# Visual Field Preservation in Surgery of Occipital Arteriovenous Malformations: A Prospective Study

*Xianzeng Tong[1-4], Jun Wu[1-4], Fuxin Lin[1-4], Yong Cao[1-4], Yuanli Zhao[1-4], Zhen Jin[5], Bo Ning[1-4], Bing Zhao[1-4], Yu Li[6], Lijun Wang[1-4], Shuo Zhang[1-4], Shuo Wang[1-4], Jizong Zhao[1-4]*

■ OBJECTIVE: **We reviewed our prospective study of patients with occipital arteriovenous malformations (AVMs) to assess whether the display of optic radiation diffusion tensor imaging (DTI) during neuronavigation-guided surgery can reduce the severity of postoperative visual field deficits (VFDs) and to evaluate the factors associated with visual field preservation.**

■ METHODS: **Forty-six consecutive patients with occipital AVMs were randomized in our study. DTI of the optic radiation was displayed during neuronavigation surgery in 24 patients. The other 22 patients were treated surgically without neuronavigation. Modified Rankin Scale (mRS) scores and visual fields were evaluated preoperatively, immediately after surgery, and at the last follow-up.**

■ RESULTS: **The patients' baseline characteristics and AVM features were statistically similar between the 2 surgical groups. The postoperative obliteration rate was 100%. The postoperative mRS scores did not differ between the 2 groups ($P > 0.05$). Preexisting VFDs were more common ($P = 0.00004$) in patients who bled than in those with unruptured AVMs. The application of DTI-incorporated neuronavigation reduced the frequency and severity of postoperative VFDs ($P = 0.013$ and 0.001, respectively). Visual fields were more likely to be preserved in patients with an AVM >5 mm from the optic radiation ($P = 0.025$).**

■ CONCLUSIONS: **A history of hemorrhage is an independent risk factor for VFDs associated with occipital AVMs. Although not showing superiority in postoperative mRS, functional MRI navigation-guided surgery may help to radically resect occipital AVMs and preserve patient visual fields. A 5-mm distance from the optic radiation may be a suitable safety margin for visual field preservation.**

## INTRODUCTION

Patients with occipital arteriovenous malformations (AVMs) tend to present with visual field disturbances and migraine-like headaches (5, 12, 29). Surgical management of an occipital AVM may also cause new visual field deficits (VFDs) or worsen existing deficits, which can have a significant effect on a patient's quality of life and should be considered a serious disability. Thus, the impact of a VFD such as complete hemianopsia should be strongly considered in the decision-making process for occipital AVMs.

Diffusion tensor imaging (DTI) tractography is currently the only noninvasive technique that enables in vivo visualization of the course and characterization of white matter fiber tracts. With DTI, it has been demonstrated that the least distance from the lesion to the optic radiation was associated with preexisting VFDs and that decreasing the lesion to optic radiation distance was a negative

**Key words**
- Arteriovenous malformation
- Diffusion tensor imaging
- Functional MRI
- Microsurgery
- Neuronavigation
- Visual field deficits

**Abbreviations and Acronyms**
**AVM**: Arteriovenous malformation
**AVM-OR**: Distance from AVM to the optic radiation
**AVM-VC**: Distance from AVM to the visual cortex
**BOLD-fMRI**: Blood oxygen level-dependent fMRI
**DTI**: Diffusion tensor imaging
**fMRI**: Functional magnetic resonance imaging
**MRA**: Magnetic resonance angiography
**MRI**: Magnetic resonance imaging
**TOF-MRA**: Time-of-flight magnetic resonance angiography
**VF**: Visual field
**VFD**: Visual field deficit

*From the [1]Department of Neurosurgery, Beijing Tiantan Hospital, Capital Medical University, Beijing; [2]China National Clinical Research Center for Neurological Diseases, Beijing; [3]Center of Stroke, Beijing Institute for Brain Disorders, Beijing; [4]Beijing Key Laboratory of Translational Medicine for Cerebrovascular Diseases, Beijing; [5]Medical Imaging Center, The 306th Hospital of PLA, Beijing; and [6]Department of Pediatric Surgery, Peking University First Hospital, Beijing, PR China*

*To whom correspondence should be addressed: Shuo Wang, M.D.*
*[E-mail: captain9858@vip.sina.com]*

*Citation: World Neurosurg. (2015) 84, 5:1423-1436.*
*http://dx.doi.org/10.1016/j.wneu.2015.06.069*

*Journal homepage: www.WORLDNEUROSURGERY.org*

*Available online: www.sciencedirect.com*

factor for postoperative visual field preservation (28). However, that study primarily concerned gliomas involving the optic radiation. Until now, the literature has provided few systematic accounts of the relationship between visual field (VF) preservation and the distance from occipital AVMs to the optic radiation or visual cortex.

Radical resection of occipital AVMs carries a high risk of new or worse VFDs. DTI is a new tool that can map the optic pathway in functional magnetic resonance imaging (fMRI). We hypothesized whether fMRI navigation-guided surgery could decrease the risk of VFDs. In this article, we review our series of patients and discuss our preliminary results.

## METHODS

### Patient Population

From January 2013 to January 2015, 46 consecutive patients with occipital AVMs were randomized in a prospective database (Functional Magnetic Resonance Imaging (fMRI) Navigation in Intracranial Arteriovenous Malformation Surgery. NCT01758211). We aimed to compare the risk of VFDs and the functional status in patients with occipital AVMs who were allocated to either fMRI-guided microsurgery or non-navigational microsurgery.

The inclusion criteria were as follows:

1. Patients aged between 6 and 60 years
2. At least 80% of the AVM nidus was located in the occipital lobe on preoperative MRI
3. Data from preoperative structural MRI, blood oxygen level-dependent (BOLD)-fMRI, time-of-flight magnetic resonance angiography (TOF-MRA), and DTI of the optic radiation were available
4. Patients with a definite diagnosis of AVM confirmed by preoperative digital subtraction angiography
5. Patients opting for surgical management at Beijing Tiantan Hospital
6. Patients without any interventional therapy (microsurgery, radiosurgery, endovascular embolization, or multimodality treatment) before admission to our hospital

The exclusion criteria were as follows:

1. Patients with acute intracranial hematoma and resultant brain hernia prompting emergency surgery
2. Patients with a hemorrhagic incident in the past month
3. Nonavailability of BOLD-fMRI and DTI data
4. Patients with other severe diseases that prevented them from having surgery
5. Patients unwilling to participate in the trial

Ultimately, fMRI navigation-guided surgery was performed in 24 patients, and standard microneurosurgery without navigation was carried out in 22 patients. The patient characteristics (age, sex, history of hemorrhage) and AVM characteristics (size, side, venous drainage, Spetzler-Martin grade and diffuseness) were collected prospectively. The study was approved by the local ethics committee and informed written consent was obtained from all adult patients and from the parents of the pediatric patients.

### Imaging Acquisition

Structural MRI scans, (BOLD-fMRI), DTI, and TOF-MRA were performed using a 3-T Siemens Tim Trio MRI (Siemens Healthcare, Erlangen, Germany) scanner as previously described (8, 9, 21, 26). For BOLD-fMRI, the neural activity maps within the visual cortex were generated with a black white checkerboard visual task. All imaging and image processing were performed by the same technical assistant, and all data analysis procedures were conducted by the first author.

### Data Analysis

The preoperative MRI data were saved in DICOM format. The data were transferred to an off-line iPlan 3.0 workstation (BrainLab, Feldkirchen, Germany) for analysis. Motion correction was performed in raw BOLD-fMRI. The raw DTI images were corrected for eddy currents. The TOF-MRA, BOLD-fMRI, and DTI images were then automatically integrated with T1 structural images. Using the general linear model, the BOLD data were analyzed according to the stimuli parameters of the visual task. The three-dimensional model of the visual area was reconstructed according to the activated volumes that were considered to consist of $P = 0.001$ activated areas. For fiber tracking of the optic radiation, the ipsilateral lateral geniculate was selected as the first seed volume. All the fibers crossing this volume of interest were tracked. The second seed volume was the activated visual cortex. Fiber tracking was initiated with fractional anisotropy of 0.2. The three-dimensional anatomic structure of the AVMs was reconstructed by threshold adjustment of the TOF-MRA data. Reconstruction of all of the three-dimensional models prompted a more direct analysis of the relationship between the AVM nidus and the optic pathway (visual cortex and optic radiation).

### Acquisition and Labeling of Important Parameters

Using the iPlan 3.0 software, the maximum diameter of the AVMs was measured from the structural MRI in the axial, coronary, and sagittal directions. The least distances of the AVM from the optic radiation (AVM-OR) and the visual cortex (AVM-VC) were measured in the axial, coronary, and sagittal directions.

### Neuronavigation and the Surgical Process

Microsurgical resection of AVMs was performed in all patients by the same senior physician (the corresponding author). Preoperative multimodality MRI reconstruction data (reconstruction of BOLD-fMRI, DTI, and TOF-MRA) were displayed on a Kolibri WS 2.0 navigation system (BrainLab, Germany) during surgery in 24 patients. Intraoperative ultrasonography and indocyanine fluorescence angiography were used in all cases to discern the margin and feeding arteries of the AVMs.

### Primary Outcome: Visual Fields

VF testing of the central 30° was performed using an Octopus field analyzer (Haag Streit International, Koeniz, Switzerland) by an experienced ophthalmologist who was blinded to the results of the