Supplementary Material

A grading scale based on arcuate fasciculus segmentation to predict postoperative language outcomes of brain arteriovenous malformations

Expanded Methods and Materials

Neuroimaging

A Brain MRI series were obtained for all patients using a 3.0-T MR scanner (SIEMENS Trio). Sagittal T1-weighted anatomical MR images were acquired using a gradient echo sequence, and the parameters were as follows: TR/TE, 2300/2.98 msec; FOV, 256 mm; slice thickness, 1 mm; total number of slices, 176 slices; matrix size, 64×64 ; voxel size, $1 \times 1 \times 1$ mm³; flip angle, 9°; and bandwidth, 240. The DTI studies were collected using the diffusion-weighted echo-planar imaging technique with the following parameters: TR/TE, 6100/93 msec; FOV, 230 × 230 mm²; slice thickness, 3 mm; total number of slices, 45 slices; matrix size, 128×128 ; and 30-directional motion-probing gradient. Time-of-flight Magnetic Resonance Angiography (TOF-MRA) was performed using a 3D TOF gradient-echo acquisition sequence: TR/TE, 22/3.86 msec, slice thickness 1 mm, slices 36×4 , FOV 220 × 220 mm², flip angle 120°, matrix 512 ×512 [1].

Neuroimaging data analyses

The AF were visualized by DTI tractography. The acquired image data were analyzed on the iPlan cranial 3.0 workstation (Brainlab). All image sets were automatically registered with each other and fused to the anatomical images by automatic rigid registration. We used the posterior parietal area of the superior longitudinal fasciculus and the posterior temporal lobe as the regions of interest to track the AF [2]. Tractography was performed with fiber propagation and stopped when the fractional anisotropy crossed below a threshold of 0.20. A minimum fiber length of 70 mm was selected. Two neurosurgeons (Y.M.J. and J.W.) blinded to the clinical information of the patients documented the locations of the regions of interest and the tracked fibers with consensus.

Arcuate fasciculus classifications

According to the criteria of the AF segments delimitation, two neurosurgeons (Y.M.J. and J.W.) who tracked the AF performed the delimitation, and discrepancies were resolved by a senior neurosurgeon (Y.C.). In the judgement for nidus involvement with segmentation I, II, III, or IV for all patients, we calculated the inter-observer ratio (kappa) between the two neurosurgeons (Y.M.J. and J.W.). Because certain nidus involved two adjacent AF segments, the involvement with segmentation I, II, III, or IV was assessed respectively. Good reproducibility was found for the identification of AF

segmentation involvement (Cohen's κ = 0.937, 0.856, 0.940, and 0.907 for the detection of segmentation I, II, III, and IV involvement, respectively) in all patients.

Surgery

The treatment strategy for bAVMs was selected based on patient condition, perceived surgical risks, and patient requirements. Instead of patients with ruptured bAVMs, those with intractable seizures, severe headache, low Spetzler-Martin grading (S-M grading), or progressive neurological deficits were also considered for surgery [3-5], which was described in our previous work [6]. Four patients received preoperative stereotactic radiosurgery (SRS), and 8 patients received preoperative embolization. Microsurgical resection of bAVMs was performed by an experienced senior physician (Y.C.). A neuronavigation system was used to help preserve white matter tracts. Intraoperative indocyanine fluorescence angiography and ultrasonography were used to discern the feeding arteries and nidus margin of AVMs. We also performed digital subtraction angiography after surgery to validate radical obliteration.

Language function evaluation and follow-up

Language function assessment was conducted by an experienced neurosurgeon (H.L.) who was blinded to the clinical information of the patients at 7 days (short-term outcomes) and at the last follow-up (long-term outcomes) after surgery. The Edinburgh Handedness Inventory was used to determine the language-dominant hemisphere. Lefthanded patients were excluded. Language function was evaluated by the Chinese version of Western Aphasia Battery, which was widely used in the diagnosis of aphasia [7-9]. Additionally, the Aphasia Quotient (AQ) was calculated from the result of the test follows: AQ = (spontaneous)speech score + auditory as comprehension $score/20 + repetition score/10 + naming score/10) \times 2$. An AQ of 93.8 or higher (maximal AQ = 100) indicates normal language function while less than 93.8 indicates aphasia [10,11]. We also ensured that no patients had any hearing disturbance or motor paresis due to pyramidal tract disturbance, both of which could affect the Western Aphasia Battery results.

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Supplementary Tables

Supplementary Table 1 Difference in baseline characteristics	between patients with and	without postoperative LD.
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	Short-term LD			Long-term LD		
Variables	No (n =73)	Yes (n =62)	P value	No (n =121)	Yes (n =14)	P value
Age (mean \pm SD, years)	27.0±12.5	29.6±11.9	0.220‡	27.3±11.4	35.4±16.9	0.113 [‡]
Male, no. (%)	51 (69.9)	39 (62.9)	0.393 [§]	79 (65.3)	11 (78.6)	0.385 [§]
LD history, no. (%)	5 (6.8)	14 (22.6)	$0.009^{\$}$	11 (9.1)	8 (57.1)	<0.001 ^{§¶}
Size (mean \pm SD, mm)	33.0±12.7	39.3±15.6	0.011 ^{‡¶}	35.8±14.0	36.8±17.7	0.802^{\ddagger}
Hemorrhage, no. (%)	38 (52.1)	31 (50.0)	0.812 [§]	57 (47.1)	12 (85.7)	$0.006^{\$}$
Deep perforating arteries feeding, no. $(\%)^*$						
AChA feeding	2 (2.7)	9 (14.5)	0.013 ^{§¶}	6 (5.0)	5 (35.7)	$0.002^{\$}$
PChA feeding	2 (2.7)	5 (8.1)	0.247 [§]	7 (5.8)	0 (0.0)	$1.000^{\$}$
LLSA feeding	9 (12.3)	8 (12.9)	0.920 [§]	12 (9.9)	5 (35.7)	0.017 ^{§¶}
DV drainage, no. (%)	5 (6.8)	7 (11.3)	0.366 [§]	10 (8.3)	2 (14.3)	0.360 [§]
Diffuse nidus, no. (%)	10 (13.7)	18 (29.0)	0.029 ^{§¶}	24 (19.8)	4 (28.6)	$0.488^{\$}$
S-M grading (mean \pm SD)	2.5±0.7	2.6±0.8	0.455 [‡]	2.5±0.7	2.6±1.1	0.667^{\ddagger}
AF segments involvement, no. (%) [†]						
I	33 (45.2)	18 (29.0)	0.053 [§]	46 (38.0)	5 (35.7)	0.866 [§]
II	5 (6.8)	14 (22.6)	0.009 ^{§¶}	12 (9.9)	7 (50.0)	0.001 ^{§¶}
III	28 (38.4)	33 (53.2)	$0.084^{\$}$	56 (46.3)	5 (35.7)	0.452 [§]
IV	16 (21.9)	9 (14.5)	$0.270^{\$}$	21 (17.4)	4 (28.6)	$0.292^{\$}$

Abbreviations: AChA= anterior choroidal artery; AF= arcuate fasciculus; DV= deep venous; LD= language deficits; LLSA= lateral lenticulostriate artery; PChA= posterior choroidal artery; S-M = Spetzler-Martin. *BAVMs supplied by more than one deep perforating arteries were counted repeatedly; [†]BAVMs involving more than one AF segments were counted repeatedly; [‡]t-test; [§]Chi-square test; [¶]P Value< 0.05.

Supplementary Table 2 Comparison of surgical outcomes of patients with type IV AF-bAVMs.

	Subtypes of			
Variables	IVa	IVb	P value	
	(n =8)	(n =17)		
Short-term LD, no. (%)	7 (87.5)	2 (11.8)	$0.001^{*\dagger}$	
Long-term LD, no. (%)	3 (37.5)	1 (5.9)	0.081^{*}	
Complications, no. (%)	2 (25.0)	5 (29.4)	1.000^{*}	

Abbreviations: AF-bAVMs= brain arteriovenous malformations (bAVMs) involving arcuate fasciculus; LD= language deficits; * Chi-square test; †P value< 0.05.

Supplementary Table 3 Difference in postoperative LD between patients with and without language eloquence involvement.

	Short-term LD			Long-term LD		
Language eloquence	No	Yes (n =62)	P value	No	Yes	P value
	(n =73)			(n =121)	(n=14)	
Broca' area, no. (%)			0.226*			0.685*
Yes	22 (62.9)	13 (37.1)		32 (91.4)	3 (8.6)	
No	51 (51.0)	49 (49.0)		89 (89.0)	11 (11.0)	
Wernicke's area, no. (%)			0.696*			0.596*
Yes	19 (51.4)	18 (48.6)		34 (91.9)	3 (8.1)	
No	54 (55.1)	44 (44.9)		87 (88.8)	11 (11.2)	

Abbreviations: LD= language deficits. *Chi-square test.