Signature: © Pol J Radiol, 2010; 75(3): 51-54

Polish Journal of Radiology
www.PolRadiol.com
CASE REPORT

Received: 2010.04.26
Accepted: 2010.07.08

Neurosurgical treatment of drug-resistant epilepsy on the basis of a fusion of MRI and SPECT images – case report

Elżbieta Jurkiewicz[1], Monika Bekiesińska-Figatowska[2], Jolanta Miśko[3], Anna Kamińska[4], Stanisław Kwiatkowski[5], Iwona Terczyńska[6]

[1] MRI Laboratory, The Children's Memorial Health Institute, Warsaw, Poland
[2] Department of Imaging Diagnostics, Institute of Mother and Child, Warsaw, Poland
[3] Laboratory of Nuclear Medicine, Międzyleski Specialist Hospital in Warsaw, Warsaw, Poland
[4] Laboratory of Nuclear Medicine, The Children's Memorial Health Institute, , Warsaw, Poland
[5] Department of Neurosurgery, University Children's Hospital of Cracow, Cracow, Poland
[6] Department of Neurology of Children and Adolescents, Institute of Mother and Child, , Warsaw, Poland

Author's address: Elżbieta Jurkiewicz, MRI Laboratory, The Children's Memorial Health Institute, Warsaw, Poland, e-mail: e-jurkiewicz@o2.pl

Summary

Background: Epilepsy concerns at least 0.5% of population and in most of the cases (approx. 70%) can be treated pharmacologically, which helps to prevent seizures. In all other patients, such a treatment does not produce the desired results. Their condition may require neurosurgical management. The aim of this work was to fuse anatomical MRI images and functional SPECT images in patients with drug-resistant epilepsy, without structural changes on MRI or with changes so severe that it would be impossible to establish which ones are responsible for seizures. The authors presented a case of a child subjected to a neurosurgical procedure carried out on the basis of the fused MRI and SPECT images.

Case Report: A seven-year-old boy with an extensive defect of the right hemisphere (cortical dysplasia with multiple balloon-like cells) operated on three times due to a history of treatment-resistant seizures present since the age of one. A subsequent MRI examination was performed with magnetic field intensity of 1.5 T, within a routine epilepsy protocol applying volumetric thin-slice T1-weighted images. Next, in the interictal period, a SPECT examination was performed with the use of the ^{99m}Tc-labelled *ethyl* cysteinate *dimer* (^{99m}TcECD). For fusion and postprocessing, the following software was used: PMOD (Biomedical Image Quantification PMOD Technologies) with PFUS (Flexible Image Matching and Fusion Tool) and a program for a quantitative analysis of counts in the region of interest, so called VOI Constructor (Volume of Interest Constructor). On the basis of the fusion of images, the boy was subjected to the next operation procedure. The remaining fragments of the right frontal and parietal lobe adjacent to the occipital lobe were removed. Seizure remission was obtained and it was already 31 months long when we were writing this article.

Conclusions: Owing to this multi-stage procedure, it was possible to avoid a total anatomical and functional hemispherectomy. This allowed for a resection limited to regions indicated by integrated imaging. Removal of cortical areas including lesions was advantageous in this presented case, as it allowed for saving active regions of the brain.

Key words: drug-resistant epilepsy • brain • magnetic resonance imaging (MRI) • single photon emission computed tomography (SPECT) • fusion of the images

PDF file: http://www.polradiol.com/fulltxt.php?ICID=881149

Background

Epilepsy concerns at least 0.5% of population and in most of the cases (approx. 70%) can be treated pharmacologically, which helps to prevent seizures [1,2]. In all other patients, such a treatment does not produce the desired results. Their condition may require neurosurgical management. A precise localisation of the seizure-onset focus is essential to plan the range of the neurosurgical procedure, and to minimise the risk of postoperative neurological deficits. An invasive EEG is used to localise the focus in a direct way: deep electrocorticography and intraoperative electrocorticography [3,4]. But of course, noninvasive methods are preferred. These are imaging examinations, including: computed tomography (CT) and magnetic resonance imaging (MRI), as well as methods related to nuclear medicine: positron emission tomography (PET), and a more available one - single photon emission computed tomography (SPECT). CT and MRI detect structural abnormalities of the brain, while SPECT and PET – perfusion and metabolism disorders. However, the SPECT method does not reveal a sufficient spatial resolution in order to show precisely the location of a seizure-onset focus. The MRI examination, on the other hand, allows for a precise anatomical localisation, but does not reveal an adequate sensitivity. Therefore, the aim of the work was to fuse anatomical MRI images and functional SPECT images in patients with drug-resistant epilepsy, without structural changes on MRI or with changes so severe that it would be impossible to establish which ones are responsible for seizures. We presented a case of a child subjected to a neurosurgical procedure carried out on the basis of the fused MRI and SPECT images.

Case Report

A seven-year-old boy, the first child of young and healthy parents without any family history of epilepsy, with an extensive defect of the right hemisphere, operated on three times due to treatment-resistant seizures present since the age of one. Previous pharmacotherapy included all antiepileptic medicines available on the Polish market, at the highest possible doses, in different regimens, including 2–5 drugs, without any spectacular results (some of the drugs increased the seizures or caused aggression). Complex partial seizures, of changing morphology, were present every day, in the number ranging from a few to a few dozens a day. The development of the boy was severely retarded. Neurological examination showed severe spastic paresis of the left limbs.

The first surgery, performed at the age of 4, consisted in removing (according to the SPECT and EEG image) the pallium of the right parietal lobe and in undercutting the cortex of the temporal, right occipital, and frontal lobe in the parasagittal area. Histopathological examination showed a cortical dysplasia with multiple balloon-like cells. Four months later, after an infection, there appeared seizures of the upper limb. Attempted modifications of the pharmacological treatment did not result in any clinical improvement. In the second neurosurgical procedure, performed on the basis of the SPECT and EEG image, the frontal lobe was exposed, up to its base. With incision of the borderline of the cortex and the white matter, the pallium was removed up to the frontal horn of the right lateral ventricle.

There was an improvement which persisted for a few months. Afterwards, there appeared seizures of a new type: psychomotor with vegetative symptoms. EEG was suggestive of focus formation in the left hemisphere, in the prefrontal/frontal area. Callosotomy was performed – 2/3 of corpus callosum were incised in the front. Due to a widened ventricular system and an enlarged porencephalic cyst following hemispherectomy, a drainage system was implanted between the porencephalic cyst and the peritoneal cavity. In the next 2 years, the child's condition was good.

A next acute infection led to seizures with a clinically defined onset within deep frontal areas. There followed developmental regress as well. One more change of antiepileptic treatment failed again. An MRI was carried out with the use of volumetric thin-slice T1-weighted images.

Next, in the interictal period, a SPECT examination was performed with the use of the ^{99m}Tc-labelled *ethyl* cysteinate *dimer* (^{99m}TcECD).

For fusion and postprocessing, the following software was used: PMOD (Biomedical Image Quantification PMOD Technologies) with PFUS (Flexible Image Matching and Fusion Tool) and a program for a quantitative analysis of counts in the region of interest, so called VOI Constructor (Volume of Interest Constructor).

Owing to the method of interpolation, SPECT images were not only adjusted to the anatomical MRI image, but also made uniform with respect to spatial resolution, and divided into the same number of transverse sections, with exactly the same thickness of each section as in the MRI (so called corregistered data).

In the fused MRI and SPECT image, in the obtained transverse, sagittal and coronary sections, the location of the lesions was determined, in which the initially visually evaluated perfusion defect overlapped with the grey matter of the cortex measuring at least 0.5 cm^3. A mean number of counts in the anatomically-adjusted region was compared with a mean number of counts within the brain, which was accepted as a reference value, defining the border between a normal and a decreased brain perfusion. The mean count in the anatomically-adjusted region was also compared with the mean count in a corresponding region in the other hemisphere (a difference of >15% was assumed as a verification of the deficit).

Three regions with visually detected perfusion deficits (in the medial part of the right temporal lobe, in the remaining part of the right frontal lobe and in a fragment of the right parietal lobe) were subjected to the above presented quantitative evaluation. The qualitative analysis showed that two of the three regions; the remaining part of the right frontal lobe (Figure 1) and of the right parietal lobe meet the conditions of perfusion deficit (Table 1).

The outcomes of the integrated neuroimaging were compared with clinical data and EEG in which the focus was found in centroparietal leads, on the right.

On the basis of the image fusion, the boy was subjected to one more procedure. The remaining fragments of the

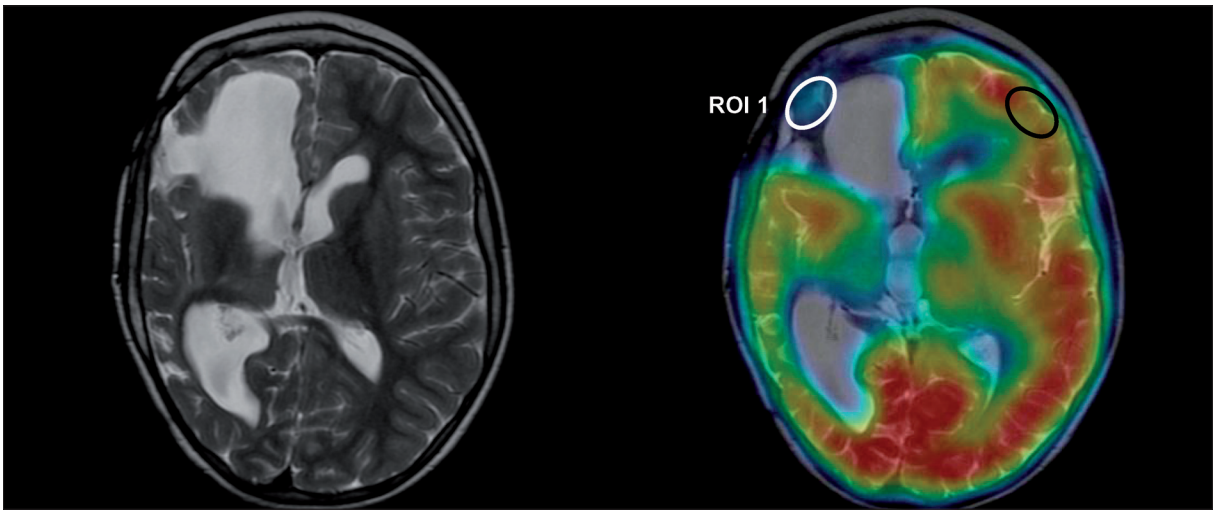

Figure 1. MRI image (**A**). Fusion of the MRI and SPECT image in the interictal phase (**B**) with a marked region of perfusion deficit within a fragment of the right frontal lobe, left after the previous surgical procedure (ROI 1 – white colour). A corresponding region in the frontal lobe of the left hemisphere, marked with black colour, revealing a normal perfusion in the SPECT examination.

Table 1. Quantative analysis of SPECT activity in the regions with perfusion defects.

	Mean count in the region	Mean count in the brain	Mean count in a corresponding region of the contralateral hemisphere	Percentage difference ROI – ROI in the other hemisphere
ROI 1 (right frontal lobe)	177	193	232	>20%
ROI 2 (right parietal lobe)	175	193	234	>20%

frontal and parietal lobe adjacent to the occipital lobe were removed.

Seizure remission was obtained and it was already 31 months long when we were writing this article. EEG showed a slow basic activity in the frontal-central-parietal and right anterior temporal region, without any distinct changes of epileptic type. However, due to the characteristics and extension of the defect and a serious past course of the disease, the boy is still being administered CBZ and VPA in the therapeutic doses (remaining unchanged for over two years). A systematic developmental progress is observed; paresis of the left limbs is currently of moderate degree.

Discussion

Noninvasive tests visualizing brain activity can be divided into those carried out during an epileptic seizure (ictal SPECT) or interictally (interictal SPECT and other: MRI, CT, PET). From among the 'other' ones, PET reveals the highest sensitivity in the detection of the seizure-onset foci in patients with temporal lobe epilepsy (84%), while the sensitivity of SPECT (interictal) amounts to 66%, and of MRI to 55%. In nontemporal lobe epilepsy, the highest sensitivity is revealed by interictal SPECT (60%); MRI and PET – 43% and 33%, respectively. However, the highest sensitivity of all has ictal SPECT – 90% in the temporal epilepsy and 81% in the nontemporal one [5,6]. SPECT carried out during an epileptic seizure shows foci of hyperperfusion. In the interictal period, perfusion deficits correspond to them.

Inability to show structural changes makes the MRI examination of the brain inappropriate for planning the resection of seizure-onset foci. It is the same with multiple lesions, e.g. in tuberous sclerosis, or in case of one but extensive lesion, when it is not known which part of it is responsible for seizures, and removal of the whole lesion is impossible. Detection of a focus of abnormal perfusion/metabolism in SPECT, on the other hand, is insufficient to plan a neurosurgical procedure, due to inadequate spatial resolution of this method.

In patients with drug-resistant epilepsy qualified for surgery, it is necessary to perform both examinations and to fuse their images with a specialist software. This should allow for a precise determination of the focus and then, after downloading of the data to neuronavigation system, the resection of the lesion [7]. The literature involves reports on methodology and usefulness of the fusion of images in the localisation of epileptogenic foci [8,9].

The reported case concerned drug-resistant epilepsy manifesting itself with everyday seizures in the number reaching a few dozens a day, in a boy with cortical dysplasia. Malformations of cortical development (MCD), including cortical dysplasia, constitute a common cause of drug-resistant epilepsy [10]. An additional difficulty in our case was the fact that the boy had already been subjected to surgical procedures three times, with seizure recurrence. With the use of MRI, it would be completely impossible to distinguish the focus responsible for the next recurrence,

from all the extensive cortico-subcortical scars after surgeries and from the remaining abnormal cortex. Only the fusion of thin-slice volumetric MRI images and SPECT examination with the calculation of mean counts in SPECT in the region of the cortex defined on the basis of the MRI, allowed for indication of the most probable locations of the seizure-onset focus. Finally, the surgery (despite so many attempts and stages) allowed for resignation from a complete anatomical and functional hemispherectomy. The operation could be restricted to regions indicated by integrated imaging. Resection of the abnormal regions within the cortex was advantageous in case of the presented child, as it allowed for saving the active areas. Implantation of a valve due to the development of 'free' fluid regions can be called 'a neurosurgical failure' but regarding the achieved result, this is the option connected with the least side effects. The conducted procedures differ from classic hemispherectomies and produced a good clinical result and a safe postoperative course.

Conclusions

1. Fusion of MRI and SPECT images allows for combining a high sensitivity of the isotopic method (in the detection of seizure-onset foci) with a high spatial resolution of the MRI method.

2. Owing to the surgical procedure carried out on the basis of fused MRI and SPECT images, it was possible to avoid a total anatomical and functional hemispherectomy and to limit the resection to the regions indicated by integrated imaging, saving the active regions.

3. Surgery based on fused images is, according to a neurosurgeon, the best method to plan a resection in case of cortical dysplasia.

References:

1. Won HJ, Chang KH, Cheon JE et al: Comparison of MR imaging with PET and ictalSPECT in 118 patients with intractable epilepsy. Am J Neuroradiol, 1999; 20: 593–99
2. Goffin K, Dedeuwaerdere S, Van Laere K et al: Neuronuclear assessment of patients with epilepsy. Semin Nucl Med, 2008; 38(4): 227–39
3. Dupont P, Van PaesschenW, Palmini A et al: Ictal perfusion patterns associated with single MRI-visible focal dysplastic lesions: implications for the noninvasive delineation of the epileptogenic zone. Epilepsia, 2006; 47(9): 1550–57
4. Vera P, Kaminska A, Cieuta C et al: Use of subtraction ictal SPECT co-registered to MRI for optimizing the localization of seizure foci in children. J Nucl Med, 1999; 40(5): 786–92
5. Spencer SS: The relative contributions of MRI, SPECT, and PET imaging in epilepsy. Epilepsia, 1994; 35(Suppl.6): S72–89
6. Spencer SS, Theodore WH, Berkovic SF: Clinical applications: MRI, SPECT, and PET. Magn Reson Imaging, 1995; 13: 1119–24
7. Murphy MA, O'Brien TJ, Morris K et al: Multimodality image-guided surgery for the treatment of medically refractory epilepsy. J Neurosurg, 2004; 100(3): 452–62
8. Grova C, Jannin P, Biraben A et al: A methodology for generating normal and pathological brain perfusion SPECT images for evaluation of MRI/SPECT fusion methods: application in epilepsy. Phys Med Biol, 2003; 48(24): 4023–43
9. Matthews R, Franceschi D, Xia W et al: Parietal lobe epileptic focus identified on SPECT-MRI fusion imaging in a case of epilepsia partialis continua. Clin Nucl Med, 2006; 31(12): 826–28
10. Sporis D, Hajnsek S, Boban M et al: Epilepsy due to malformations of cortical development – correlation of clinical, MRI and Tc-99mECD SPECT findings. Coll Antropol, 2008; 32(2): 345–50