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Therapeutic management of intracranial dural arteriovenous shunts with leptomeningeal venous drainage: report of 53 consecutive patients with emphasis on transarterial embolization with acrylic glue

Clinical article

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Object. There is a strong correlation between the venous drainage pattern of intracranial dural arteriovenous shunts (ICDAVSs) and the affected patients' clinical presentation. The ICDAVSs that have cortical venous reflux (CVR) (retrograde leptomeningeal drainage: Borden Type 2 and 3 lesions) are very aggressive and have a poor natural history. Although the necessity of treatment remains debatable in ICDAVSs that drain exclusively into a sinus (Borden Type 1), lesions with CVR must be treated because of the negative effects of the retrograde venous drainage. Surgery, radiosurgery, and embolization have been proposed for management of these lesions, but endovascular therapy is considered the most appropriate therapeutic strategy in ICDAVSs. New embolic materials, such as Onyx, have been recently developed and are considered to represent a kind of "gold standard" for embolization of these lesions. The purpose of this study is to emphasize the importance of transarterial embolization using acrylic glue in the therapeutic management of ICDAVSs with CVR, and to compare the results the authors obtained using this treatment with those reported in the literature for Onyx treatment of the same type of dural shunts.

Methods. The clinical and radiological records of 53 consecutive patients suffering from ICDAVSs with CVR (Borden Types 2 or 3) were reviewed. All cases were managed with the same angiographic and therapeutic protocol. Localization of the lesions, their clinical symptoms, their angioarchitecture, their therapeutic management, and the results were analyzed.

Results. Fourteen ICDAVSs were located at the superior sagittal sinus and/or convexity veins, 13 at the transverse and sigmoid sinuses, 10 at the tentorium, 5 in the anterior cranial fossa, 4 at the foramen magnum, 3 at the torcula, 2 at the straight sinus, and 1 at the vein of Galen. One patient presented with an infantile form of ICDAVS with multiple shunts. Hemorrhage had occurred in 36% of cases. Forty-three patients underwent transarterial embolization (42 with acrylic glue). Complete closure of the fistula was obtained in 34 patients. Suppression of the CVR with partial occlusion of the main shunt was achieved in all other cases. No mortality or permanent morbidity was observed in this series.

Conclusions. Intracranial dural arteriovenous shunts can be safely managed by transarterial embolization, which can be considered in most instances as an effective first-intention treatment. Acrylic glue still allows a cheap, fast, and effective treatment with high rates of cures that compare favorably to those obtained with new embolic materials.
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Key Words • intracranial dural fistula • cortical venous drainage • embolization • glue • Onyx

The natural history of ICDAVSs depends on the venous drainage of the lesion.[2,3,6] The so-called "benign lesions" exclusively drain into sinuses (Borden Type 1, and Cognard Types I and IIa) and do not compromise the cerebral venous drainage; thus, they carry very low clinical risks.[15] In most of these cases, long-term spontaneous resolutions of symptoms occur. On the contrary, ICDAVS with CVR (that is, retrograde leptomeningeal drainage; Borden Types 2 and 3, and Cognard Types IIb–V) represent aggressive lesions with an annual mortality rate of 10.4%, whereas the annual risks for hemorrhage and nonhemorrhagic neurological deficits are 8.1 and 6.9%, respectively, resulting in an annual event rate of 15%.[17] Moreover, ICDAVSs with CVR carry a high risk of early rebleeding with more severe consequences than resulted from the initial hemorrhage[7] and therefore require aggressive management.[14] Sev-

Abbreviations used in this paper: CVR = cortical venous reflux; ICDAVS = intracranial dural arteriovenous shunt; NBCA = *N*-butyl-cyanoacrylate; VA = vertebral artery.

eral therapeutic approaches can be proposed, including surgery, radiosurgery, and embolization, but endovascular treatment is often considered as the first-intention treatment. New embolic materials, such as Onyx (ev3 Neurovascular), have recently been developed and are considered to be a kind of "gold standard" for embolization of these lesions. The purpose of this study was to review our series of ICDAVSs with CVR; to analyze the results obtained using endovascular therapy in this group of patients treated according to the same protocols, with emphasis on transarterial embolization with acrylic glue; and to compare our results obtained with those available in the literature with Onyx in the same type of dural shunts.

Methods

Patients

Fifty-three consecutive patients (35 male, 18 female) suffering from ICDAVSs with CVR were treated by the same interventional neuroradiology team between 1990 and April 2008. The patients' age ranged from 6 to 85 years (mean 52 years).

Location of the Lesions

The ICDAVSs were located at the superior sagittal sinus and/or convexity veins (14 cases), transverse and sigmoid sinuses (13 cases), tentorium (10 cases), anterior fossa (5 cases), foramen magnum (4 cases), torcula (3 cases), straight sinus (2 cases), and vein of Galen (1 case). One 21-year-old man presented with multiple shunts corresponding to an infantile form of ICDAVS.[9]

Clinical Presentation

All clinical files were reviewed. Intracranial hemorrhages occurred in 36% of the cases: parenchymal hematoma in 13, subarachnoid hemorrhages in 5 cases, and ventricular hemorrhage in 1. Seizures (5 cases) and neurological deficits (21 cases) were the main symptoms in 49% of cases, followed by chronic headaches in 25% (13 cases) and pulsatile tinnitus in 23% (12 cases). In 3 patients (6%), the lesions were found incidentally—in 2 after CT scan for head trauma and in 1 during angiographic evaluation of a scalp arteriovenous malformation.

Four patients had been previously treated with embolization performed by other teams, using either a transarterial approach with glue and particles or a venous approach with coils.

Technical Aspects

All endovascular treatments were performed with the patients in a state of general anesthesia. No anticoagulation therapy was used before, during, or after treatment. A 6 Fr sheath was introduced into the femoral artery and selective angiography was performed, either with a 4 Fr VA catheter (Terumo Corp.) or with a guide catheter (Envoy, Cordis Corp.; or Guider, Boston Scientific Corp.), with the intention of using the same catheter for diagnostic as well as therapeutic purposes. All vessels potentially giving rise to feeding arteries supplying the shunt were catheterized to build up the lesional anatomy and architecture of the lesion. Particular attention was paid to the venous drainage of the brain as compared with the drainage of the lesion. When embolization was decided upon, a Magic microcatheter was used (1.8, 1.5, or 1.2 Fr FM [Balt, Inc.], depending on the size and other morphological characteristics of the vessels) to superselectively catheterize the main feeding artery. Progression of the microcatheter was aided by the use of a microguidewire (Mirage 008, ev3; or Terumo GT 12 with 45° tip) to allow distal catheterization as close as possible to the shunt. When a safe embolization position was achieved, selective injection of contrast medium was performed to reveal the focal angioarchitecture of the malformation compartment. If embolization was decided upon, the catheter was flushed with a 5% dextrose solution, and then cyanoacrylate glue (Histoacryl, B. Braun) or Glubran 2 (GEM, Srl) mixed with Lipiodol (Guerbet) was injected under fluorographic guidance (3 images per second). No provocative test was ever performed, the decision to embolize being made according to strict anatomical rules. When the decision was made to use glue via a transarterial approach, its dilution varied according to the position of the catheter, the size of the vessel, and blood flow. When treating high-flow direct arteriovenous fistulas supplied by large vessels, highly concentrated glue (mixture of 2 cm^3 NBCA, 0.2 cm^3 Lipiodol, and 0.5 g Tantalum powder [Balt, Inc.]) was injected through 2.5-ml syringes with a maximum deposit of glue per pedicle corresponding to the total content of the syringe. When diluted glue was necessary, specifically when a wedge catheterization was achieved, an at least 50% mixture of glue and Lipiodol was injected through 1-ml syringes with a maximum deposit of 1 ml of glue per vessel. After proper glue deposition, the microcatheter was rapidly withdrawn. An 8-mg dose of betamethasone was injected intravenously by the anesthesiologist on request before injection of the glue, and 3 other 8-mg doses were administered during the first 24 hours after the procedure. This was followed by oral administration of prednisone at a dosage of 1 mg/kg for ~ 1 week. This corticotherapy was administered to reduce the inflammatory and potentially edematous reaction after injection of glue. Because of the proper deposition of glue and the obliteration of the shunt obtained without significant contamination of the cortical draining veins by the embolic agent, postembolization anticoagulation was never needed.

When venous access was required, a 6 Fr sheath was introduced into the femoral vein and a guiding catheter (Envoy or Guider) was put into the jugular vein. A microcatheter (Excel 14, Boston Scientific) over a 0.014-in microguidewire (Transend 14, Boston Scientific) was then used to reach the shunting zone in the pathological sinus draining the ICDAVS, and the sinus was secondarily occluded with coils (Guglielmi detachable coils or fiber coils, Boston Scientific).

Follow-Up Protocol

After each endovascular treatment, even if cure was demonstrated after the first therapeutic session, 3- or 6-month follow-up angiography or, in elderly patients, MR imaging or MR angiography (or both) was performed

to evaluate the results with respect to both the ICDAVS and the brain. Clinical evaluation was performed at the same time. If the condition was determined to be cured at this stage, no further follow-up imaging studies were scheduled. Patients were informed that any future change in their clinical status would require new consultation and evaluation to rule out de novo shunt formation.

Results

The overall results of the management of ICDAVSs in this case series are summarized in Table 1.

Endovascular therapy was initially proposed as a primary treatment in all 53 cases.

In 4 patients, spontaneous thrombosis of the lesion was diagnosed during the therapeutic session and thus no embolization procedure was performed. In 3 of these patients there had been previous bleeding, resulting in intracerebral hematomas. One of these 3 patients died as a consequence of massive intracranial hemorrhage.

Despite our proposal of embolization, surgery was performed as the initial treatment in 2 patients: 1 with an ethmoidal ICDAVS and 1 with a frontal ICDAVS. In both cases the surgical procedure was successful and the patients were considered to be cured.

One transarterial approach failed in an 81-year-old man with a foramen magnum lesion fed by a small tortuous dural branch arising from the right VA. The patient subsequently underwent successful surgery.

Transvenous embolization was selected as a treatment in 3 patients (as a complementary treatment after transarterial embolization in 2). Of these 3 patients, 1 was cured and demonstrated normal results on neurological examination. A 68-year-old woman initially presenting with headaches, pulsatile tinnitus, and cognitive dysfunction, improved dramatically after both transarterial (with glue) and transvenous (with coils) endovascular therapy obliterating most of the shunt and resolving the CVR; she refused further treatment and was lost to follow-up. A 21-year-old man with an infantile form of ICDAVS and multiple shunts was treated by means of glue embolization via both transarterial and transvenous routes. Although the lesion has been only partially treated as of this writing, the patient's clinical condition has improved and further treatment sessions are planned.

Forty-three patients were effectively treated by transarterial embolization.

One 81-year-old male with a fortuitously discovered parietal ICDVAS with CVR supplied by multiple small indirect feeding vessels was treated in 1996 by embolization with particles only and by surgery. A follow-up angiogram confirmed obliteration of the lesion.

In 42 cases, acrylic glue embolization was performed. Particles were used in association with glue to further reduce the shunt in 4 patients (with straight sinus, petrodural, superior sagittal sinus, and transverse sinus ICDAVSs). The condition of the patient with the straight sinus shunt improved after the treatment and the patient refused further therapy; the patient with the petrodural shunt was cured by the procedure; the patient with the superior sagittal sinus shunt underwent secondary surgical treatment because of the inaccessibility of a small residual compartment; the condition of the patient with the transverse sinus ICDAVS vascularized by multiple bilateral feeders improved and stabilized.

Glue was used as the sole embolic material in 38 patients. One single session was needed to complete the treatment in 29 patients, 2 sessions in 4 patients, and 3 sessions in 5 patients, for an average of 1.37 sessions per patient. Embolization was performed via 1 single feeding vessel in 18 patients, 2 in 8 patients, 3 in 7 patients, 4 in 1 patient, 5 in 1 patient, 7 in 1 patient, 8 in 1 patient, and

TABLE 1: Summary of management and outcome in 53 cases of ICDAVS with CVR*

Management	No. of Cases	Outcome
angiography w/o endovascular embolization or surgery	4†	3 cures, 1 death
surgery	3‡	cure in all 3 cases
embolization	46	
transvenous routes	3	1 cure; 1 improved, lost to FU; 1 improved, scheduled for further sessions (infantile form of ICDAVS)
transarterial routes	43	
embolization w/ particles & secondary surgery	1	cure
embolization w/ acrylic glue	42	
glue & particles	4	2 clinical improvements; 1 cure; 1 secondary surgery
glue only	38	34 cures (89.5%)—29 immediate, 5 w/ secondary thrombosis & cure; 3 improvements w/ other sessions scheduled; 1 death (unrelated to ICDAVS)

* FU = follow-up.

† During angiographic examination, spontaneous thrombosis of the lesion was diagnosed in 4 patients—after hemorrhage in 3 of the 4. One of these 3 died as a result of the hemorrhage, and spontaneous thrombosis of the dural fistula was confirmed at autopsy.

‡ Surgery was performed in 2 cases despite proposed embolization and in 1 case after failure of embolization.

11 feeding vessels in 1 patient, for an average of 2.37 per patient.

In 29 patients, an immediate cure was obtained by means of embolization (Figs. 1 and 2). Secondary thrombosis of the ICDAVS led to cure in 5 patients (13%) (Fig. 3). Complete cure of the shunts was thus obtained in 34 (89.5%) of the 38 patients in whom glue was used as the sole embolic agent.

Three patients are currently still under care and are scheduled for further endovascular treatment and/or angiographic follow-up, initial embolization having lead to important control of the shunt with clinical improvement. Four patients were lost to follow-up after partial treatment resulted in control of > 50% of the shunt, suppression of the CVR, and clinical improvement. One patient died (death unrelated to her ICDAVS) 6 years after partial treatment, her lesion having been stabilized and her clinical status normalized.

Two transient clinical complications occurred in posterior fossa ICDAVSs (cerebellar syndromes). Both patients recovered rapidly with corticosteroid therapy.

No permanent complications and no mortality related to endovascular therapy were seen in our series.

Discussion

The various classifications of ICDAVS all emphasize the poor natural history of the disease when it is associated with cortical venous drainage.[5] Embolization is currently considered the first-line treatment for these lesions. The treatment has to be focused on the leptomeningeal venous drainage, as the suppression of this feature protects the patient and normalizes the natural history of the lesion. If the shunt drains primarily into cerebral veins, the disconnection of the initial portion of the vein cures the ICDAVS. Transarterial embolization is the preferred treatment for lesions with this architecture. If the shunt drains first into a patent sinus with secondary reflux into cortical veins, therapeutic management should control the shunting to reduce the hyperpressure reigning in the pathological venous drainage and thus suppress the retrograde flow into cortical veins. The decision to occlude the sinus or leave it untreated relies mainly on whether the sinus is patent or partially thrombosed.

Transarterial or transvenous endovascular approaches have been proposed. Several modalities of transvenous embolization have been described: catheterization of the affected sinus by a venous route (considered by some teams as the best management for ICDAVS);[13,16] a transcranial approach with direct puncture of the pathological sinus if selective endovascular navigation is considered impossible for anatomical or architectural reasons;[4,8] and selective obliteration of the CVR after intravenous navigation without occlusion of the dural sinus.[11] This latter technique is rarely used because of the tortuosity and

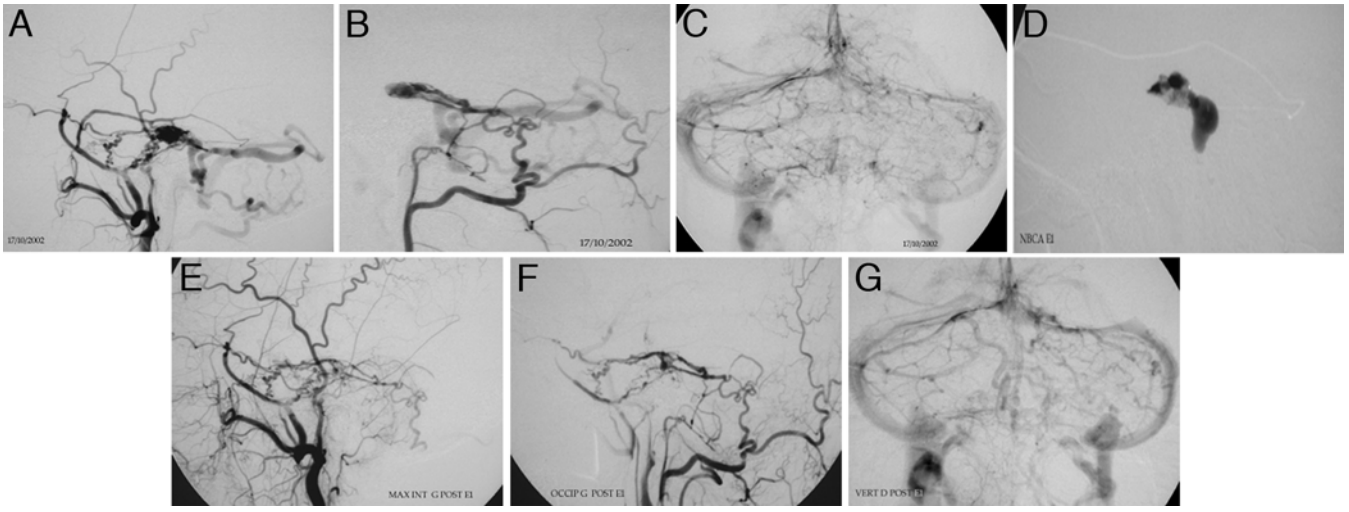

Fig. 1. Angiograms obtained in a 49-year-old man who presented with 2 recurrent hemorrhages in the posterior fossa. **A and B:** Lateral views of the left internal maxillary (A) and occipital (B) arteries demonstrating a petrotentorial dural arteriovenous shunt of fistulous type draining initially into a petrous vein and resulting in congestion of the posterior fossa veins. Other feeding vessels arose from the left internal and ascending pharyngeal arteries (not shown). **C:** Left VA angiogram in anterioposterior view confirming poor filling of left hemispheric cerebellar veins due to congestion of the veins because of the ICDAVS. All of the feeding vessels converged toward a single shunting zone. **D:** Image obtained at the end of the angiographic session showing the cast of glue injected into the shunt. Distal catheterization of the basal tentorial branch of the middle meningeal artery, which extended into the fistula, was performed with a Magic 1.2 microcatheter, and a 50% mixture of NBCA and lipiodol was injected in a wedge position to cast the shunt and penetrate into the proximal portion of the petrous vein, thus occluding the ICDAVS. **E–G:** Immediate postembolization images confirming cure of the fistula. Injection of all the previously described arteries (internal maxillary artery [E], occipital artery [F], as well as the internal carotid artery [ICA] and ascending pharyngeal artery [not shown]) does not opacify the shunt anymore but fills all the regional arteries without opacification of the venous drainage. Late phase of the postembolization left VA angiogram (G) shows normal filling of the hemispheric veins, confirming the suppression of the venous congestion. A 5-month control angiogram (not shown) confirmed total obliteration of the fistula. The patient returned to normal life.

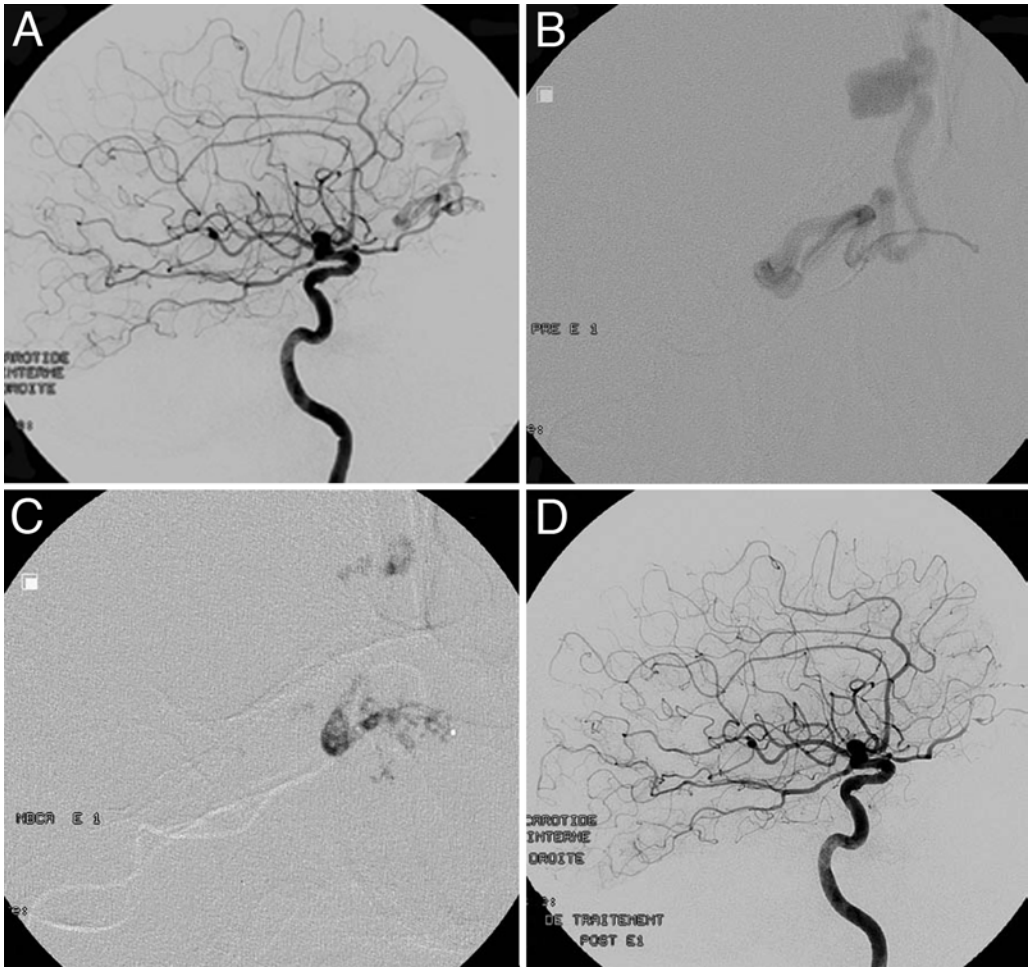

Fig. 2. Angiograms obtained in a 75-year-old man who presented with acute headaches due to a right frontal lobe hemorrhage. **A:** Lateral view of a right ICA injection showing an ICDAVS located at the level of the lamina cribriformis. The fistula is vascularized by a posterior ethmoidal artery arising from the ipsilateral ophthalmic artery (OA). It drains into a frontal vein harboring a false aneurysm (indicating the rupture point of the lesion) and reaches secondarily the superior sagittal sinus. **B:** Image obtained after superselective catheterization of the ethmoidal feeding vessel was performed via the OA and confirmed this architecture. **C:** Image showing embolization of the whole shunt performed in wedge position with NBCA. **D:** Right ICA angiogram obtained immediately after treatment confirming cure of the ICDAVS with respect to the OA and its branches. The patient remained asymptomatic. Follow-up MR imaging and MR angiography obtained 3 months later confirmed cure of the lesion.

fragility of the leptomeningeal veins and the risk of rupture during selective catheterization. In our experience, transvenous management has been used in only 3 cases in which the sinus was already partially thrombosed. We believe indeed that patent sinuses draining ICDAVSs should not be occluded transvenously as an initial treatment strategy, as the normal venous drainage of the brain could be compromised, leading to delayed ischemic complications. Furthermore, secondary development of de novo ICDAVS can occur, potentially causing impairment of intracranial venous drainage if 1 sinus is already suppressed.

We favored transarterial access in all but the above-described 3 cases of ICDAVS. We used this approach to superselectively catheterize the arterial feeding vessels as well as to occlude the shunt itself. The use of particles as a sole embolic agent is becoming more and more restricted because of their instability and short-term effects. They have thus no role in the treatment of ICDAVS with CVR, and when needed they are mostly used in specific lesions as an adjuvant embolus to reduce the flow in collateral vessels and help to induce thrombosis.[1]

Our therapeutic protocol has remained unchanged since the beginning of our experience in the management of intracranial arteriovenous shunts in 1987. In this series of cases, one of the largest and most homogeneous reported in the literature to the best of our knowledge, we exclusively used nonabsorbable embolic agents like acrylic glue when liquid agents were indicated. Acrylic glue has indeed proven its effectiveness and stability in endovascular procedures for more than 30 years, and offers therefore the longest duration of anatomical and clinical follow-up of all the embolic agents. Whether in its classical form (NBCA, Histoacryl, B. Braun) or a modified version[10] (Glubran 2, GEM Srl), it is injected as a liquid but solidifies when it is in contact with blood, thus occluding

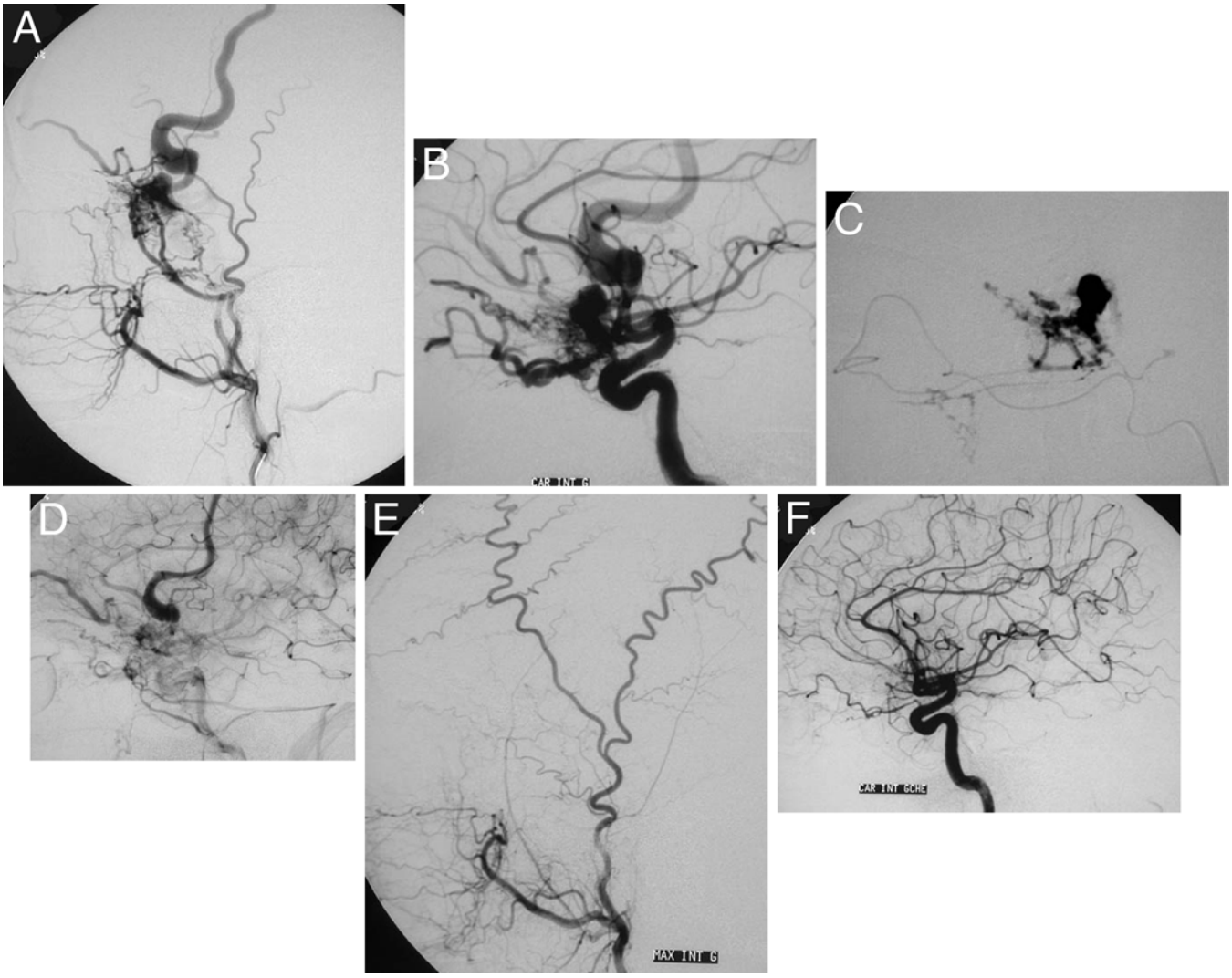

Fig. 3. Angiograms obtained in a 61-year-old man who presented with headaches and an episode of nonspecific discomfort and in whom MR imaging revealed a suspected vascular malformation in the sphenoid region. **A and B**: Lateral views after injection of the left internal maxillary artery (A) and ICA (B) revealed a dural shunt located at the level of the sphenoid ridge and draining into 2 cortical frontal veins, which drained into the superior sagittal sinus. A first injection of glue via the middle meningeal artery failed to penetrate properly into the proximal portion of the draining vein because of lack of wedge catheterization. **C:** Image obtained after a second injection of glue (during the same session) into the recurrent branch of the OA, showing the casting of the remaining portion of the nidus and penetration into the foot of the main cortical vein. **D:** Immediate postoperative angiogram obtained after left ICA injection showing persistent, although reduced, flow in the shunt. Because of adequate reduction of flow, no further embolization was performed. **E and F:** Internal maxillary artery (E) and ICA (F) injection angiograms obtained 3 months after treatment, confirming secondary thrombosis of the shunt and cure of the ICDAVS. The patient returned to normal life without any complaints.

the shunt. Postembolization secondary thrombosis has occurred in 5 patients in our series in whom some flow was still present on the immediate posttreatment angiograms (Fig. 3) despite proper placement of glue in the initial portion of the draining vein. To the best of our knowledge, this kind of secondary thrombosis after partial embolization with glue has not been reported previously.

The ideal injections of glue are performed after wedge catheterization, when the tip of the microcatheter establishes flow arrest in the vessel.[12] This technique allows control of glue delivery through the arteriovenous shunt toward the venous side to occlude the ICDAVS, the shunt draining either directly into cortical veins or first into a partially thrombosed sinus ("sinus suspendu," distal and proximal sinus thrombosis with a patent intermediate portion) with secondary cortical venous reflux. In this latter situation, diluted glue could even be injected through small arterial feeding vessels to fill the whole shunt—with penetration into the pathological venous segment—and completely occlude the lesion. Using this method we have been able to avoid the direct preoperative puncture of the sinus that has been reported by other authors.[8] Wedge catheterization also makes it possible to obtain arterio-arterial reflux to properly occlude multiple

TABLE 2: Comparison of case series treated with NBCA and Onyx*

Variable	Onyx	NBCA
mean no. of pedicles treated	2.5	2.37
mean no. of sessions	1.2	1.37
rate of cure	80% (24/30 pts)	89.5% (34/38 pts)
no. of permanent complications	2	0
mean duration of injection (range)	45 min (7—100 min)	few secs (<1 min)
costs	× 5 (1.5 ml = €800)	× 1 (1.5 ml = €150)
long-term stability	?	>30 yrs
secondary thrombosis	?	yes

* The results of the present case series are presented in the NBCA column; those of Cognard et al.[4] are presented in the Onyx column. Abbreviations: pts = patients; ? = unknown.

dural feeders and avoid multiple catheterizations. Indeed, in our series, we treated an average of 2.37 pedicles per patient in an average of 1.37 sessions to obtain improvement or morphological cure of CVR. The global high rates of cure obtained by embolization with glue in our series (34 of 38 patients) are evidence of the efficacy of our management with this embolic agent.

Total obliteration of the connection was not possible in 2 patients because of the angioarchitecture and extension of their lesion (patent sinuses with CVR). Embolization has however transformed these aggressive lesions into benign ones with suppression of the CVR, and with associated clinical improvement.

The low rates of morbidity and the absence of mortality in our series show that, when used under proper technical and anatomical conditions, glue remains an adequate and safe embolic material that still can compare advantageously to the new liquid agents such as Onyx (Table 2), which is often promoted nowadays (Klucznik RP, Diaz O, presented at the Ninth Congress of the World Federation of Interventional and Therapeutic Neuroradiology, 2007)[3,4,8] as a new "gold standard" for endovascular therapy of these lesions but that has not proven yet its superiority in terms of cost, length of the procedure, and doses of radiation or necessary long-term stability (Terbrugge KG, presented at the Ninth Congress of the World Federation of Interventional and Therapeutic Neuroradiology, 2007).[18]

Conclusions

Endovascular management of ICDAVSs with CVR is both a medical and a technical challenge. The success of therapy relies on proper analysis of the architecture of the shunt. The complications reported are often predictable and can be avoided if one follows precise anatomical, physiopathological, and technical rules. Experienced operators are needed for safe embolizations of any type, and one may not consider that one particular embolic material makes the procedure safer than another. Our series, which is based on an angiographic and therapeutic protocol that has not changed since the beginning of our experience, shows that with glue one can obtain high rates of primary or secondary cure of these lesions with good clinical results and at a low cost during endovascular procedures of short duration. It is our belief that acrylic glue is still a valuable agent in the endovascular treatment of these lesions. To the best of our knowledge, Onyx has not proven at this stage to be more effective than glue.

Disclaimer

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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