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Endovascular transvenous treatment for superficial intracranial arteriovenous malformations

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A B S T R A C T

Objective: The objective of this study was to evaluate the feasibility and outcomes of transvenous endovascular embolization (TVE) for superficial intracranial arteriovenous malformations (AVMs).
Methods: After collecting clinical and imaging data, a prospective series of 11 patients presenting with superficial AVMs were treated by endovascular embolization using a transvenous approach between November 2016 and October 2018.
Results: Ten patients (90.9%) had ruptured AVMs before TVE. The mean nidus size was 3.27 ± 1.47 cm, and the median Spetzler-Martin grade was II. The rate of immediate angiographic occlusion of the AVMs was 90.9% (10/11). One patient was treated with transarterial embolization since TVE was not achieved due to an unsuccessful positioning of the microcatheter. Two patients (cases 8 and 11) suffered a intracranial hemorrhage and a cerebral infarction with encephaledema, respectively, but no procedure-related mortalities were observed. Eight patients (72.7%) were independent with a modified Rankin Score (mRS) ≤ 2 at discharge and the mRSs of all patients, which were collected 30 days postintervention, were not more than 2. The mean follow-up period was 17 months. There were no nidus recurrences during the follow-up period.
Conclusions: The curative transvenous embolization of superficial AVMs seems feasible and effective while carefully monitoring for embolization-related complications.

Conventional approaches (neurosurgery, transarterial embolization, stereotactic radiotherapy) for the treatment of superficial intracranial arteriovenous malformations (AVMs) still have deficiencies. Patients who were treated with neurosurgical techniques suffered higher complication rates.[1] Large malformations are still not suitable for stereotactic radiotherapy (SR) because of the delay in the obliteration of the lesion and high radiation-induced brain injuries.[2] Curative occlusion was achieved in only 23.5% of the patients for transarterial embolization.[3] However, the development of embolization materials and techniques have improved, which reduces complication rates and increases cure rates during AVM embolization. Recent studies have demonstrated that transvenous treatment of AVMs had satisfactory clinical outcomes,[4–6] but these were not unified indications for transvenous treatment. In this study, we summarized the use of TVEs for the treatment of superficial AVMs.

1. Methods

1.1. Patients and clinical decision making

This prospective study was approved by the Institutional Ethics Committee of Zhengzhou University People's Hospital and written informed consent was obtained from each participant. Eleven cases were included in this study between November 2016 and October 2018. Therapeutic methods were determined on a multidisciplinary basis. All procedures were performed by the same team of experienced interventional neuroradiologists and other relevant professionals. Baseline clinical and angiographic data were collected from all patients.

All patients received TVEs if they met the following criteria: 1) the location of the nidus was superficial, 2) patients refused to undergo neurosurgery or SR or their lesions were not suitable for neurosurgery or SR, and 3) patients or their legal representatives were capable of signing written informed consents.

1.2. Embolization procedure

All procedures were performed under general endotracheal anesthesia and full heparinization by the same team of experienced interventional neuroradiologists and supporting personnel. Catheterization was performed in all patients using a femoral approach with a 6-F sheath, and selective digital subtraction angiography (DSA) was performed before each treatment to further evaluate the angioarchitecture of the nidus. Depending on the location of the AVMs, the right or left jugular

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vein was punctured and a 6-F venous sheath was inserted.

A 6-F transarterial guiding catheter (Envoy; Codman & Shurtleff, Inc., Raynham, Massachusetts, USA), used for control injections, and in cases of double arterial and venous treatments, was positioned in the cervical internal artery or the vertebral artery. One or two transvenous microcatheters (Marathon [Medtronic]; Apollo [Medtronic]; Echelon [Medtronic]; or Headway DUO [Micro Vention, Inc., Aliso Viejo, California, USA]) were then moved through the draining vein of the AVMs and placed next to the nidus.

Due to the high risk of hyperperfusion intracranial hemorrhage, one of the following methods was used to control mean arterial pressure: 1) ethylene vinyl copolymer (Onyx-18) was the embolic agent of choice for the transarterial injection, although alcohol was used as an embolic material in 2 cases; or 2) temporary balloon occlusion of the main arterial feeder. The transvenous embolization was initiated by slowly injecting Onyx-18, Glubran-2, or an ethylene vinyl alcohol copolymer (EVAL-I), using a pressure cooker technique,[7] into the nidus. After anatomically obliterating the AVMs, the microcatheters were cut with a blade at the level of the jugular sheath.

All patients underwent a brain computed tomography (CT) scan postoperatively to rule out any intracranial hemorrhage. Blood pressure was then closely monitored for 2–3 days to prevent hyperperfusion syndrome.

1.3. Follow-up

Pre-embolization, immediate postembolization, and follow-up angiographic results at 6 and 18 months postembolization were evaluated as: total occlusion, residual nidus as a percentage of the total AVM volume, or AVM volumes larger than pre-embolization. All patients underwent brain magnetic resonance imaging (MRI) 24–48 h before and after embolization, and at 6, 18, and 36 months after embolization, performed in a 3-T system (Achieva, Philips Medical System) with a T2-weighted spin-echo sequence with fluid-attenuated inversion recovery (FLAIR), a T2-weighted sequence, a 3D T1-weighted sequence, and diffusion-weighted imaging (DWI) to evaluate for potential ischemia and encephaledema.

1.4. Statistical analysis

Categorical and continuous variables were presented as numbers and ranges. Quantitative indicators are described in terms of means ± standard deviations, medians, minimums, and maximums.

2. Results

All patients presenting with superficial AVMs who underwent TVEs at our hospital between November 2016 and October 2018 were included in this study.

2.1. Baseline characteristics and endovascular approaches

Clinical and imaging data are shown in Table 1. Nine male and 2 female patients (mean age 33 ± 18 years, range 12–59) who suffered AVMs and who refused to accept or whose conditions precluded conventional endovascular, neurosurgical techniques and SRs, were treated by TVE. Among these patients, all but 1 (case 7) suffered from cerebral hemorrhages. Five patients presented with cerebral parenchymal hemorrhages, 5 with intraparenchymal hemorrhages breaking into the ventricle, and only 1 patient had a subarachnoid hemorrhage (SAH). Two patients had trepanations and drainage evacuations of hematomas during hospitalization. Only two cases[8 and 11] presented with neurological deterioration (modified Rankin Score (mRS): 5 and 1, respectively) at discharge. All AVMs had single superficial draining veins. The mean nidus size before TVE was 3.27 ± 1.47 cm. The initial Spetzler-Martin grade, before we initiated TVE, wasIfor 5 patients (45.5%), II for 2

Table 1
Patients' clinical characteristics, AVM angioarchitecture, and outcomes.

Case No.	Age (y)/Sex	Location	S-M Grade	Venous Drainage/No.	Previous Embolization	Technique	Complications	mRS Score			Immediate Occlusion
								Preoperative	At Discharge	Final/Mos	
1	59/M	T/L	III	Cortical cerebral vein/1	No	DAC + TVE	No	1	1	0/25	Yes
2	20/M	P/R	III	Cortical cerebral vein/1	No	SAC + TVE	No	4	4	1/23	Yes
3	59/M	F/L	I	Cortical cerebral vein/1	No	DAC + TVE	No	3	1	1/21	Yes
4	14/M	F,T/L	II	Labbé vein/1	Yes	DAC + TVE	No	1	0	0/21	Yes
5	54/M	O/L	III	Cortical cerebral vein/1	Yes	SAC + TVE	No	1	1	0/21	Yes
6	31/M	T/L	I	Cortical cerebral vein/1	Yes	DAC + TVE	No	1	0	0/21	Yes
7	19/M	F,P/R	I	Cortical cerebral vein/1	No	DAC + TVE	No	1	1	0/15	Yes
8	49/F	T/R	I	Cortical cerebral vein/1	No	DAC + TVE	Hemorrhage	4	5	1/15	Yes
9	12/M	F/L	I	Cortical cerebral vein/1	No	TAE + surgery	No	5	4	2/14	No
10	31/M	F/L	II	Cortical cerebral vein/1	Yes	DAC + TVE	No	0	0	0/9	Yes
11	16/F	F,P/L	III	Cortical cerebral vein/1	No	DAC + TVE	Infarction	0	1	0/2	Yes

DAC: double arterial catheterization, F: frontal, L: left, mRS: modified Rankin Scale, NA: not available, O: occipital, P: parietal, R: right, S-M: Spetzler-Martin, SAC: single arterial catheterization, T: temporal, TAE: transarterial endovascular embolization.

patients (18.2%), and III for 4 patients (36.4%). Seven (63.6%) patients were treated with a single-session transvenous embolization approach, while in 4 (36.4%), we implemented conventional transarterial embolization before the final TVE.

2.2. Anatomic results

All procedures were performed with TVEs, although the Apollo microcatheter (Ev3, Irvine, CA, USA) failed to get as close as possible to the nidus via the drainage vein in 1 case. An anatomic cure rate was documented in 10 (90.9%) cases. Onyx-18 was used alone in 6 sessions, Onyx-18 combined with EVAL-I was used in 2 sessions, EVAL-I was used alone in 2 sessions, and Glubran-2 was used only in 1 session. Only patient 9 had supplementary treatments. For the pressure cooker technique, coils were implanted before liquid agent injections through the TVEs in 10 sessions.

2.3. Complications and outcomes

A total of 2 (14%) cases presented technical or clinical complications (patients 8 and 11): 1 (9%) case of a hemorrhagic complication (thalamus hemorrhage breaking into the ventricle), who was treated with trepanation and drainage; and 1 (4.5%) case of a ischemic complication, who was treated with adjuvant drugs. Two cases achieved an mRS score of no more than 2 30 days postoperatively (Fig. 1).

2.4. Clinical and angiographic follow-up

Immediate and complete exclusion was achieved in 10 cases (90.9%). One case's procedure failed and that patient subsequently received transarterial endovascular embolization and a craniotomy. The median follow-up for all patients was 21 months (range: 2–25). Six patients underwent angiography and 2 patients had brain MRIs at 3–6 months postintervention, with complete exclusion of the nidus being confirmed. The mRS scores were assessed at postoperative day 30 and the score was 2 in 1 patient and not more than 1 in the remaining patients.

3. Discussion

3.1. Treatment options

The treatment options for AVMs include microsurgery, transarterial endovascular embolization, SR, and the novel transvenous endovascular embolization. The angioarchitecture, location, and symptomatology of AVMs usually determine the choice of treatment methods.[3] However, the decision for which treatment is suitable for an AVM may often be controversial. The aim of all treatment options is to completely embolize the AVM. The narrowness and tortuosity of the feeding artery pose a great challenge to the traditional endovascular embolization approach which often is an adjunctive technique.

Only a few previous case reports or series of AVMs have been performed using a transvenous endovascular approach. Viana et al.,[4] published a series of 12 AVM cases where a transvenous embolization strategy was used with a curative intent. Ten of the AVMs were supratentorial (83.3%) and 2 (16.7%) were infratentorial. The superficial AVMs were treated using a transvenous method while simultaneously assessing the safety and efficacy of this type of approach. Obliteration was achieved in all patients at the 6-month follow-up and no procedural or clinical complications were noted in this group of patients. Iosif et al.,[8] published their experiences with transvenous Onyx embolization. Of 5 occluded superficial AVMs, only one arterial pedicle dissection occurred during the operation without clinical consequences (mRS was 0 at the 6-month follow-up). In 2016, we implemented this procedure within China and our center has already reported on the first series.[9] In summary, although the transvenous technology is risky, the cure rate is high.

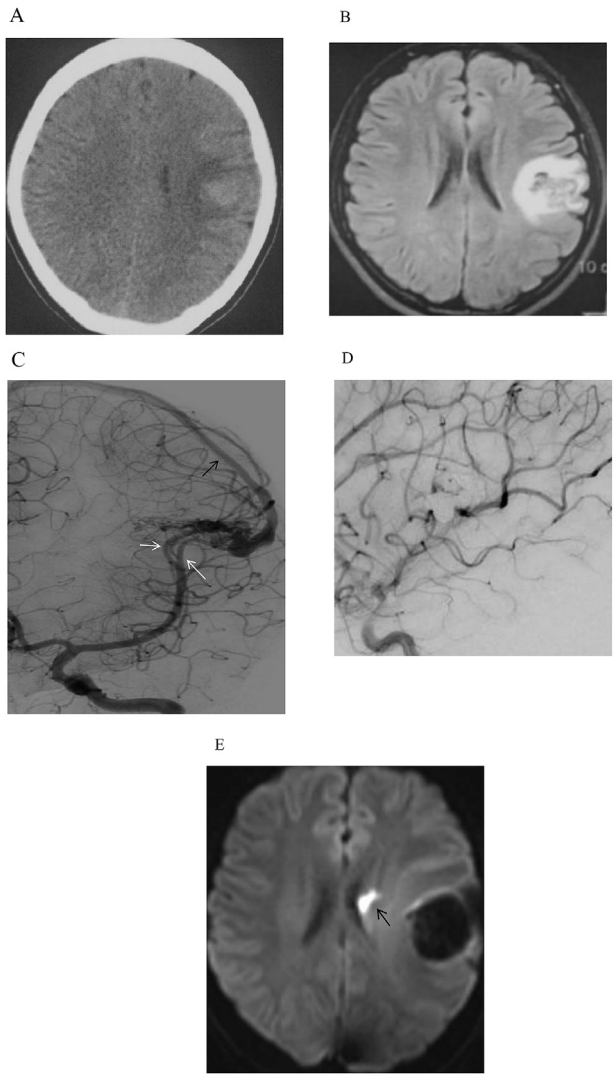

Fig. 1. 1A: A 16-year-old patient presented with acute headache. Non-enhanced CT scan in axial view showed acute hematoma in his left frontal and parietal lobes.
1B: Diffusion-weighted image in the axial section revealed an AVM located in the left frontal and parietal lobes.
1C: Selective left internal carotid artery digital subtraction angiography in anteroposterior views revealed an AVM supplied by two branches of the middle cerebral artery (white arrows): the drainage was single and superficial (black arrow).
1D: An immediate control digital subtraction angiography of the left internal carotid artery in anteroposterior views confirmed anatomic exclusion of the lesion.
1E: Postoperative diffusion-weighted image displayed a new cerebral infarction in the left caudate nucleus (black arrow).

3.2. Technique specifications

Two reviews[10,11] summarized the positive results of the transvenous endovascular approach in treating AVMs, most of which (68.3%) presented with deep AVMs. Although the location of all lesions in this study were superficial, this study shows our experience in using the transvenous approach to achieve successful retrograde catheterization of the nidus. First, rotational 3D angiography with volumetric reconstruction was generated to identify the angioarchitecture of AVMs which assisted in developing the specific embolization scheme. Secondly, maintaining persistent hypotension during the procedure has been studied in detail[12,13] and may be crucial to the success of the transvenous therapy.

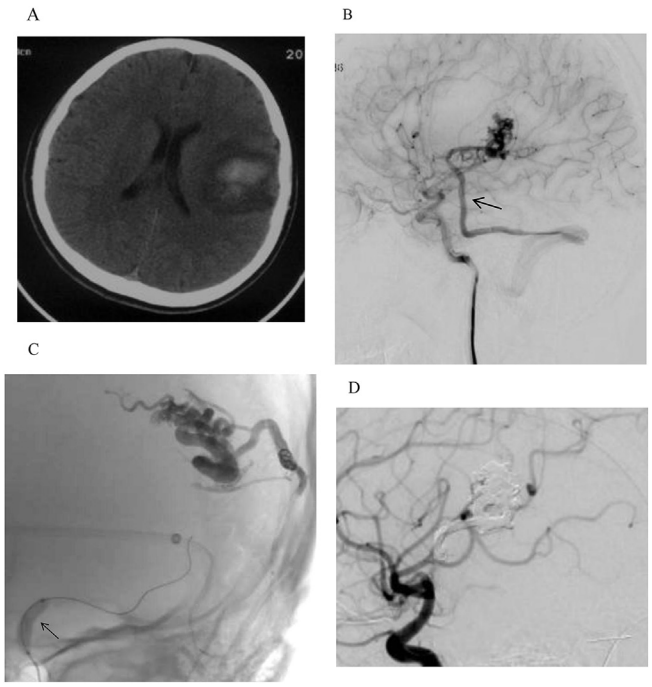

Fig. 2. 2A:A healthy 21-year-old man presented with sudden headaches and right-sided mild facial paralysis. Pre-operative computed tomography (CT) scans showed a left frontal and parietal hematoma.
2B: Left selective internal carotid artery angiogram, in lateral views, revealed an AVM supplied by branches of the middle cerebral artery. The drainage was from a single Labbé vein (arrow).
2C: Intra-operative single shot showing the use of the Hyperglide balloon (eV3, Medtronic, MN, USA) to maintain a hypotensive state (arrow).
2D: A 5-month control digital subtraction angiography of the left internal carotid artery in lateral views confirmed the anatomic exclusion of the lesion.

Some authors have reported a temporary balloon occlusion of an artery, which may reduce the arterial pressure in the AVM while reducing the risk of re-rupture of the nidus.[14,15] Partial feeding arteries and balloon occlusion techniques were used to decrease AVM flows in our study (Fig. 2). Thirdly, because of the inherent characteristics of cortical veins, it was difficult for microcatheters to approach the nidus with TVEs; therefore, 3D T1-weighted black-blood MRI sequences were used to understand the structure of vascular lumens.

3.3. Complications

Despite the advantages of the transvenous technique, a number of potential complications must be considered. George et al.,[16] demonstrated that 3 complications included intraprocedural venous ruptures, arterial pedicle dissections, and hemorrhagic transformations of venous infarctions. We only encountered 2 procedure-related complications: one CT-confirmed intra-operative hemorrhagic transformation with ventricular involvement where trepanation and drainage was performed (the mRS score was 2 at the 30-day follow-up); and a postoperative infarction and encephaledema, which was potentially related to ethanol use in the transarterial endovascular embolization procedure, whose symptoms included mild hemiplegia and a National Institutes of Health Stroke Scale (NIHSS) of 2 at discharge. No recurrent hemorrhages and infarctions were observed during the follow-up period.

4. Conclusions

Our preliminary study points to the feasibility of using endovascular transvenous embolization for superficial AVMs in the clinical setting. However, risks for complications should be taken seriously and additional large-sample and long-term studies need to demonstrate its safety.

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