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The use of functional MRI in evaluating cerebral arteriovenous malformations adjacent to language and sensorimotor cortex

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Abstract

Surgical planning in arteriovenous malformations depends on the angiographic features of the lesion and its relationship with neighboring functional brain areas. Topographic evaluation of the lesion can be made on conventional images but the relationship with the functional areas cannot be revealed. Functional magnetic resonance imaging (MRI) has begun to be used more frequently in mapping memory, visual, language and sensorimotor areas. In our study, functional areas in or around arteriovenous malformations were evaluated with functional MRI before surgical or endovascular therapy.

Keywords: Intracranial arteriovenous malformations; Magnetic resonance imaging; Functional; Motor cortex

1. Introduction

Cerebral arteriovenous malformations (AVMs) are related to maldevelopment in vascular morphogenesis or malfunction of the embryonic capillary maturation [1]. The majority of the AVMs usually occurs postnatally and contains different types of dysfunctional endothelial cells [2]. Surgical excision, endovascular therapy and stereotactic intervention are main treatment protocols in AVMs [3]. The clinical outcome following treatment depends on many factors, including AVM features (e.g., nidus size and venous drainage) and the location of the lesion relative to the functional cortex [4]. Although conventional magnetic resonance imaging (MRI) supplies sufficient data about the topographic location of AVM, it is insensitive in revealing its relationship with adjacent functional eloquent areas [5]. Revealing these functional areas affects the therapy protocol that would be applied. Functional areas may be determined by pre- and intraoperative techniques [positron emission tomography (PET), magnetoencephalography (MEG), electroencephalography (EEG), direct cortical stimulation tests] [6,7]. Intraoperative cortical stimulation tests produce more realistic results than the other methods. But it has some disadvantages such as requiring an invasive procedure and allowing to study in a limited area of the brain [8]. These functional areas may be shown by functional MRI and may be repeated several times. Sensorimotor, language and visual areas may be assessed according to the location of the lesion [9–19]. Since AVMs may result in hemorrhage and ischemia in time, remodeling may be seen in neighboring functional areas. Furthermore, abnormalities occurring in blood flow (steal phenomenon, retrograde flow) cause variabilities in blood oxygen levels [18]. In the present case series, our purpose was to reveal the sensorimotor and language areas preoperatively in three AVM cases by using blood oxygen level dependant (BOLD) functional MRI method.

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1.1. MR examination protocol

Morphologic and functional MR imaging were performed by using 1.5-T whole-body MR imaging system with echo-planar capabilities and a standard whole-head transmit-receive coil (Signa LX, GE Medical Systems). T1-weighted SE and T2-weighted FSE images on axial plane and T2-weighted FSE images on sagittal plane were acquired on routine examination. Functional MRI were performed with BOLD technique and single-shot gradient-echo echo planar sequence [TR/TE (3000/60), matrix 64×64, FOV 200 mm $\times$ 400 mm, slice thickness 7 mm, slice gap 1 mm and totally eight slices]. Total 480 images, of each from 10 slices, were obtained in 3 min. Image analysis was performed off-line using Functool software (GE Medical Systems, Milwaukee, WI) on an Advantage Windows workstation. Finger tapping or sponge squeezing was performed to activate sensorimotor centers. Exercises such as passive speech (speaking some definite words quietly and repetitively or murmuring), word generation (forming a new word by using the last letter of a given word), and sentence formation (forming a sentence including the given word) were performed to activate language areas. Finger tapping was arranged in three forms for right, left and both hands. The study, including active and passive phases, was repeated three times. Both phases lasted 30 s (totally 3 min). Functional MRI activation maps were generated with cross-correlation coefficient ($P < 0.001$). Source functional images obtained were combined with high-resolution anatomic images and functional mapping was performed. To minimize movement, patient's head were immobilized in a standard head coil with combination of a pillow and foam rubber pads.

2. Case report

2.1. Case 1

A 45-year-old male was admitted to the clinic with the complaint of headache. On physical examination minimal motor deficit was found on the left proximal extremity. Laboratory tests showed no abnormalities. On conventional MRI, lesion consistent with AVM was revealed at the right rolandic level (Fig. 1A). Since the lesion was in a close location to sensorimotor area, functional MRI was also performed. Extensive activation was seen around the area of AVM and in primary sensorimotor areas. Activation could not be found at locations, where AVM nidus and dilated vascular structures exist. The area where the nidus exists, were very close to sensorimotor areas (less than 1 cm). Normal activation was found in supplementary motor area, contralateral sensorimotor area, both parietal areas and at pre-supplementary motor area and at cingulate areas (Fig. 1B and C). Surgery or embolisation could not be performed because the patient rejected these choices of the treatment.

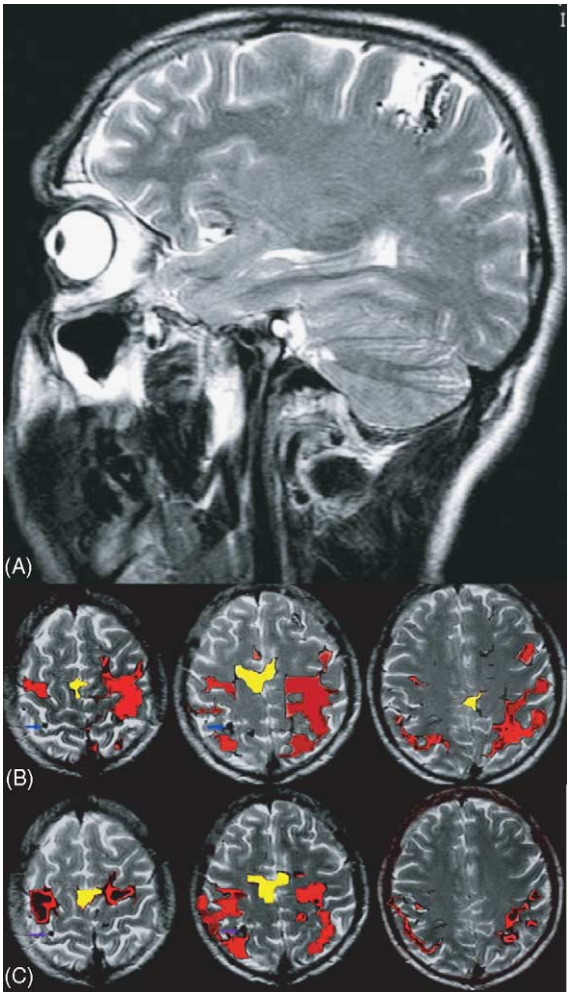

Fig. 1. (A) AVM is seen located in the postcentral gyrus at the right rolandic level on T2-weighted sagittal image. (B) and (C) Cortical activation areas corresponding with the finger tapping of the right (B) and left (C) hands on three axial consecutive images. Sensorimotor areas of the right hand are located in both cerebral hemispheres, but considerably in the left cerebral hemisphere. And sensorimotor areas of the left hand are located in both hemispheres, but considerably in the right cerebral hemisphere (red colored areas). Sensorimotor areas are laterally displaced minimally on the lesion side. Activation areas belonging to supplementary area are seen in the midline location (yellow colored areas).

2.2. Case 2

A 29-year-old male was admitted to the clinic with complaints of severe headache and motor deficit at the left arm. The patient had a history of seizure only once. On physical examination, minimal motor and sensorial deficit were found. Laboratory tests were normal. On conventional MRI, an AVM, extending from right cingulate gyrus to parietal convexity was seen (Fig. 2A). Functional MRI was performed because of the closeness of the lesion to the sensorimotor areas (between 1 and 2 cm). The examination, on which both hands were investigated separately, activation could not be found in the area of vascular nidus. The right sensorimotor area was displaced laterally. Supplementary area of the