent to the localizer scan. This kind of scan is rapid and is aimed to show a low resolution image which helps to centre the patient's head, while eliminating any rotation on the images. The next step was a structural scan. High resolution T2-weighted images of the brain's structure were acquired. The scan resulted in 900 images in horizontal plane. Finally, a functional scan was performed. The technique used was echo planar imaging (EPI). The paradigm parameters in this case were block design with go/stop commands. There were 3 rest periods and 2 activation periods. Each period took 30 seconds and the total scan duration was 2.5 minutes. Due to patient movement and failure to perform tasks properly however, the studies had to be repeated several times and the total examination time was about 30 minutes. The data obtained in this way were analysed using two different computer programs: NordicICE 2.3.1 (NordicNeuroLab) and Functool 2.6.6 (GE Healthcare).

3. ANALYSIS OF THE OBTAINED DATA

3.1. PRELIMINARY ANALYSIS

In the first step of digital processing of obtained data preliminary analysis was done. While scanning, two groups of data were acquired: images which show the brain's activity and images which show it at rest. A computer does not recognize images and cannot assign them to any group. Consequently, it was essential to group registered images. Pre-processing can consist of either two or three tasks. In this case, only two were carried out, as normalization was not neccesary. The purpose of this process is to reshape an image of a subject's brain, so that all parameters would be most similar to the template. Four types of affine transformation are usually made: translations, rotations, zooms and shears. Such transformations aim to enable comparing images of two or more different patients with ease. In this particular study only one patient was examined, so there was no necessity to do this task. The tasks which were done were realignment and spatial smoothing. The whole examination took some time, so it was impossible for the patient to remain motionless. Accordingly, some artefacts were noticeable on the images. It was extremely important to correct head moves by spatial fitting. It was also necessary to make slice time correction, since each slice is scanned at a slightly different time. The next step which was made was spatial smoothing. Its aim was to reduce low and high frequency noise. Improving signal-to-noise ratio (SNR) was desired.

Pre-processing was performed in order to remove various types of artefacts and improve the condition of obtained data for later statistical analysis, which is the next step in digital processing. General linear model (GLM) was used to determine which voxels are activated by the stimulation. There are some brain actions which are performed continuously in different brain parts. Thus, in order to decide which part is responsible for a particular activity (e.g. finger tapping), a kind of subtraction of images was made. The images of the brain at rest were subtracted from the images of the brain's activity. Consequently only brain areas which were activated by the stimulation were displayed. It was important to assume pure insertion. It enabled some simplification that the obtained activity is a result of only one process caused by stimulation.

Finally, there was an opportunity to choose a threshold – decide on a level of significance at which parts of the brain were truly activated. When the threshold was selected, it was applied to every voxel in the statistic map. In this way whole preliminary analysis was carried out and its results could be simply visualized in Functool 2.6.6. The other program (NordicICE) enables more complicated visualization.

3.2. RESULTS' VISUALIZATION

Functool presents only results of pre-processing and GLM analysis. NordicICE's properties are more complex so the image of the stimulated activity could be presented on the structural image. Finally, 18 images were obtained. They show 18 different slices of patient's brain. Most important slices in this case are ones from the top of the head (slices no 13-18).

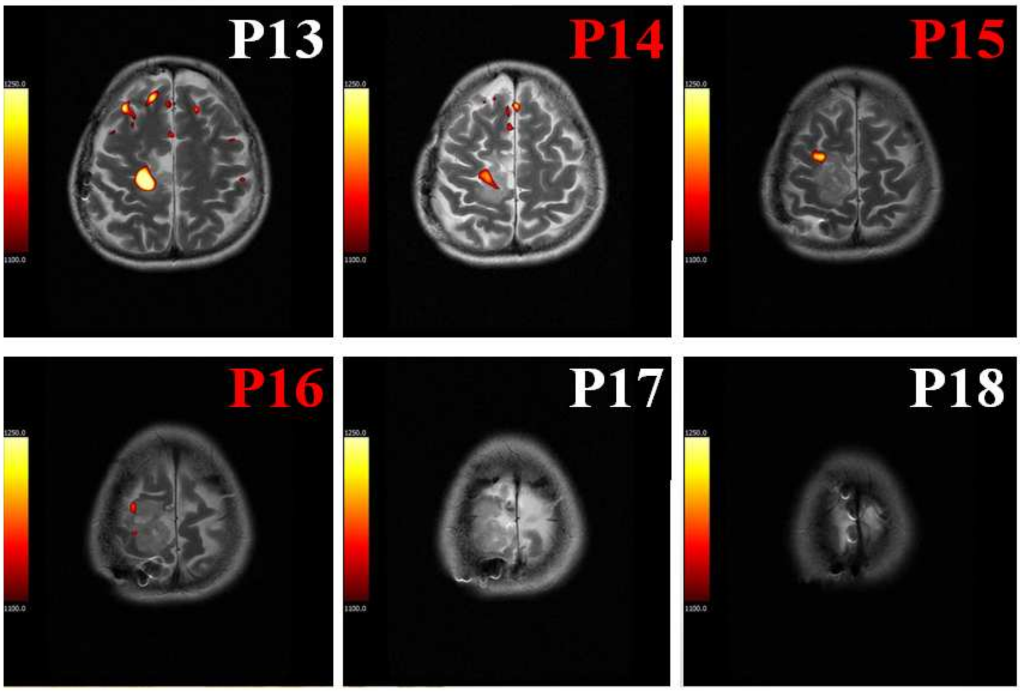

Fig.1. Result of the analysis – slices no 13-18.

Each picture contains of the brain image and the colour scale. It informs about the intensiveness of the brain's activity. More active areas are white coloured and less active ones are red. In the images 13-16 some colourful areas are noticeable. They are regions of brain's activity during stimulation.

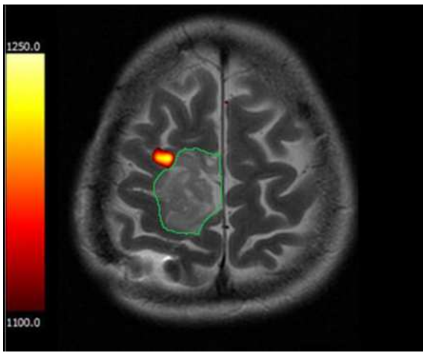

Fig. 2. Result of the analysis – slice no 15.

The picture shows the 15th slice of the patient's brain. The tumour is contoured by the green line. It lies next to the colourful area which is active while finger tapping. This particular image is especially interesting because there is one more diagnostic element on it. There is an artefact noticeable on the left bottom. This kind of artefact is caused by metal clips, which had been set into the subject's head after the previous surgery.

4. CONCLUSIONS

Thanks to the examination it was possible to localize areas of the patient's brain which are responsible for finger tapping. These areas were accepted as very important and especially protected. While tumour's resection a neurosurgeon has to get to the tumour and the knowledge of tumour's location is essential. The fewer cells are damaged, the better it is for the patient. Obtained images enable planning of the neurosurgery so that any handicap is minimized.

The problem, however, is that the examination does not always give good results. There are numerous kinds of artefacts that can occur in fMRI and affect badly the quality of the exam. It should be noticed that the essential thing in this kind of examination is good cooperation between an examiner and a patient. In the case described in the paper, the examination had to be repeated several times due to the patients movement. Very important was the fact that the patient was stressed so that she did not do the tasks properly for the most time e.g. she started to tap too fast or too late. It is not always easy to notice such mistakes and consequently examination is not repeated and can give not proper results. Another serious problem which cannot be easily controlled by an examiner is the possibility that a patient focuses at something else. Obtained data would include not only the signal caused by tapping, but also the signal connected with another task. Such situation does not affect the result if the activated areas are far from each other. In former case the examination's results would be wrong. The paper's author believe that the patient examined while her internship was extremely stressed about the idea of the examination and the stress made her focus only on the tasks she should do. Consequently obtained data were not affected by undesired factors and the examination gave good results in this case.

BIBLIOGRAPHY

[1] BLINK E.J., Basic MRI: Physics.
[2] BRYLL A., KOZUB J., URBANIK A., Badania funkcjonalne MR mózgu w planowaniu zabiegów neurochirurgicznych, OPM 9-10, 2010 (in Polish).
[3] JEDNORÓG K., MARCHEWKA A., Metoda MRI, fMRI zarys.
[4] GUT M., MARCHEWKA A., Funkcjonalny rezonans magnetyczny – nieinwazyjna metoda obrazowania aktywności ludzkiego mózgu, Konferencja Nowe metody w neurobiologii, 2004, pp. 35−40 (in Polish).
[5] HORNAK J.P., The Basics of MRI.
[6] URBANIK A., Czynnościowe obrazowanie RM (cRM) mózgu, Polski Przegląd Radiologiczny, Blackhorse Publishing, Vol. 65, No. 2, 2000, pp. 87-90.