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Complete Obliteration of Intracranial Arteriovenous Malformation with Endovascular Cyanoacrylate Embolization: Initial Success and Rate of Permanent Cure

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BACKGROUND AND PURPOSE: **Endovascular treatment with cyanoacrylate embolization is an option when complete obliteration of the nidus of an intracranial arteriovenous malformation (AVM) is the goal. Our purpose was to evaluate the rates of initial success and permanent cure of such treatment in a Chinese population.**

METHODS: **Twenty-seven consecutive patients with an intracranial AVM underwent endovascular embolization with cyanoacrylate between June 1995 and May 1997. Twenty-six patients had cerebral AVMs and one had a cerebellar AVM. Curative embolization was attempted in 10 patients in whom 1) the nidus was not larger than 3 cm, 2) the number of feeders did not exceed three, and 3) the nidus was accessible with the tip of the catheter. We used a flow-directed microcatheter and a 20–25% mixture of cyanoacrylate in contrast medium. Long-term outcomes were observed angiographically and clinically.**

RESULTS: **Complete embolization was achieved in six patients. No procedure-related complications occurred during attempted curative embolization. Follow-up angiography performed at 17–32 months showed complete obliteration of the AVM nidus in the six patients after initial embolization. These patients remained asymptomatic 5–7 years after treatment. The rate of permanent cure of the initially complete embolization was 100% (six of six). The success rate of endovascular cure for patients treated with curative intent was 60% (six of 10). The overall cure rate was 22% (six of 27).**

CONCLUSION: **The overall initial cure rate of intracranial AVM with cyanoacrylate embolization was 22%. Initial angiographic evidence of complete embolization indicated permanent cure in these patients.**

Treatment options for intracranial arteriovenous malformations (AVMs) include radiosurgery, conventional surgery, and endovascular embolization. Applications of endovascular treatment include curative embolization, nidus reduction before conventional surgery or radiosurgery, and palliative embolization. The goal of curative embolization is the complete and permanent obliteration of the AVM nidus, with the restoration of normal arterial blood flow and the preservation of venous drainage.

Currently, cyanoacrylates are the most effective materials for endovascular embolization (1). Curative embolization with cyanoacrylate has been considered possible in 5–10% of patients with AVMs. Success rates for curative embolization of intracranial AVMs vary greatly. Although a success rate as high as 40% has been reported (1), the rate is lower in most other reports (2–5). Moreover, permanency of the initially complete obliteration of the nidus has not been well assessed. We aimed to evaluate the rates of initial success and permanent cure of complete AVM obliteration with cyanoacrylate embolization in a Chinese population.

Methods

Our institutional review board approved this prospective study. Forty-two consecutive patients with intracranial AVMs were included between August 1995 and April 1998. Tables 1

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TABLE 1: Demographic data and outcomes of patients initially treated with endovascular embolization

Sex/Age (y)	Presentation	Location	AVM Size (cm)	Spetzler and Martin Grade	Embolizations	Glue	Complication	Initial Angiographic Occlusion	Subsequent Procedure	Latest Angiographic Outcome	Modified Rankin Score
M/35	Headache, LOC	L temporal	1.8	2	1	0.3 mL 16%	None	80%	Radiosurgery	No residual	1
M/24	ICH	R frontal	2.7	1	1	0.4 mL 25%	None	Near-complete	Radiosurgery	No residual	1
M/46	ICH	R temporal	5	2	1	0.5 mL 25%	ICH	90%	Excision	No residual	5
M/46	ICH	R frontoparietal	4.5	4	1	0.3 mL 25%	None	70%	Excision	No residual	1
F/17	ICH	L occipital	3.8	3	1	0.9 mL 25%	None	60%	Excision	Residual	0
F/26	Seizure	L parietal	2.5	2	1	0.7 mL 25%	None	40%	Radiosurgery	No residual	1
F/31	ICH	R thalamic	4.8	4	1	1.1 mL 25%	None	40–50%	None	Residual	4
M/25	IVH	Corpus callosum	2.6	2	2	0.6 mL 25%	None	Complete	None	No residual	1
M/48	Seizure	R parietal	6.7	5	1	0.3 mL 25%, 0.7 mL 33%	None	30%	Radiosurgery	Residual	1
F/29	Seizure	R parieto-occipital	7	5	3	1.7 mL 20%, 0.9 mL 25%	Transient headache	80–85%	Radiosurgery	Residual	0
F/24	Incidental	R parietal	3.8	4	3	0.6 mL 20%, 0.4 mL 25%	None	60%	Excision	Residual	0
F/11	ICH	R temporal	3	2	1	2 mL 25%	None	Complete	Radiosurgery	No residual	1
M/16	ICH	L parieto-occipital	4	3	2	0.2 mL 25%	None	Near-complete	Radiosurgery, excision	No residual	0
F/43	Headache	R frontal	3.8	2	1	1.2 mL 25%	None	80%	Excision	No residual	1
M/44	Seizure	R parietal	1	2	1	0.2 mL 20%	None	Near-complete	Radiosurgery	No residual	2
M/30	ICH	L temporal	2	1	1	0.3 mL 25%	None	66%	Excision	No residual	1
F/22	Headache	L occipital	5.3	4	2	3.4 mL 25%	None	80%	Radiosurgery	No residual	1
M/22	ICH	L temporoparietal	4.3	3	2	1.4 mL 25%	None	80%	Radiosurgery	No residual	1
F/44	Seizure	L temporal	6.3	4	3	2.2 mL 20%	L hemiparesis and dysphasia at third stage	Near-complete	None	No residual	4
M/27	ICH	L frontal	6	2	4	1.7 mL 25%	None	80%	Radiosurgery	Residual	1
F/12	ICH	R thalamus	5.7	4	1	2.3 mL 25%	None	70%	Radiosurgery	Residual	2
F/13	ICH	R cerebellum	1.3	3	1	0.3 mL 25%	None	Complete	None	No residual	0
M/32	Headache	L parietal	6.7	5	4	1.4 mL 25%*	None	60%	Radiosurgery, excision	No residual	2
M/55	ICH	L temporal	2.5	1	1	0.8 mL 25%	Gluing of catheter	Unknown	Excision on same day	No follow-up	6†
M/43	ICH	L occipital	1.2	2	1	0.3 mL 20%	None	Complete	None	No residual	0
F/11	ICH	L temporoparietal	2.5	2	1	0.5 mL 25%	None	Complete	None	No residual	0
M/33	IVH	Corpus callosum	1.3	2	1	0.2 mL 20%	None	Complete	None	No residual	0

Note.—ICH indicates intracerebral hemorrhage; IVH, intraventricular hemorrhage; and LOC, loss of consciousness.

* Embolization of an arteriovenous fistula with a Guglielmi detachable coil.

† Died of massive brain infarct after surgery.

and 2 list patient demographic data and characteristics of their AVMs.

Patients

Patients were examined with CT and digital subtraction angiography. During these studies, diagnosis was confirmed, and location of AVM, size of nidus, number of arterial feeders, and site of draining veins were defined.

Fifteen patients were treated with surgical excision without preoperative embolization. Fourteen presented with acute intracerebral hemorrhage. Of these, three required craniotomy to evaluate a blood clot and underwent simultaneous AVM excision. Two of the 15 patients had a cerebellar AVM with AVM feeders close to the arterial feeders of the brain stem; they were therefore treated with surgical excision. Surgical excision was offered to the other 10 patients, because their AVMs were of Spetzler and Martin grade 1 or 2 (6).

Twenty-seven patients were treated with endovascular cyanoacrylate embolization. Ten of these patients had an AVM 3 cm or smaller, and they preferred embolization to surgical excision because of reduced invasiveness. Seventeen patients had a relatively large AVM that was not amenable to surgical resection; they required endovascular embolization either as a size-reducing preoperative procedure or as a flow-reducing palliative procedure.

Patient Selection for Curative Embolization

Patients whose AVM features fulfilled the following criteria were selected to undergo endovascular embolization with curative intent: 1) the AVM nidus was not larger than 3 cm, 2) the number of AVM feeders was not more than three, 3) the AVM nidus was accessible with the tip of microcatheter. On the basis of these criteria, we selected 10 patients (seven male, three female; average age ± SD, 30.6 years ± 13.7; range, 11–57 years). AVM nidus range was 1–3 cm, with a median of 2.2 cm and an average of 2 ± 0.7 cm. The lesions were fed by one feeder in eight patients, by two feeders in one patient, and by three feeders in one patient. According to the Spetzler and

TABLE 2: Demographic data and outcomes of patients initially treated with surgical excision

Sex/Age (y)	Presentation*	Location	Spetzler and Martin Grade	Treatment	Latest Angiographic Outcome	Modified Rankin Score
F/32	ICH	R parietal	2	Excision	No residual	2
F/18	ICH	L occipital	1	Excision	Small residual	0
F/5	ICH	R parietal	2	Excision	No residual	2
F/69	ICH	R occipital	2	Excision	No residual	1
M/20	ICH	R temporal	1	Excision, radiosurgery	Small residual	1
M/10	ICH	L frontal	1	Excision	No residual	0
M/36	ICH	L frontal	1	Excision	No residual	2
M/14	Seizure	L frontal	1	Excision	No residual	1
M/37	ICH	L parietal	1	Excision	No residual	1
M/12	ICH	Cerebellar	3	Excision	No follow up	5
F/29	ICH	Putamen	3	Excision	No follow up	6
F/34	ICH	R frontal	1	Excision	No follow up	6
F/18	ICH	Cerebellar	2	Excision, radiosurgery	No residual	1
M/49	ICH	Cerebellar	3	Excision	No residual	6†
M/27	ICH	R frontal	1	Excision	No follow up	‡

* ICH indicates intracerebral hemorrhage.

† Died of lung carcinoma.

‡ No follow-up.

Martin scale, the patients had two grade 1 lesions, seven grade 2 lesions, and one grade 3 lesion.

Embolization Procedure

Informed consent was obtained from each patient before the procedure. The embolization procedures were performed by one radiologist (M.S.Y.C.) who had 5 years' experience in interventional neuroradiology. In 11 patients, the procedure was performed with local anesthesia, with a selective arterial Amytal test with a coaxial technique carried out before embolization. In the other 18 patients, the procedure was performed with general anesthesia, and the patient was closely monitored by an anesthesiologist.

Systemic heparin with a dose of 3000 U was given as an intravenous bolus. The AVM nidus was accessed with a flow-directed, 1.8F, 1.5F, or 1.2F Balt Magic microcatheter (Target Therapeutics, Fremont, CA); this was introduced through a 6F guiding catheter. We used a mixture of 20–25% Histoacryl (B Braun, Aesculap, Tuttlingen, Germany) in Lipiodol (Guerbet, Aulney-Sous-Bois, France) to obliterate the nidus, depending on the flow dynamics of the AVM.

Postembolization angiography was performed, and the images were interpreted by the radiologist who performed the embolization, together with two neurosurgeons (W.S.P., J.M.K.L.), to assess the degree of nidus obliteration.

Follow-up Observation and Subsequent Treatment

The patients were hospitalized for at least 3 days after the procedure for clinical observation by the neurosurgeons. No anticoagulation therapy was given to patients with incomplete AVM obliteration. For those with complete AVM obliteration and an increased risk of retrograde thrombosis in the stump of the feeder artery, low-molecular-weight heparin was given subcutaneously for 3 days. No special measure was used to manage the patients' blood pressure in the immediate post-treatment period.

Patients with residual AVMs after embolization were offered subsequent treatment, including surgical excision, radiosurgery after 1998, or a combination of excision and radiosurgery.

Follow-up angiography was performed for at least 1 year after the treatment procedure in patients with complete obliteration of the nidus after embolization and in those undergoing subsequent treatment. The radiologist who performed the embolization interpreted the follow-up angiograms, together with the two neurosurgeons. Regular clinical follow-up was provided for at least 5 years. The clinical examinations were performed by neurosurgeons.

Results

No procedure-related complications occurred in the 10 patients in whom curative embolization was attempted. Complete nidus occlusion was achieved in six patients. Five patients required one treatment session, and one patient required two sessions. In two of these six patients, the AVM was located in the deep supratentorial region, three were in the supratentorial convexity region, and one was in the cerebellum. The number of arterial feeders for these lesions ranged from one to three, with a median of one and an average of 1.5.

In these six patients, follow-up angiography was performed 17–32 months after embolization (average, 23 months). Images showed that the AVM lesions remained completely obliterated without evidence of recurrence. These patients remained clinically asymptomatic 5–7 years after embolization.

On the basis of these results, we conclude that the permanent or long-term cure rate after initial complete occlusion of the nidus was 100% (six of six). The success rate of endovascular cure for patients treated with curative intent was 60% (six of 10). The overall cure rate was 22% (six of 27).

Twenty-one patients had a residual AVM after embolization. Seven were subsequently treated with surgical excision, 11 were treated with radiosurgery between April 1998 and June 2002, and two were treated with a combination of excision and radiosurgery. Table 1 shows the clinical and angiographic outcomes of all 27 patients treated with embolization. Table 2 provides the clinical outcomes of the 15 patients initially treated with surgical excision.

Discussion

In many intracranial AVMs, lesions are not amenable to surgery or radiosurgery. Surgery is usually limited to relatively small lesions located in noneloquent regions without complex deep venous drainage, such as Spetzler Martin grade 1 or 2 lesions (7). In contrast, radiosurgery is restricted to lesions smaller than 3 cm. Endovascular embolization provides a treatment option.

Small AVM lesions that fulfill the selection criteria for curative embolization are likely to be suitable for surgical excision or radiosurgery as well. In fact, the treatment outcome of these two other options is extremely good. The risk of major complications from surgical excision is close to zero for AVM lesions smaller than 3 cm (7). For radiosurgery, the risk of major complications for AVM lesions in the cerebral cortex and smaller than 2 cm is also close to zero (8), and the risk is less than 5% in lesions smaller than 3 cm diameter (9–11). Nevertheless, endovascular embolization remains a less invasive alternative for patients who are reluctant to undergo open surgery or too anxious to wait for the therapeutic effects of radiosurgery. Although embolization poses a risk of intracranial hemorrhage and stroke, the complication rate is minimal and comparable to that of surgery and radiosurgery in patients selected according to the criteria for curative embolization; this observation is exemplified by the zero complication rate in the present series of patients treated with curative intent. The only treatment-related mortality was due to massive brain infarction after surgery, which was performed to remove a glued catheter complicating an embolization procedure. It is now understood that the surgical removal of such glued catheters is not necessary.

The goal of endovascular embolization is the permanent and complete obliteration of the AVM nidus and the restoration of normal cerebral blood flow (12). Despite that cyanoacrylate embolization is the most effective technique for endovascular embolization (1, 13), endovascular cure of an AVM is considered unusual if not rare (13). Only about 40% of practitioners who routinely perform cyanoacrylate embolizations of intracranial AVMs claim to have achieved a true cure of any AVM (8). The most widely reported endovascular cure rates for AVMs are in the range of 5–10% (2–5, 13).

An initially high degree of obliteration of the AVM nidus may be followed by its recurrence shortly after embolization. The extent to which the collateral supply develops and the time required for its development may depend on the degree of nidus obliteration and the material used for the obliteration. Permanent, complete endovascular cure is considered possible with the use of cyanoacrylate. The degree of permanent obliteration is probably high but remains unknown (13).

In the present study, we found that the permanent cure rate of initially complete endovascular cure was 100%, as evaluated by use of follow-up angiography performed 17–32 months after treatment. We believe that complete AVM obliteration at such delayed follow-up is a reliable indication of permanent cure, as an AVM is unlikely to recur after such a long time. A similar finding at 4-month follow-up also suggests permanent cure (13).

The size of the AVM nidus was one of the selection criteria we adopted for attempted curative embolization in this study. About 34% of the AVM lesions in our series were 3 cm or smaller; this percentage concurs with the 30% reported in another larger series (14). Of 10 patients who had received attempted curative embolization, six had successful complete embolization, resulting in an initial success rate of 60%. Our overall initial success rate of 22% was higher than that reported in most series in the literature.

The criteria we adopted for attempted curative embolization were based on radiologic observation of the features of AVM lesions regarding the technical feasibility and likelihood of complete embolization. We had not considered a comprehensive analysis of the angioarchitecture of the AVM and the intrinsic vascular composition of the AVM nidus, as is possible with superselective angiography; although Valavanis and Christoforidis (1) recommend this approach. In that consecutive series of 387 patients, the overall success rate of complete embolization was 40%. This was an exceptionally high rate not yet reproduced; perhaps it was related to a detailed analysis of the angioarchitecture and vascular composition before the procedure. However, the authors did not report the long-term success rate or the permanency of the initial success. Another limitation of our current study was that the assessment of success was based on the assumption that complete nidus obliteration at 17–32 months was equivalent to permanent cure.

Conclusion

The overall initial cure rate for intracranial AVMs treated with cyanoacrylate embolization was 22%. In select patients treated with curative intent, the initial cure rate was 60%. The rate of permanency cure was 100%. Initial angiographic evidence of complete embolization indicated a permanent cure.

References

1. Valavanis A, Christoforidis G. **Endovascular management of cerebral arteriovenous malformations.** *Neurointerventionist* 1999;1:34–40
2. Deruty R, Pelisson-Guyorat I, Mottolese C, et al. **The combined management of cerebral arteriovenous malformations. Experience with 100 cases and review of the Literature.** *Acta Neurochirurgica (Wien)* 1993;123:101–112
3. Fournier D, TerBrugge KG, Willinsky R, et al. **Endovascular treatment of intracerebral arteriovenous malformations: experience in 49 cases.** *J Neurosurg* 1991;75:228–233
4. Hurst RW, Berenstein A, Kupersmith MJ, et al. **Deep central arteriovenous malformations of the brain: the role of endovascular treatment.** *J Neurosurg* 1995:82:190–195
5. Wilms G, Goffin J, Plets C, et al. **Embolization of arteriovenous malformations of the brain: preliminary experience.** *J Belge Radiol* 1993;76:299–303

6. Spetzler RF, Martin NA. **A proposed grading system for arteriovenous malformations.** *J Neurosurg* 1986;65:476–483
7. Hamilton MG, Spetzler RF. **A prospective application of a grading system for arteriovenous malformation.** *Neurosurgery* 1994;34:2–6
8. Pollock BE, Flickinger JC. **A proposed radiosurgery-based grading system for arteriovenous malformations.** *Neurosurgery* 2002;96:79–85
9. Columbo F, Pozza F, Chierego G, Casentini L, DeLuca G, Francescon P. **Linear accelerator radiosurgery of cerebral arteriovenous malformations.** *Neurosurgery* 1994;34:14–21
10. Steiner L, Lindquist C, Adler JR, Torner JC, Alves W, Steiner M. **Clinical outcome of radiosurgery for cerebral arteriovenous malformations.** *J Neurosurg* 1992;77:1–8
11. Karlsson B, Lax I, Soderman M. **Factors influencing the risk for complications following gamma knife radiosurgery of cerebral arteriovenous malformations.** *Radiother Oncol* 1997;43:275–280
12. Aletich VA, Debrun GM. **Intracranial arteriovenous malformations: the approach and technique of cyanoacrylate embolization.** In: Connors JJ, Wojak JC, eds. *Interventional Neuroradiology: Strategies and Practical Techniques. W. B. Saunders Company;* 1999:240–258
13. Connors JJ, Wojak JC. **Intracranial arteriovenous malformations: general considerations.** In: Connors JJ, Wojak JC, eds. *Interventional Neuroradiology: Strategies and Practical Techniques.* Philadelphia: W. B. Saunders Company; 1999:227–240
14. Valavanis A. **Arteriovenous malformations of the brain.** In: *Interventional Neuroradiology.* Berlin: Spinger-Verlag; 1993:93–110