

# PREOPERATIVE PET ACTIVATION FOR ASSESSMENT OF MOTOR CORTEX AREA IN PRECENTRAL CHONDROMA

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Schreckenberger M, Spetzger U, Sabri O, Meyer P, Schulz G, Hermanns B, Krombach G, Gilsbach J, Buell V. Preoperative PET activation for assessment of motor cortex area in precentral chondroma. *Surg Neurol* 1999;52:24–9.

## BACKGROUND

A main problem in the preoperative planning for precentral tumors is the exact assessment of the spatial relationship between the tumor and the functionally relevant brain areas, which may be difficult using only morphologically oriented imaging (CT, MRI). Therefore, we applied motor activation PET and PET/MRI overlay in a patient with a precentral tumor.

## DESCRIPTION

We report the case of a 21-year-old woman suffering from progressive right-sided headache and intermittent dysesthesia of the left leg. MRI showed a hypointense tumor with inhomogenous contrast enhancement in the right precentral area. For preoperative assessment of the spatial relationship between the tumor and the motor cortex area, the patient underwent two F-18-fluorodeoxyglucose positron emission tomography (PET) scans (1. resting condition and 2. motor activation of the left leg) and subsequent calculation of subtraction images of activation minus rest. Fusion of PET and MRI data (PET/MRI overlay) was performed for bimodal function and morphology presentation. PET revealed an activation pattern behind and below the tumor, indicating that the motor cortex area was shifted to the back. PET findings were confirmed by intraoperative electrophysiology. Cortical stimulation combined with intraoperative neuronavigation localized the motor area of the left foot and leg exactly at the dorsal border, below and lateral to the lesion. After complete resection of the solid tumor, histopathological examination revealed a chondroma. The postoperative course was uneventful, and the patient was discharged without neurological deficits.

## CONCLUSIONS

This case shows that biomodal imaging (PET/MRI) provides a noninvasive exact assessment of functionally important cortex areas for preoperative planning in patients with cerebral lesions. © 1999 by Elsevier Science Inc.

## KEY WORDS

PET, <sup>18</sup>F-fluorodeoxyglucose, motor activation, PET/MRI overlay, preoperative planning, chondroma, precentral area.

Positron emission tomography (PET) enables an assessment of the perfusional and metabolic cerebral processes which are correlated with sensorimotor or cognitive tasks. Depending on the applied radiotracer, regional cerebral perfusion ( $H_2^{15}O$ ,  $^{15}O$ -butanol) or regional cerebral glucose metabolism ( $^{18}F$ -fluorodeoxyglucose) as markers for neuronal activity can be detected with sufficient spatial resolution (4–6 mm). For recording functionally important brain areas, PET studies using a special activation paradigm (e.g., motor or sensory task, language task) [16] reveal the activated brain areas by calculating parametric subtraction images activation minus rest. Image fusion of one patient's PET and MRI data (PET/MRI overlay) enables bimodal presentation of individual anatomy and function. Information about the exact spatial extent of functionally relevant brain areas (e.g., primary motor cortex, Broca's area) is important for the preoperative planning of the approach to avoid or minimize surgically induced cortex damage. Using only morphologically oriented imaging (CT, MRI), this assessment is very problematic due to the considerable interindividual variability of primary motor cortex [3,17] and language related cortex [13,18],

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and to the displacement of these areas by slowly growing tumors.

## CASE REPORT

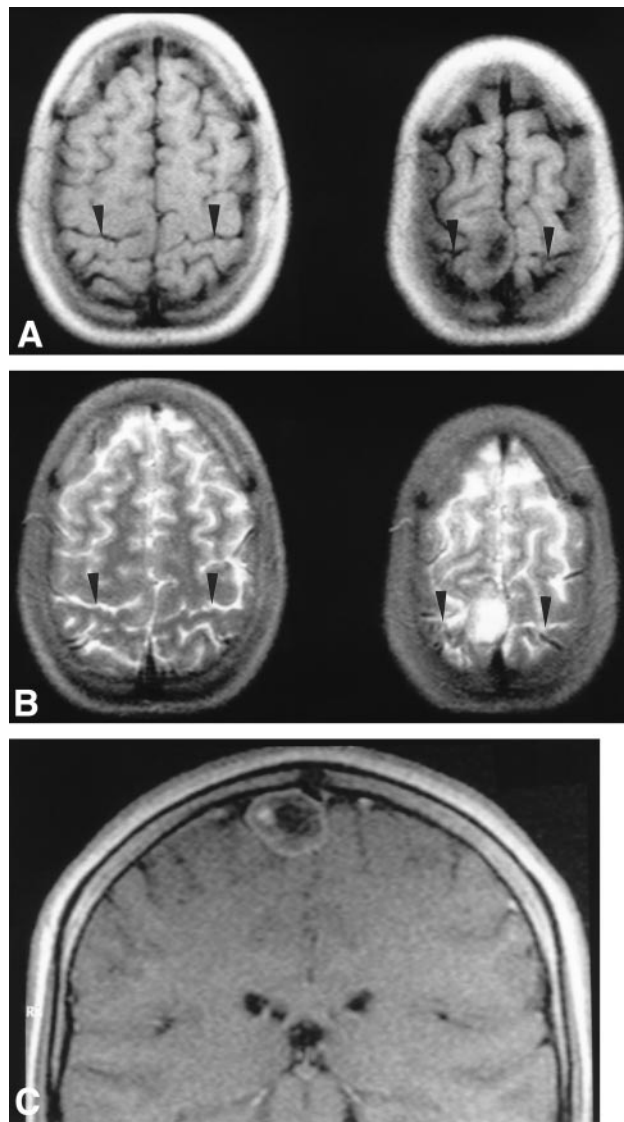
A 21-year-old woman was admitted with progressive right-sided headache and intermittent dysesthesia of the left leg in the form of sensory Jacksonian seizures. Clinical examination showed normal neurologic status without focal signs.

### PREOPERATIVE IMAGING

CT scan demonstrated an isodense lesion ( $3 \times 2 \times 1.5$  cm) without calcification and no contrast enhancement in the right precentral gyrus that was attached to the falx cerebri and the sagittal sinus. MRI revealed a hypointense central signal with inhomogenous and ring-shaped contrast enhancement on T1-weighted images after administration of gadolinium. No peritumoral edema was seen on T2-weighted sequences. The sagittal sinus was slightly compressed, but not completely occluded (Figure 1).

For preoperative planning, the patient underwent a T1-weighted 3D-flash MRI (Magnetom 1.5 T, Siemens, Erlangen, Germany) and two PET scans (ECAT Exact, Siemens, Erlangen, Germany) on two consecutive days. The first PET scan was performed 30 min. after i.v. injection of 315 MBq F-18-fluorodeoxyglucose (18-FDG) under resting conditions (dimmed light, closed eyes, no sensorimotor or cognitive activation). The second scan was performed on the following day under a specific motor activation task: 1 min. before i.v. injection of 285 MBq 18-FDG, the patient was asked to start moving the left lower leg and foot by regular stretching for 30 min. with subsequent PET scanning. After normalization of the global cerebral counts of the first PET scan to the global cerebral counts of the second scan, MRI and PET data were realigned using a special multi-purpose imaging tool [15]. Thereafter, subtraction images activation minus rest were calculated and fused with the MRI data (PET/MRI overlay).

PET images under resting conditions revealed a lack of glucose metabolism in the area of the right medial precentral gyrus that exceeded the tumor region, indicating a reduced glucose metabolism in the morphologically normal cortex around the tumor. Within the tumor area, the lack of evidence of hypermetabolic tissue would point away from a high-grade glioma. The subtraction images (Figure 2) demonstrating the cortex area activated by the motor task, revealed an increased cerebral glucose



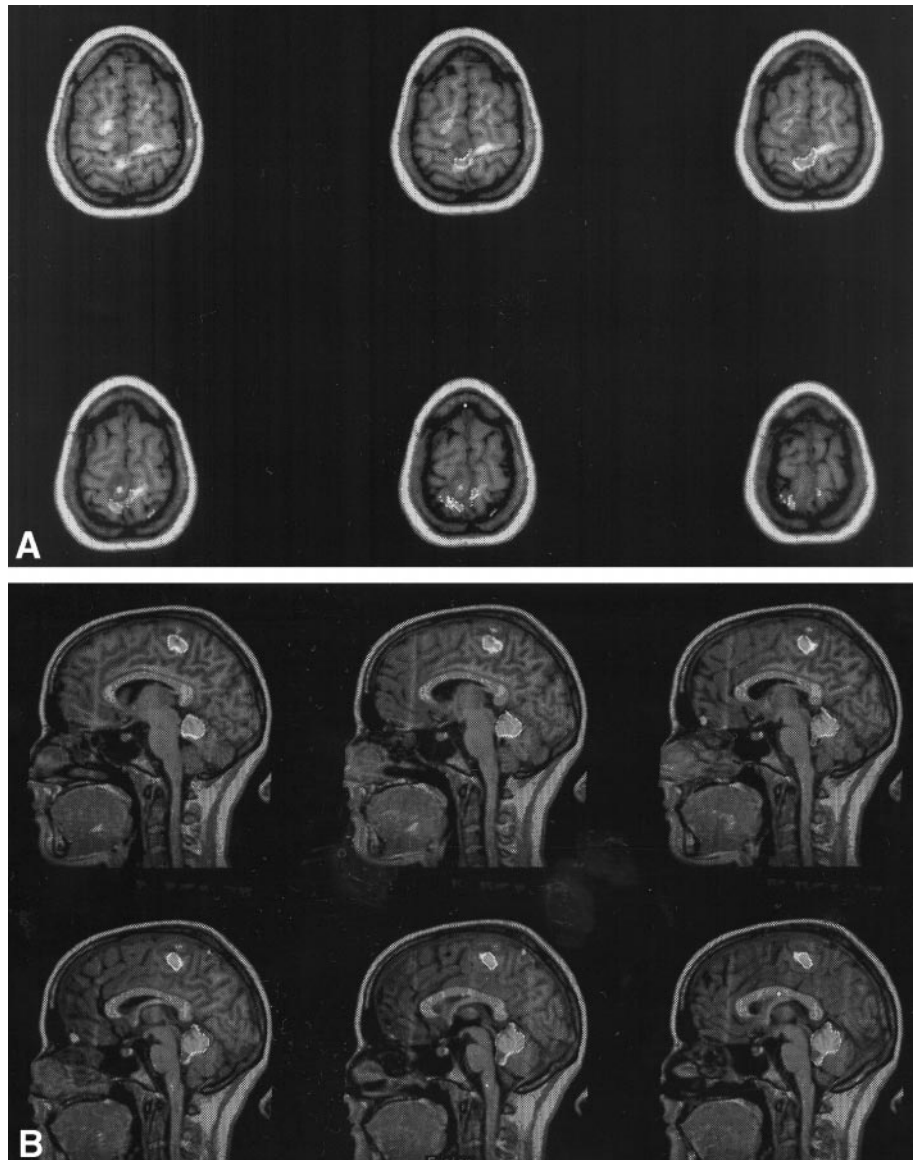
**1** MRI showing a parafalxial lesion in the right sensorimotor cortex. (A) Axial T1 images (TR480/ TE 15) demonstrate hypointense signal and (B) high intensity on axial T2 images (TR 3500/ TE 100) without peritumoral edema. The central sulcus is clearly visible (arrow). Coronal (C) gadolinium enhanced T1 image (TR 420/ TE 20) shows oval-shaped and inhomogenous ring-like contrast enhancement.

metabolism in the area behind, lateral to, and below the tumor. Additionally, considerable activation was seen in the bilateral cerebellum. Remarkably, no motor activation could be found in front of the tumor area.

### SURGERY

After preoperative planning and targeting of the right parietal cortex, parasagittal craniotomy was performed using the neuronavigation system EasyGuide Neuro. After U-shaped opening of the

**2** PET/MRI-overlay demonstrates motor activated brain areas behind and lateral to tumor (A: transverse sections), below tumor and in cerebellum (B: sagittal sections).



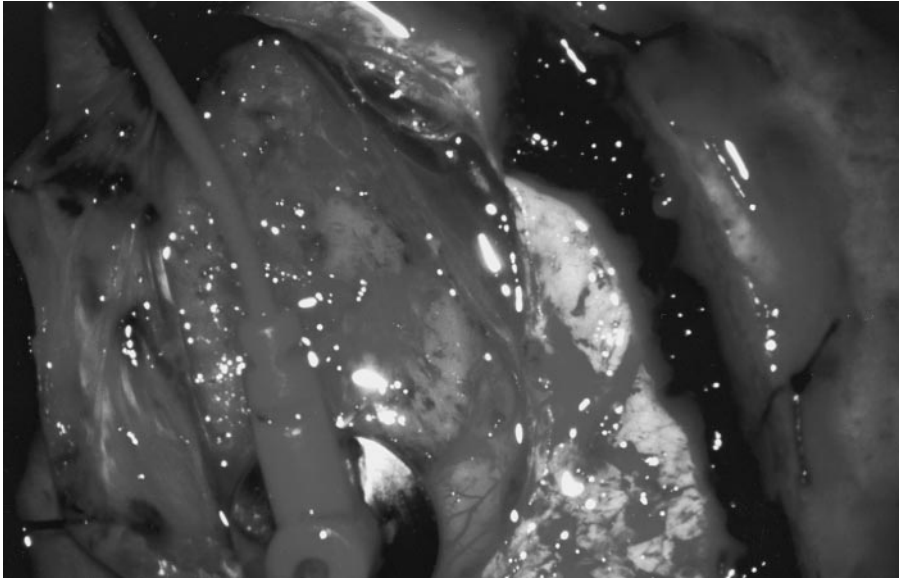
dura perpendicular to the sagittal sinus, a smooth and solid tumor was visible. The greyish tumor with an opalescent surface and a firm-elastic consistency was strongly adherent to the falx cerebri and the lateral wall of the sagittal sinus (Figure 3). However, the arachnoid layer of the adjacent precentral cortex was intact, and microsurgical dissection around this cleavage plane was possible. Intraoperatively, electrophysiological monitoring was performed with a monopolar anodal electrical stimulus, delivered from a constant voltage stimulator (Viking IV, Nicolet Biomedical Instruments, Madison, WI) through a silver plate electrode of 1 cm<sup>2</sup> contact surface. One train of stimuli contained 5 pulses, each of 100 μs duration. When stimulating the cortex at the back and lateral to the tumor, a repro-

ducible stimulus response in the muscle of the left thigh and lower leg could be detected. Total resection of the lesion was possible without damaging the sensorimotor cortex, and final electrophysiological stimulation elicited an unchanged stimulus response in the above-described areas, and additionally in the area below the site of the tumor. The postoperative course was uneventful; the moderate hypoesthesia of the left leg during the first postoperative days disappeared completely. There was no neurologic deficit when the patient was discharged one week after the operation.

#### HISTOPATHOLOGY

Histologic examination of the tumor showed atypical cartilaginous tissue with moderate cell density





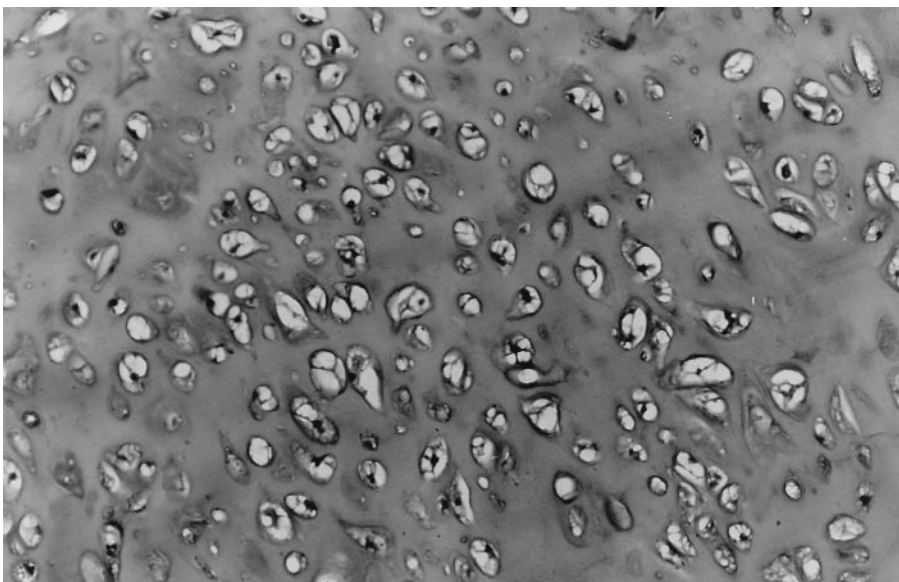
**3** Intraoperative photograph shows opalescent surface of the chondroma and monopolar electrode for cortical stimulation at back of the tumor over the motor cortex. Direct cortical stimulation of this area induced reproducible muscle contraction of left leg.

and predominantly small nuclei (Figure 4). Tumor tissue showed numerous pyknotic nuclei but no mitoses. The final histopathological diagnosis was chondroma since a malignant chondrosarcoma was ruled out by immunohistochemical staining (MIB 1 against proliferation-associated antigen Ki 67: less than 5% of the nuclei showed a positive immunohistochemical reaction).

## DISCUSSION

One of the main difficulties concerning the preoperative planning of precentral tumors is the exact assessment of the spatial relationship between the

tumor and the functionally relevant brain areas. In order to avoid irreversible damage from the approach or the resection procedure, exact anatomic localization and functional monitoring are important. Slowly growing tumors may considerably displace the motor area without causing relevant neurologic symptoms [3]. As a consequence, anatomical landmarks may be of little use in exactly defining areas related to motor function in such patients. In the case presented here, MRI showed a tumor in the central sulcus area suggesting the location of the primary motor cortex in front of the tumor (Figure 1). In contrast, activation PET using a simple motor activation task could reveal that the



**4** Rather well-differentiated and mature cartilaginous tissue. Chondrocytes are in bright cartilaginous areas, and have small and round nuclei in most cases. Most of the chondrocytes show slightly variable size. Cells with double nuclei are rare. (Magnification: 100 ×)

motor cortex area was shifted to the back by the chondroma and was found at the rear of and below the tumor. This finding was confirmed by intraoperative electrophysiological cortex stimulation, which was regarded as the "gold standard" [3,11,17]. This case demonstrates the clinical relevance of PET activation studies providing a noninvasive assessment of motor cortex area in patients with precentral tumors. Thus, PET/MRI overlay increases safety in the preoperative planning of approach and microsurgical strategy. In the case presented here, the extra-axial tumor (chondroma) was quite hypometabolic. The use of subtractive FDG-PET activation studies in hypermetabolic intraaxial lesions (e.g., high-grade gliomas) may be difficult due to partial volume effects, if the activated areas are very close to the hypermetabolic tumor tissue. In these cases, the clinical benefit of this method depends mainly on i) the full-width-at-half-maximum (FWHM) of the PET scanner and ii) the quality of exact PET/MRI realignment. The PET scanner we used in this study has a FWHM of 6 mm in the x and the y direction, whereas the contact surface of the monopolar electrostimulation probe is 1 cm<sup>3</sup>. The image realignment tool used here has a maximum axial translation variance of 2.2 mm [15] which is considerably smaller than the FWHM of the PET scanner and the spatial resolution of the stimulation probe, respectively. Herholz et al [5] evaluated the accuracy of preoperative localization of language-related cortex by using <sup>15</sup>O-water PET in eight patients with left-side gliomas, and revealed a sensitivity of 73% and a specificity of 81% in predicting aphasic symptoms during intraoperative stimulation.

In the literature, very few case reports exist of solitary chondromas of the falx and the convexity dura with comparable neuroradiological image studies [6,8,12] but none have included PET investigation. To date, there are few publications describing the clinical application of activation PET in patients with cerebral tumors. They mainly concern arteriovenous malformations [2,9,10,14]; few authors describe activation PET in glioma patients [4,5]. In addition to PET, the first functional MRI (fMRI) studies were reported for preoperative functional imaging in brain tumor patients [1,7,11]. In contrast to PET, fMRI has a very low signal-to-noise ratio, requiring multiple repeated measurements to obtain sufficiently constant signals. Beyond this, fMRI is very sensitive to motion artifacts during the activation procedure, whereas F-18-fluorodeoxyglucose PET is less susceptible because acquisition scan starts after activation is finished. However, further comparative investigations are needed to

assess the validity and reliability of fMRI versus PET in neurosurgical tumor patients.

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text before surgery using activated FDG-PET studies fused with an MR scan. The PET findings were confirmed by intraoperative cortical mapping using direct cortical electrical stimulation. The techniques described in this patient may be useful for preoperative mapping of the sensorimotor cortex and have not previously been well characterized.

In this particular patient, the tumor was clearly extra-axial and the preoperative imaging studies to localize the sensorimotor cortex did not especially improve the management of this patient. Also, the tumor was very hypometabolic. This technique would be most useful in the operative management of patients with intra-axial lesions, especially those that are not well demarcated from normal brain, such as gliomas. As the authors point out in the discussion, it is not clear how useful subtracted FDG-PET images will be when a more metabolically active intra-axial lesion is studied. Further studies of a larger number of patients are needed to see if this technique will be clinically useful.

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#### COMMENTARY

The authors present a well-illustrated case of an intracranial chondroma of the falx cerebri in which they successfully mapped the adjacent motor cor-

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**A** larger share of spending will go for health in the years ahead. Demand for the latest lifesaving technologies will continue to increase, pushing costs higher. Americans will insist on the best care possible, but to pay for it, they'll have to tighten their belts on other spending.

—“THE KIPLINGER WASHINGTON LETTER”  
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