Endovascular Treatment of Cervical Giant Perimedullary Arteriovenous Fistulas

BACKGROUND: Giant perimedullary arteriovenous fistulas (GPMAVFs) located in the cervical region are a rare pathology with distinctive characteristics.

OBJECTIVE: To evaluate clinical presentation and different endovascular treatment options of cervical GPMAVFs and review previously published data in the literature regarding cervical GPMAVFs.

METHODS: Six patients with cervical GPMAVFs were found in the spinal vascular malformations database of our group collected between 1990 and 2009. Endovascular techniques and treatment outcomes were evaluated and compared with other published series.

RESULTS: Clinical presentations were progressive motor deficit (5 patients), hematomyelia (1 patient), meningeal syndrome (1 patient), and respiratory arrest and gait apraxia (1 patient). Three patients were treated by the transarterial approach. One patient was treated by the transvenous approach due to previous embolizations resulting in a proximal occlusion and preventing a safe transarterial approach. A transvenous approach was used in another patient due to complex arterial anatomy. In 1 patient, direct percutaneous puncture of the venous pouch was necessary because of previous proximal occlusion of the arteries. All embolizations resulted in complete occlusions with clinical improvement, and there was no recanalization during a mean follow-up of 21 months.

CONCLUSION: Transarterial embolization of cervical GPMAVFs is safe and effective when it is done in highly experienced centers. Cervical GPMAVFs that cannot be accessed by the transarterial technique due to their complex angioarchitecture can be treated by transvenous embolization or direct puncture of the venous pouch.

KEY WORDS: Arteriovenous fistula, Direct puncture, Embolization, Giant perimedullary, Transarterial, Transvenous

Perimedullary arteriovenous fistulas (PMAVFs) are pathological connections between spinal arteries and medullary veins without an intervening nidus. Spinal vascular malformations are uncommon, and perimedullary AVFs account for 17% to 39% of them. Djindjian et al first described PMAVFs in 1977 as intradural extramedullary spinal arteriovenous malformations fed by the anterior spinal artery.

Various classifications of the spinal arteriovenous shunts have been set out in the literature. According to the Merland classification, there are 3 types of PMAVFs. Type 1 PMAVFs are small, slow-flow fistulas that are fed by a single spinal artery, and neither the feeding artery nor the draining vein is dilated. Type 2 PMAVFs are more voluminous and are fed by 1 or 2 dilated spinal arteries. Type 3 PMAVFs have rapid flow and multiple dilated arteries and ectatic drainage veins. Large venous pouches are usually seen at the shunt level. Type 3 perimedullary AVFs differ
from the other 2 groups by their high flow and its local venous drainage to the epidural space. These also are known as named giant perimedullary arteriovenous fistulas (GPMAVFs). This type of PMAVF is most commonly seen in children, and a high association with hereditary hemorrhagic telangiectasia has been reported in the literature. GPMAVFs can present with hemorrhage, venous hypertension, and mass effect due to venous ectasia or steal phenomena. In children, the most common presentation is hemorrhage.

Few series or case reports regarding GPMAVFs have been published in the literature, and the information regarding GPMAVFs located at the cervical level is even more limited. Cervical PMAVFs are less common than their thoracolumbar counterparts; however, they present more often with subarachnoid hemorrhage (SAH) or hematomyelia, especially in children. Although transarterial embolization of cervical GPMAVFs is a straightforward treatment in experienced centers, some cases with complex angioarchitecture can provoke treatment dilemmas and create pathologies that are very difficult to treat safely. The purpose of this article is to review the literature about giant PMAVFs located in the cervical medulla and to present our experience in endovascular treatment of 6 patients with cervical giant PMAVFs.

PATIENTS AND METHODS

We reviewed a series of 369 spinal vascular malformations treated between January 1990 and December 2009. For classification of the spinal arteriovenous fistulas, we used the Merland classification. According to that system, 6 patients in this series had type 3 PMAVFs located in the cervical medulla. Age, sex, clinical presentation, endovascular technique, treatment outcome, and follow-up results are summarized in Table 1. The patients included 4 girls and 2 boys. At the time of treatment, their ages ranged from 18 months to 17 years (mean age, 5.4 years). Clinical presentations were progressive motor deficit due to myelopathy in 5 patients, causing tetraparesis, hemiparesis or paraparesis; spinal cord hemorrhage in 1 patient; and meningeal syndrome with nuchal pain during flexion and extension of the neck in another patient. One patient, in addition to the progressive motor deficit, had respiratory arrest and gait apraxia due to compression of the venous pouch over the medulla oblongata. Two patients had undergone previous embolizations in other centers. Patient 4 had 1 previous transarterial embolization with proximal occlusion of the arterial feeders and incomplete occlusion of the AVF. Patient 6 had 2 sessions of transarterial embolization in another center, without occlusion of the fistula, that did not prevent progression of the motor deficit. None of our patients had an associated syndrome such as Rendu-Osler-Weber or Cobb syndrome. Based on the consensus of our multidisciplinary team of interventional neuroradiologists, neurosurgeons, and neurologists, endovascular treatment was offered as the primary treatment for patients with type 3 PMAVFs.

TREATMENT

A complete spinal angiographic examination was performed before the definitive treatment. For each patient, 1 of 3 different endovascular techniques was used: transarterial embolization, transvenous embolization, or direct puncture of the ectatic venous pouch. In the transarterial approach, either embolization with coils and N-butyl-cyanoacrylate (NBCA) (patients 2 and patient 3) or embolization with a detachable balloon (patient 1) was used. In 2 patients (patients 4 and patient 5), transvenous embolization was performed because it was not possible to reach the fistula by the transarterial approach. Patient 4 previously had had several transarterial embolization procedures in another center. These previous embolizations occluded the arterial feeders of the fistula proximally, preventing us from reaching the fistula by the transarterial approach. Patient 5 had a very tortuous and small-caliber origin of the anterior spinal artery (ASA). At that time (1992), we were not able to reach the fistula through the ASA, so we finally decided to embolize the fistula by the transvenous approach. For the embolization with transvenous approach we used coils with NBCA.

When neither of the other 2 endovascular methods nor surgery was considered appropriate due to the complex angioarchitecture or long and tortuous anatomy of the ASA, we offered a direct venous puncture and then embolization of the fistula with coils and NBCA.

All treatments were performed under general anesthesia without applying any provocative test. For transarterial embolization,
a right femoral artery access was used to place a guiding catheter in the segmental artery using an appropriate microcatheter (Tracker 18 or Excelsior SL-10, Target Therapeutics, Fremont, California) to deploy coils and to inject NBCA and a microwire (Terumo GT 0.012, Terumo Medical Corporation, Somerset, New Jersey; Mirage 0.08 ev3 Neurovascular, Irvine, California; Figure 1). The main goal in every embolization was to reach the beginning of the venous side of the fistula and realize the embolization from that point. In the only case where we used a detachable balloon in a transarterial embolization, the balloon was inflated and detached at this point, as in balloon occlusion of the carotidocavernous and vertebovertebral fistulas; in all other patients, fistulas were embolized with coils and NBCA. Coils were placed at the beginning of the venous side to provide primary venous drainage. After contrast injection through the microcatheter to evaluate the angioarchitecture of the fistula, a mixture of NBCA and Lipiodol (1:1) was prepared. Then the embolic mixture was injected through the microcatheter until reaching a complete occlusion of the fistula and the proximal part of the venous drainage.

When transvenous embolization was necessary, a 5-French introducer was used to access the jugular vein and then a 5-French guiding catheter was placed in the straight sinus (Figure 2). Finally a Tracker 18 microcatheter was navigated through the pial veins toward the fistula, catheterizing the fistulous point and venous pouch. After placing coils to occlude the venous pouch and the fistula, the embolization was finished by the NBCA injection.

In 1 case, we used a direct percutaneous puncture of the venous pouch to embolize the fistula with coils and NBCA. The procedure was done under general anesthesia with the neurosurgical team on standby. The diagnostic catheter was positioned in the right vertebral artery to control the fistula during puncture of the venous pouch percutaneously under biplanar roadmap guiding (Figure 3A). The patient was positioned in a left oblique position. With the right C3-4 neural foramen (a venous pouch was present at the C3-5 level in a right anterolateral situation) displayed, we punctured the venous pouch through this foramen with the aid of an 18G Abbocath intravenous catheter (Abbott Laboratories, Abbott Park, Illinois; Figure 3B). The needle was placed in the center of the venous pouch, and a blood reflux through the needle was observed. Then contrast material was injected through the intravenous catheter to confirm the correct position within the venous pouch. A hemostatic valve was placed on the Abbocath, and a Rapid Transit microcatheter (Codman Neurovascular, Raynham, Massachusetts) was introduced with a Terumo 0.016 guidewire (Terumo Medical Corporation, Somerset, New Jersey) to catheterize the exact point where the arterial feeders drained into the venous side. Once the microcatheter was in the right position we continued the embolization of the draining vein with coils and NBCA, achieving complete occlusion of the fistula and the draining vein. The final control by all the feeders showed complete occlusion of the PMAVF and the reappearance of normal venous drainage at the cerebellar level (Figure 3C). The catheter was withdrawn from the venous pouch simultaneous with injection of the NBCA to avoid any hemorrhage. A CT examination was performed immediately after the procedure, confirming that there was no hemorrhagic complication after the embolization.

After all embolizations, patients were observed in the intensive care unit with IV heparin 10 000 U/24 hr and IV dexamethasone 4 mg/6 hr for a period of 24 hours to prevent any progressive venous thrombosis, which can compromise the normal venous drainage, or any severe inflammatory reaction due to the thrombosis of the fistula. Follow-up studies were done by either spinal angiography alone or spinal angiography and MRI together.

RESULTS

In all patients, complete angiographic obliteration of the fistula was achieved. During a transvenous embolization (patient 4), the microcatheter was glued to the venous side after a prolonged injection. In this case, after occluding the fistula, we had to leave the microcatheter in place, from the venous side of the fistula to the jugular vein, and then we cut the microcatheter and left the rest of the material inside. The patient did not experience any clinical consequence. There was clinical improvement following the embolization in all cases. Three patients were asymptomatic after the embolization (patients 1, 2, and 3). Two patients (patients 4 and 5) recovered from the motor deficit they had before embolization; however, they continued to have minor sensory disturbances without interfering with normal life activity. One patient who previously had right hemiparesis impeding her walking (patient 6) had a mild motor deficit with normal activity after the treatment. The follow-up period ranged from 6 months to 48 months (mean, 21 months). Follow-up controls were realized either by spinal angiography alone in 2 patients (patients 2 and 3) or by spinal angiography plus MRI in the remaining 4 cases in addition to the clinical examination. No recanalization of the fistula was seen in radiologic follow-up studies.

DISCUSSION

Epidemiology

Giant perimedullary arteriovenous fistulas (GPMAVF) correspond to the type IVc spinal AVF of the classification of Heroes et al and type 3 PM-AVFs according to the classification of Merland. GPMAVFs are giant connections of multiple dilated medullary arteries and dysplastic/ectatic veins through rapid arteriovenous shunting. There are few series and case reports in the literature; only a total of 15 cases of cervical GPMAVF have been reported12,15 (Table 2). In these series, cervical localization is reported for 16% to 27% of all GPMAVF. They are less common than their thoracic and lumbar counterparts. Cervical PMAVF can cause fatal intramedullary bleeding and subarachnoid hemorrhage. Because of the higher localization of the fistula, cervical GPMAVF may produce venous hypertension earlier than their thoracolumbar counterparts, and they may affect the brainstem.
FIGURE 1. The right vertebral arteriogram (A) shows a dilated anterior spinal artery (ASA) feeding a cervical giant perimedullary arteriovenous fistula (GPMAVF) (arrow). Venous drainage into the perimedullary veins and epidural venous plexus is seen in the late phase of the arteriogram. B, the ASA arising from the third dorsal segmental artery and entering into the fistula through the same hole (arrow), like the ASA in A. C, superselective catheterization of the venous pouch through the ASA arising from the third dorsal segmental artery and injection of contrast medium shows the correct position of the microcatheter inside the primary venous drainage. D, postembolization arteriograms of the right vertebral artery (RVA; left) and third dorsal segmental artery (right) show complete occlusion of the fistula and normal continuity of the ASA.
A high association of GPMAVFs with hereditary hemorrhagic telangiectasia (HHT) has been reported in the literature.\textsuperscript{6,18,19} In the series of Rodesch et al,\textsuperscript{18} 5 of the 6 GPMAVFs were associated with HHT. An association with Cobb syndrome also has been reported.\textsuperscript{7,20} When we focus on the cases of cervical GPMAVF (Table 2), there is only 1 reported case associated with HHT,\textsuperscript{16} and there are 2 cases (from separate studies) associated with Cobb syndrome.\textsuperscript{7,20} Our series of cervical GPMAVFs included 6 cases, and there was no association with either of these syndromes. This may indicate that there is a less common association of cervical GPMAVFs with syndromes such as HHT or Cobb when compared with their thoracolumbar counterparts.

**Symptomatology**

Symptoms seen in patients with GPMVFVs may be due to venous hypertension, vessel rupture, steal phenomenon, or direct compression by the ectatic veins. Two thirds of patients who have PMAVFVs are younger than 25 years.\textsuperscript{21} Patients can present with progressive radiculomedullary symptoms, with or without acute deterioration episodes. Complete spinal transection may develop in 7 to 9 years if they are not treated.\textsuperscript{15} Some patients may present with spinal SAH or hematomyelia. Children are more likely to present with hemorrhage than are adults. Children with hematomyelia have a more severe deficit at presentation than the children with SAH, who develop milder symptoms.\textsuperscript{22} In our series, all but 1 patient had progressive myelopathy with motor deficit. The patient who did not present with motor deficit (patient 1) had meningeal syndrome with pain during head flexion and extension. We believed this symptom was related to the mass effect of the giant venous pouch. Only 1 patient (patient 6) had hematomyelia, and she also had right hemiparesis after the acute deterioration following the hemorrhage. Spinal SAH was the presenting symptom in 3 of 9 cases (33\%) of cervical GPMVFVs reported previously in the literature, and no case presented with hematomyelia. Rodesch et al\textsuperscript{13} reported a correlation between hemorrhage and angioarchitectural factors such as pial venous reflux, AVFs, and venous ectasias, all of which are found in GPMVFVs. It is known that spinal intradural AVFs are more prone to hemorrhage than spinal dural AVFs.\textsuperscript{23} Among spinal dural AVFs, cervical dural AVFs are associated with a higher rate of SAH than those in other locations.\textsuperscript{24} Rodesch et al\textsuperscript{18} also documented a higher rate of hemorrhage in the AVFs located in the cervical spinal cord. A higher rate of hemorrhage in cervical dural AVFs can be explained by the greater likelihood of having a cranially directed venous drainage. Other authors have proposed the supracardiac position, which increases the hemorrhagic presentation in cervical AVFs, as a factor, whereas hemodynamics of thoracolumbar AVFs are counterbalanced by thoracoabdominal pressure.\textsuperscript{25} However, in our series of 6 cases, only 1 patient had hemorrhage that presented as hematomyelia. None of our patients had spinal SAH. When we analyze all the cases reported in the literature, including the present series, the rate of presentation with hemorrhage is 26\% (4 of 15 reported cases).
Treatment

Many authors have proposed endovascular embolization of this type of fistula as an effective and safe technique. As long as they are not extremely tortuous, dilated arterial feeders can be catheterized, and the microcatheter can be navigated until the fistulous point, especially with today’s highly navigable microcatheters. Surgery of GPMAVF is considered dangerous due to dilated and ectatic veins and superposition of multiple vascular structures over the fistulous point. Although some authors report that a surgical intervention was necessary after the embolization of a GPMAVF, postembolization surgery was not indicated in any of our cases. Nagashima et al reported a case that required surgical intervention to resect the venous pouch after a complete embolization. A cervical type 2 PMAVF was obliterated by embolization, but almost 1
month after, the patient’s clinical situation aggravated and she developed a tetraparesis. They postulated that this deterioration was due to the propagation of the thrombus into the venous drainage and mass effect of the thrombosed varix. We think that surgical resection of the fistula and venous pouches is not necessary after a complete embolization of the fistula, because congested veins shrink, and pulsatile mass effect of the dilated arteries disappears after a successful embolization. An MRI study after successful embolization of a GPMAVF usually shows thrombosis and shrinkage of the varix and other congested veins and reduction of the caliber of the medullary arteries (Figure 3D).

Partial embolization of a fistula is an indication for surgical obliteration as long as it does not convey an excessive risk of medullar damage. We consider surgery to be indicated in cases of aggravation of symptoms after embolization that could be due to mass effect or in case of persistent cord compression that needs an urgent decompression. In these cases, the mass effect can sometimes be secondary to periprocedural bleeding produced during the progressive occlusion of the shunt, the moment in which there is a “vascular stress” on the arterial and venous sides due to these possible complications and due to the development of highly navigable microcatheters. In 1 case (patient 1) we used transarterial balloon occlusion because of our previous experience with balloon occlusion of other types of AVFs and the lack of experience with the use of coils at that time (1990).

Ricolfi et al reported a case where gelatin sponge was used to occlude 3 radicular feeders in a cervical GPMAVF, and sudden tetraplegia and death occurred 36 hours after treatment. Autopsy showed a massive gelatin sponge pulmonary embolism. We believe that particle embolization cannot occlude the fistula effectively due to the high flow and huge size of a GPMAVF, and there is always a risk of pulmonary embolism with particles. We prefer to use transarterial embolization with coils and NBCA as the primary option, especially in cervical GPMAVFs because of the short course of the spinal arteries at the cervical level. Coils are placed in the beginning of the venous drainage to slow down the flow in the fistula and to create a turbulence that helps the polymerization after the injection of the NBCA. This also allows us to use a more liquid embolizing mixture, leading to a controlled and slower injection. It is also easier and less traumatic to retrieve the microcatheter when a more liquid mixture is used.

In 4 cases (patients 2, 3, 4, and 5), including the transvenous cases, we used NBCA as the liquid embolic agent because there was no other liquid agent available on the market and we did not have sufficient experience with the use of Onyx liquid embolic material (ev3 Neurovascular, Inc., Irvine, California) in spinal vascular malformations. In the only case where we used direct venous puncture (patient 6), NBCA was used instead of Onyx because the occlusion produced by Onyx is more progressive and slower than NBCA, and this might have created a moment of hemodynamic stress which could have provoked a hemorrhage. We prefer to use NBCA for a more controlled injection since we have more experience with NBCA in spinal vascular malformations than Onyx.

### Transarterial Approach

Successful obliteration of GPMAVFs by detachable balloons has been described.1,7 Mourier et al reported a series of 22 type 3 PMAVFs that were embolized solely with detachable balloons. They had 15 efficient embolizations (dramatic improvement in 3 cases and partial improvement in 12 cases), 6 partial embolizations (2 cases clinically worsened and 4 remained unchanged), and 1 death, which followed a quadriplegia after the obliteration. Balloons can deflate in the long term and can migrate distally, causing venous outflow obstruction and rupture of the fistula.7 Rupture of an anterior spinal artery with a detachable balloon causing spinal SAH also has been reported.16 Today, embolization of PMAVFs with balloons has been almost completely abandoned due to these possible complications and due to the development of highly navigable microcatheters. In 1 case (patient 1) we used transarterial balloon occlusion because of our previous experience with balloon occlusion of other types of AVFs and the lack of experience with the use of coils at that time (1990).

### Transvenous Approach

We used the transvenous approach in 2 cases. In 1 case (patient 4), transarterial embolization was not possible due to a previous...
embolization, which caused proximal occlusion and elimination of the arterial access (Figure 2). The other case (patient 5) had extremely tortuous and short arterial feeders that prevented sufficiently distal navigation of the microcatheter. When there is an arterio-venous type PMAVF, as in cases of dural cerebral AVFs or in some vein of Galen arteriovenous malformations, a retrograde venous approach reaching the common venous collector can be used to occlude the fistula.29

Halbach et al16 described successful embolization of lumbar GPMAVFs by the transvenous approach. The venous approach to giant PMAVFs is technically feasible and allows us to treat this pathology safely. To our knowledge, transvenous embolization of a cervical GPMAVF has not been reported before.

Direct Percutaneous Puncture and Catheterization of the Fistula

In patient 6, previous attempts with transarterial or transvenous embolization did not successfully obliterate the fistula. With the low success expectations of transarterial or transvenous endovascular approaches, surgical resection was the next option. However, taking into account the anterolateral location and the superficial topography of the venous pouch and after multidisciplinary discussion, it was decided to attempt the direct percutaneous approach for this PMAVF. Our team had previous experience in this kind of approach for the treatment of peripheral and craniofacial AVFs. Furthermore, the venous pouch was in close proximity to the primary venous collector, allowing us to catheterize it by a transforaminal puncture (Figure 3). Potential risks of this approach included instability of the Abbocath catheter, its accidental mobilization, or the accidental puncture of a dilated vessel on the way to the venous pouch. To avoid these potential risks, it is fundamental to use simultaneous bilateral roadmapping and to have the patient under general anesthesia, completely relaxed and fixed. The intervention was performed with the neurosurgical team on standby, which was prepared for an emergency surgical resection in case of a hemorrhagic complication.

Results and Follow up

In our series, all patients improved clinically, and 3 patients were asymptomatic after a mean follow-up period of 21 months. We used postoperative heparinization in all our patients to prevent any possible further propagation of the thrombosis occluding the normal venous drainage.49 We did not observe any recanalization in the radiologic follow-up of our patients, and our experience coincides with that of other authors; if the shunt is occluded all the way to the venous side with glue, whether or not it is associated with coils, revascularization is rarely seen.18,50

Surgical or endovascular interventions for cervical PMAVFs may lead to abrupt complications such as quadriplegia because of the higher localization and level of the arterial feeders. Mouri
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ou et al3 reported 1 patient who died following a quadriplegia after the embolization of a cervical GPMAVF with a detachable balloon. In our series, we did not have any complications leading to a clinical consequence during or after the endovascular treatment of cervical GPMAVFs.

Cervical GPMAVF is a rare pathology that it presents some distinctive properties compared with other spinal vascular malformations. Transarterial embolization of cervical GPMAVFs with coils and NBCA is safe when it is realized in highly experienced centers. Surgery of this type of fistula can be used to address incomplete embolizations or postembolization complications. Cervical GPMAVFs with complex angioarchitecture can be treated with transvenous embolization or direct puncture of the venous pouch with very good clinical results.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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the authors present a case series and review of the management of giant perimedullary arteriovenous fistulas. This is an extremely rare disease entity, which makes the management somewhat challenging. Although there were only 6 patients in this report, it actually represents a relatively large cohort of patients with this rare disorder. The authors have gleaned some useful insights with their experience. They emphasize the importance of treating the “isthmus point,” i.e., the precise region between artery and vein, as a key maneuver for successful endovascular treatment. By coincidence, we treated a patient of our own with a giant perimedullary fistula the same week we reviewed this manuscript, and profited from the authors’ useful observations. Many of the cases were performed before Onyx was widely available, and it will be interesting to see how its use will affect the management of these lesions.

We prefer to embolize these lesions in children under general anesthesia with continuous monitoring of motor evoked potentials and somatosensory evoked potentials. In a recent case, in which a patient had recovered from hemorrhage from a ventral cervical perimedullary fistula 6 months earlier, the motor evoked potential signal improved immediately after closure of the fistula. The observation of improvement during the procedure provides some insight into the pathophysiology of these lesions, and lends support to the notion that venous hypertension contributes to spinal cord dysfunction.

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This month’s issue of *Neurosurgery* features an outstanding review of the endovascular management of cervical giant perimedullary arteriovenous fistulas. These uncommon lesions require clear understanding of the relevant anatomy, hemodynamics, and treatment goals.

The authors bring their nearly 2 decades of experience dealing with these lesions to their report. Indeed, one can enjoy tracing the developments in tools available to the neuroendovascular specialist, from both an access and a permanent occlusive agent point of view.

In recognizing the uncommon nature of the cervical giant perimedullary arteriovenous fistula, the reader will appreciate the legitimate chance that he or she may never come across one of these lesions. Therefore, the detailed review of the methodology employed by the authors is instructive. Their thorough review of these lesions, including epidemiology and symptomatology, contextualizes the clinical problem. Finally, the review of the treatment literature neatly summarizes the body of thought regarding how to approach these uncommon lesions.

Of note, the authors assert their preference for NBCA over other liquid embolics. They believe it provides a more controlled injection and is less likely to produce a hemodynamic stress that could result in hemorrhage. Perhaps the authors’ greater experience using NBCA in spinal vascular malformations makes them unique for present-day and recently completed trainees, where, at times, the elegance of NBCA is lost in the face of the seemingly greater control of Onyx.

I salute the authors for contributing their knowledge and experience to the literature. One can only wonder what a 19-year experience starting at the present time would take shape as in 2030 when it would be completed.

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