



## Surgical Treatment of Cavernous Malformations Involving the Posterior Limb of the Internal Capsule: Utility and Predictive Value of Preoperative Diffusion Tensor Imaging

Fuxin Lin<sup>1-4</sup>, Jun Wu<sup>1-4</sup>, Lijun Wang<sup>6</sup>, Bing Zhao<sup>1-4</sup>, Xianzeng Tong<sup>1-4</sup>, Zhen Jin<sup>5</sup>, Shuo Wang<sup>1-4</sup>, Yong Cao<sup>1-4</sup>

■ **OBJECTIVE:** The surgical treatment of cavernous malformations involving the posterior limb of the internal capsule (PLIC-CMs) is challenging. The aim of this study was to determine the utility and predictive value of preoperative diffusion tensor imaging (DTI) in the surgical treatment of PLIC-CMs.

■ **METHODS:** Patients with PLIC-CMs who were surgically treated between September 2012 and June 2015 were reviewed. All patients underwent preoperative DTI. Three major fiber tracts were selected for evaluation: 1) corticospinal tract (CST); 2) arcuate fasciculus (AF); and 3) optic radiation (OR). The utility of preoperative DTI for surgical approach selection and intraoperative navigation was documented. An involvement grading system of the major fibers was applied to determine the predictive value of preoperative DTI. A last modified Rankin Scale (mRS) score of 0–2 was considered a good outcome, and a last mRS >2 was considered a poor outcome.

■ **RESULTS:** Thirteen patients with 13 PLIC-CMs were reviewed in this study. All the lesions were radically resected via the corridor formed by CST, AF, and OR. None of the patients suffered from mRS >3, and 7 patients (53.8%) got good outcomes at the last clinic visit. The difference between the preoperative mRS scores and last mRS scores

was not significant ( $P = 0.673$ ). The involvement grade of the fiber tracts was significantly associated with the surgical outcome ( $P = 0.011$ ).

■ **CONCLUSIONS:** Preoperative DTI may be a promising tool to determine the surgical approach and predict the surgical outcomes in patients with PLIC-CMs.

### INTRODUCTION

Cavernous malformations (CMs) located at the lateral aspect of the posterior thalamus or medial aspect of the lentiform nucleus often involve the posterior limb of the internal capsule. The surgical treatment of cavernous malformations (CMs) involving the posterior limb of the internal capsule (PLIC-CMs) is challenging. Hemorrhage from untreated lesions can result in devastating neurologic injury, but surgery is also associated with potentially serious risks.<sup>1,2</sup> The benefits of surgery for these lesions, namely the elimination of the risk of a stepwise neurologic deterioration, must be weighed against the risks of creating a new or worsening of an existing neurologic impairment during surgery.<sup>3</sup> Given the sensitivity of highly eloquent tissue and distorted anatomic structures by CMs (Figure 1), comprehensive

#### Key words

- Cavernous malformation
- Corticospinal tract
- Diffusion tensor imaging
- Posterior limb of internal capsule
- Surgery

#### Abbreviations and Acronyms

- AF:** Arcuate fasciculus  
**CAO corridor:** Corridor formed by corticospinal tract, arcuate fasciculus, and optic radiation  
**CMs:** Cavernous malformations  
**CST:** Corticospinal tract  
**CST/CM:** Spatial relationships between corticospinal tract and CM  
**DTI:** Diffusion tensor imaging  
**FA:** Fractional anisotropy  
**MRI:** Magnetic resonance imaging  
**mRS:** Modified Rankin Scale  
**OR:** Optic radiation

**PLIC-CMs:** Cavernous malformations involving posterior limb of internal capsule  
**ROIs:** Regions of interest

From the <sup>1</sup>Department of Neurosurgery, Beijing Tiantan Hospital, Capital Medical University, Beijing; <sup>2</sup>China National Clinical Research Center for Neurological Diseases, Beijing; <sup>3</sup>Center of Stroke, Beijing Institute for Brain Disorders, Beijing; <sup>4</sup>Beijing Key Laboratory of Translational Medicine for Cerebrovascular Disease, Beijing; <sup>5</sup>Medical Imaging Center, the 306th Hospital of PLA, Beijing; and <sup>6</sup>Department of Neurosurgery, Hongqi Hospital, Mu Dan Jiang Medical University, Mu Dan Jiang, Hei Long Jiang province, P. R. China

To whom correspondence should be addressed: Yong Cao, M.D.  
 [E-mail: caolaoban6@126.com]

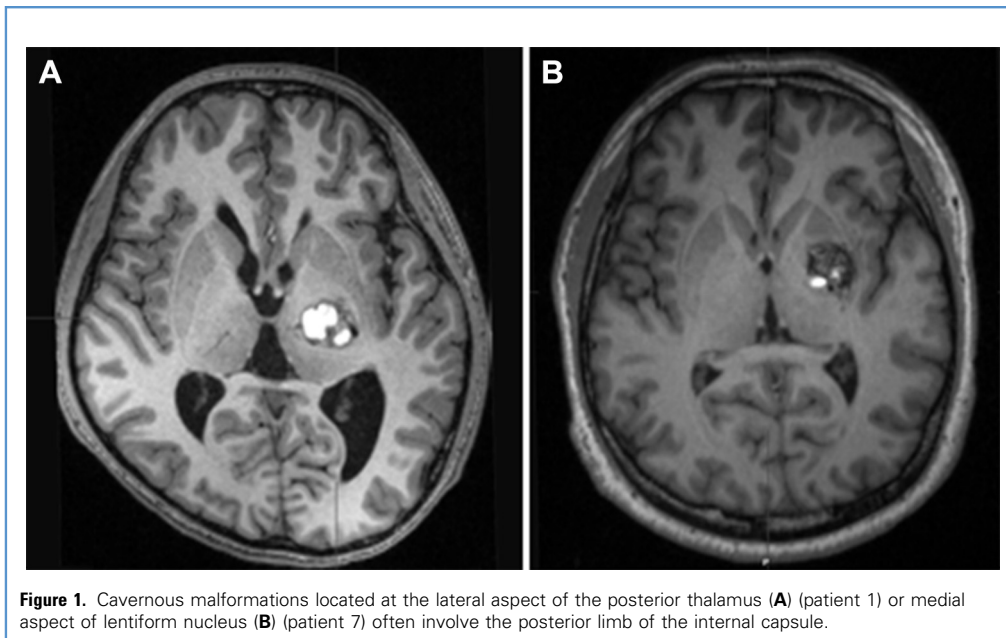
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**Figure 1.** Cavernous malformations located at the lateral aspect of the posterior thalamus (A) (patient 1) or medial aspect of lentiform nucleus (B) (patient 7) often involve the posterior limb of the internal capsule.

preoperative planning is of paramount importance to identify the eloquent tissues around the lesion and select the optimal approach. Diffusion tensor imaging (DTI) tractography is an advanced magnetic resonance technique and the only noninvasive method allowing the in vivo identification of the trajectories of white matter (WM) tracts.<sup>4</sup> According to the literature, DTI reconstructions of the corticospinal tract (CST), arcuate fasciculus (AF), and optic radiation (OR) are reasonably accurate and reliable. Therefore they can be used in the preoperative period for trajectory and resection strategy planning in brain tumor patients.<sup>5,6</sup> Recently, the diffusion tensor properties of CMs and their effect on immediately adjacent brain tissue

have been investigated, and the feasibility of DTI tractography in the context of brain CMs was revealed.<sup>7</sup> Thus preoperative DTI might present new opportunities to identify the eloquent fiber tracts around the lesion and select the optimal approach to improve the surgical outcomes of patients with PLIC-CMs. The aim of this study was to determine the utility and predictive value of preoperative DTI in the surgical treatment of patients with PLIC-CMs.

## METHODS AND MATERIAL

### Clinical Materials

Patients with PLIC-CMs who were surgically treated at the Department of Neurosurgery of Beijing Tiantan Hospital between September 2012 and June 2015 were retrospectively analyzed using data obtained by a review of charts and office visit records. This study was approved by the institutional review board. Two neurosurgeons (EXL, JW) collected the necessary clinical information from our electronic medical system. The baseline information included sex, age, clinical presentation, number of hemorrhages before surgery (No. of hemorrhages), the interval between the last hemorrhage and surgery (ILHS), postoperative events, detailed neurologic examinations, and modified Rankin Scale (mRS) scores at admission, 7 days after surgery and at the last clinic visit. The lengths of inpatient rehabilitation stays and follow-up (at least 3 months) were also recorded. The mRS was used to grade surgical outcomes. A final mRS score of 0–2 was considered a good outcome, and a final mRS >2 was considered a poor outcome.

### Neuroimaging and Functional Findings

All patients underwent conventional brain magnetic resonance imaging (MRI) with and without gadolinium contrast as part of their diagnostic workup. Sizes were measured on thin-slice T1-weighted sequences, including the extralésional hematoma

**Table 1.** Involvement Grading System of Eloquent Fiber Tracts on Preoperative Diffusion Tensor Imaging, Grade = CST score + AF score + OR score

Fiber	Description	Score
CST	Fibers contacting with CMs or Disrupted	3
	Fibers passing through hemosiderin rim but not contacting with CMs, or contacting with associated hematoma	2
	Fibers outside the hemosiderin rim	1
AF	Fibers contacting with CMs	1
	Fibers not contacting with CMs	0
OR	Fibers contacting with CMs	1
	Fibers not contacting with CMs	0

CST, corticospinal tract; AF, arcuate fasciculus, OR, optic radiation; CM, cavernous malformation.

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