Functional MRI of the Brain with Vascular Malformation

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Introduction

Functional magnetic resonance imaging (fMRI) is a powerful non-invasive means of studying cognitive neurophysiology. Functional MRI has been utilized in many successful clinical applications, such as presurgical mapping of the eloquent cortex in patients with brain tumor or intractable epilepsy (1, 2). However, the application of fMRI for the management of patients with arteriovenous malformation (AVM) has been limited (3, 4). Because the high blood flow known to exist within the AVMs might mask the induced blood flow changes by neuronal activation, the usefulness of fMRI has been questioned. In the present study, clinical application of fMRI for presurgical mapping using a standard 1.5T MR scanner is evaluated in patients with AVM.

Materials and Methods

Five normal subjects and three patients with AVM were studied on a 1.5T Siemens Magnetom Vision system with echo-planar imaging (EPI) capabilities, using a volume head coil. In each study, 16 oblique axial slices (6 mm with a gap of 0.6mm) were obtained. The volume of interest extends caudally to include the occipital cortices and cephalad to the superior sagittal sinus. Each study consisted of 90-128 EPI images (TR/TE:2.5 sec/60 msec, FOV=22cmx22cm, α=90, 128x128 matrix). The EPI images were analyzed with STIMULATE to generate functional maps using a student t-test ($p < 0.001$). Depending on the location of the AVM, patients underwent varying fMRI studies to localize their motor, visual, language and/or memory centers. In the motor study, subjects performed a finger-thumb opposition and/or tongue movement tasks. In visual study, a photic stimulation at 8 Hz frequency was delivered through a checkerboard LED matrix. For language activation, subjects silently repeated words under auditory guidance (5), i.e., words were given through the intercom system during the task period. In the memory study, six names of animals were repeatedly presented aurally during the task period (50 seconds), and the subjects were instructed to memorize the names as well as the order the names were given only during the task period, while refraining from rehearsing or recalling the items during the control periods. Functional maps were superimposed on 3D T1-weighted anatomical images and/or 3D venograms for analysis. The patients also underwent the conventional catheter Wada test and preoperative embolization of the AVM after the fMRI study. The patients were evaluated by neurosurgeons post-operatively to identify any neurological deficit.

Results

Patient 1: J.G. was a 22-year-old male who presented with a sudden onset of headache, nausea, vomiting, and photophobia. Head CT, MRI, and angiogram demonstrated a left parieto-occipital AVM. The patient underwent a photic stimulation fMRI study, which revealed activation in the right primary visual cortex and in small area in the left inferior visual cortex. The area occupied by the AVM was not activated. The AVM was resected, carefully leaving the left inferior visual cortex indicated by the fMRI map undisturbed. The patient fully recovered from the operation with no clinically detectable visual deficit.

Patient 2: D.H. was a 40-year-old female presented with a left parieto-temporo-occipital AVM. FMRI evaluation of silent speech revealed that Broca's area was left dominant while Wernicke's activation was right hemisphere dominant. The Wada test also revealed that language generation was left hemisphere dominant, and language comprehension was right hemisphere dominant. The right finger localization nicely correlated to the left motor strip, and the associated time course response curve appeared rather robust for the left motor strip region. Likewise, tongue movement typically activated the further inferior motor strips bilaterally.

Patient 3: R.M. was a 40-year-old female presented with a right parietal AVM. FMRI of silent speech demonstrated activation on the left inferior frontal (Broca) area and ipsilateral posterior temporal (Wernicke) area. The left finger tapping activated the right motor strip and the tongue movement activated the motor cortex for the tongue bilaterally. The time course of functional MR imaging clearly showed signal changes in the regions of interest and displayed the on/off activation properly. During the Wada test, the patient's response was significantly limited due to the extensive steal.

Discussion and Conclusions

The present study demonstrated that fMRI on a 1.5T system could reliably identify the eloquent cortices of interest. All subjects and patients successfully performed the silent speech tasks. The signal changes in time course of functional MR imaging followed the tasks on/off properly. The time courses of functional MR imaging signal changes also appeared quite robust. In the three cases presented, no viable brain function existed within the nidus of the AVM as suggested by the fMRI maps. FMRI findings were validated by post-operative clinical evaluation and by blinded studies of language lateralization using the Wada technique by independent investigators. The current study validated both the specificity and clinical utility of fMRI in the management of AVM.

References

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