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Complex Vertebral Arteriovenous Fistula and Ruptured Aneurysm in Neurofibromatosis: A Therapeutically Challenging Case

ABSTRACT—The objective and importance of this study was to describe the challenges encountered with treating a high-flow vertebral arteriovenous fistula (AVF) and ruptured aneurysm in a patient with life-threatening hemorrhage. A 36-year-old female with Neurofibromatosis type 1 (NF1) presented 2 weeks after uneventful cesarean section with a rapidly expanding pulsatile neck mass. Angiography demonstrated a complex left vertebral AVF and multiple associated vertebral artery aneurysms. Emergent endovascular coil embolization was performed using a retrograde and antegrade approach to occlude the fistulas and trap the ruptured aneurysm, successfully treating the acute hemorrhage. Subsequent definitive therapy was accomplished utilizing a combined neurointerventional and neurosurgical strategy of direct-puncture acrylic embolization and ligation of the vertebral artery. Recent advances in neurointerventional technology allow novel approaches in the primary and/or preoperative treatment of complex vascular lesions such as those seen in NF1.

In patients with Neurofibromatosis type 1 (NF1), arterial aneurysms and arteriovenous fistulas (AVFs) are known to occur. These patients can present acutely with life-threatening complications of their disease.¹⁻⁸ Because of the complex nature of the lesions and the underlying vascular dysplasia, treatment options are somewhat limited and carry significant risk. Incomplete treatment is associated with recurrence. With advances in neurointerventional and microneurosurgical techniques, therapeutic paradigms continue to evolve. We present a challenging case and discuss the various neuroradiological and neurosurgical strategies used to definitively treat a complex vertebral AVF and ruptured aneurysm.

CASE REPORT

A 36-year-old female with known NF1 presented to an outside hospital with sudden onset of severe, sharp, nonradiating left shoulder pain. Her past medical history was significant for an uneventful cesarean section 2 weeks prior to admission. During the immediate postpartum period, she experienced intermittent episodes of left neck and arm pain as well as left leg weakness. Her symptoms were exacerbated by exercise and relieved by rest and analgesics. Fifteen minutes after presenting to the emergency room she was observed to have an expanding left neck mass, which rapidly pro-

gressed to cause significant tracheal deviation, necessitating endotracheal intubation.

Upon arrival at our institution, she was noted to have a large mass of the left neck and chest wall, which were mildly ecchymotic and covered with cutaneous neurofibromas. She was intubated but awake, alert and hemodynamically stable. She had a left-arm monoplegia with intact touch and pressure differentiation and absence of left, arm reflexes, but was otherwise neurologically intact. No bruit was auscultated.

Angiography revealed a markedly dysplastic left vertebral artery with multiple (pseudo) aneurysms extending from the skull base to the thoracic inlet. A complex, high-flow extracranial AVF was present with rapid shunting to the epidural and paraspinal venous plexus (Fig. 1). A large ruptured proximal aneurysm was responsible for the expanding hematoma. The posterior circulation was supplied by a normal right vertebral artery, which also filled the aneurysms and fistula in a retrograde fashion. The anterior circulation was unremarkable with posterior communicating arteries present bilaterally. The left subclavian artery was dysplastic with poor distal flow.

Planned treatment included embolization of the aneurysms and exclusion of the AV connections in a distal-to-proximal fashion, likely requiring occlusion of

the parent vertebral artery. Initial attempts at antegrade catheterization of the distal left vertebral artery were unsuccessful due to the complex high-flow nature of the fistula, which preferentially directed the microcatheter into the venous system. Therefore, a 6-French guiding catheter (Cordis, Europa, NY) was placed in the cervical segment of the right vertebral artery and a microcatheter/guidewire (Target Therapeutics, Natick, MA) combination was advanced co-axially to the vertebral-basilar junction, and then retrograde to the distal left vertebral artery (Fig. 2A).

With road-mapping technique, the most distal aneurysm was occluded by endosaccular embolization using several fibered platinum microcoils (Cook, Bloomington, IN). The tortuous course of the catheter did not allow the use of the Guglielmi Detachable Coils (GDC; Target Therapeutics). The initial embolization resulted in decreased arteriovenous shunting and allowed for subsequent antegrade catheterization of the left vertebral artery (Fig. 2B). Microcoils were used sequentially to occlude a mid-cervical segment aneurysm and fistula, to trap the ruptured proximal aneurysm, and finally to occlude the proximal left vertebral artery.

Control angiography from the right vertebral artery after placement of 66 coils showed no residual shunt

Figure 1. (A) Aortogram shows a dysplastic left vertebral artery with multiple aneurysms. The left subclavian artery is also dysplastic. (B) A left subclavian injection shows the complex, high-flow vertebral arteriovenous fistula with shunting to the epidural and paraspinal venous plexus. The large, proximal vertebral artery aneurysm had ruptured (arrow).

Figure 2. (A) A left vertebral artery microcatheter (small arrows) injection performed during placement of initial microcoils to occlude the distal most aneurysm and fistula. With several coils in place (arrow) there is still partial filling of the aneurysm and continued AV shunting. (B) A mid-late arterial phase right vertebral artery control angiogram following more dense packing of the distal aneurysm shows absence of AV shunting and good intracranial runoff. (C) Unsubtracted and, (D) Subtracted right vertebral artery angiogram after placement of 66 platinum microcoils. After the most distal coils (arrow) were placed using a retrograde approach, an antegrade approach was used to occlude the mid-vertebral aneurysm and fistula, trap the ruptured aneurysm and occlude the proximal left vertebral artery.

Figure 3. Late arterial phase of a right vertebral artery injection 6 months after initial treatment shows relative slow filling of the two distal aneurysms (arrows) and recurrence of an AVF with shunting to predominantly the jugular venous system.

and complete exclusion of the giant ruptured aneurysm (Fig. 2C, D). There continued to be normal runoff to the posterior circulation with retrograde flow to the level of the left posterior inferior cerebellar artery (PICA). Following the procedure, the patient rapidly improved and was discharged 2 weeks later with a resolving left brachial plexopathy.

Six months after the initial treatment, the patient returned for routine follow-up angiography. There was continued occlusion of the proximal left vertebral artery without recanalization of the coil mass. Injection of the right vertebral artery demonstrated recurrence of an AVF with shunting to the superficial and deep neck veins of predominantly the jugular system (Fig. 3). There was no shunting to the epidural veins. The two most distal aneurysms were again filling from the distal left vertebral artery in a retrograde fashion. The angiographic appearance of the anterior circulation and the left subclavian artery were unchanged with left external carotid artery collaterals to the left upper extremity but not to the AVF.

Planned treatment at this time was occlusion of the distal left vertebral artery. No antegrade endovascular approach was available and it was felt that a repeat of the retrograde approach would be more difficult and higher risk with the coil masses present. Primary surgical ligation inferior to PICA would also pose a significant risk due to the abundance of dilated, arterialized veins and the distorted anatomy. Therefore, a combined neuroint-

erventional-neurosurgical strategy was used, utilizing direct-puncture embolization to decrease shunt flow and decompress the venous system prior to surgery.

Angiography was again performed via the right vertebral artery, and road-mapping technique was used to guide percutaneous placement of a 21-g spinal needle into the aneurysms. Slow, controlled injections of approximately 1 cc of a 1:1 mixture of *n*-butyl cyanoacrylate (NBCA) (Histoacryl, Braun, Germany) and ethiodized oil (with tungsten powder for improved fluoroscopic visualization) were injected at the presumed sites of fistulization. Postembolization control angiography showed no AV shunting, stagnating flow in the residual aneurysms, and improved intracranial run off (Fig. 4).

Surgery was performed with electrophysiological monitoring. The therapeutic goal was to obtain proximal and distal control of the vertebral artery. Using a left paramedian approach, a left suboccipital craniectomy was performed and the lamina of C1 and C2 were exposed. Due to bony dysplasia associated with neurofibromatosis, the left vertebral artery could not be adequately exposed, as it entered the dura at the suboccipital triangle. Therefore, the dura of the posterior fossa was opened and the vertebral artery was identified at the level of the PICA.

The vertebral artery was then clipped proximal to the spinal arteries using a straight Sugita clip. Surgical exposure was facilitated and blood loss was minimized by preoperative embolization, however, the vertebral artery did not completely collapse after clipping. Numerous large vascular structures were also identified within and overlying the cervical vertebrae and within the superficial muscles of the neck, raising the possibility of persistent shunting.

The patient tolerated the procedure well and was discharged 2 days later. She remained asymptomatic and returned to another institution for a follow-up angiogram approximately 6 months after the direct puncture embolization and surgery. Aortography showed retrograde filling of the left vertebral artery to the level of the surgical clip, without AV shunting or recanalization of the aneurysms (Fig. 5). The patient will be followed clinically and angiographically.

DISCUSSION

Extracranial AV fistulas of the vertebral artery are uncommon lesions and they are usually of traumatic origin. Nontraumatic vertebral AVFs can be congenital or "spontaneous," and the latter can complicate vascular dysplasias.^{2,9} There has been an increasing awareness of vascular lesions in patients with NF1, including stenoses, aneurysms, and AVFs. The AVFs are more common in women and are more often left-sided.⁴ Symptoms vary according to the anatomic location, flow patterns, and associated lesion of NF. A bruit may

Figure 4. (A) Arterial phase of a right vertebral angiogram after percutaneous direct-puncture embolization of the aneurysms shows slow, partial filling of the distal aneurysm and the subtraction artifact from the acrylic cast (arrow). (B) Venous phase of the same injection shows dense, stagnating contrast in the residual aneurysms. There was no shunting or significant venous distention.

or may not be present. Cord compression by dilated epidural veins or cord ischemia due to elevated venous pressure commonly causes motor or sensory deficits.⁴

Histologic analysis has shown proliferation of Schwann cells in the adventitia of the arterial wall, as well as intimal fibrosis and fragmentation of the elastica and smooth muscle with associated aneurysm formation.¹⁰ Large-vessel involvement (i.e., of the carotid and vertebral arteries) is generally due to adventitial compression/Schwann cell proliferation, with extensive fibrosis and smooth-muscle loss presumably representing later stages following degeneration and healing.⁵ Small-vessel involvement relates to mesodermal dysplasia and presents as stenosis or occlusion. Aneurysm formation may be due to arterial wall destruction or post-stenotic dilation. Aneurysm rupture into an adjacent vein may produce a pathological fistula, or alternatively, a high-flow fistula may secondarily lead to aneurysm formation and eventual rupture.² An AVF could arise congenitally as a manifestation of NF mesodermal dysplasia and progress with time. It is interesting that our patient presented in the postpartum period, possibly implicating additional hemodynamic factors related to blood volume and hormonal changes.

Ever since Deans et al² first reported the association of AVF and NF in the English literature in 1982, treatment with preoperative or intraoperative endovascular embolization in conjunction with surgical ligation has

been advocated.⁹ Because the natural history of this disease process is still not completely understood and disastrous complications can occur, complete occlusion of the AVF is necessary. Individual lesions must be meticulously evaluated, with special attention to flow patterns. Simple, proximal endovascular or surgical occlusion of the vertebral artery will decrease antegrade flow, but is generally ineffective because of recruitment of collateral supply to the fistula, making subsequent therapy more difficult. In addition, long-standing hemodynamic changes may be present. When there is steal from the carotid arteries and the contralateral vertebral artery, abrupt occlusion of the AVF may lead to a hyperperfusion syndrome and so-called abnormal perfusion pressure breakthrough with intracranial hemorrhage.^{3,6} As neurointerventional technology continues to advance, many tools will be available to address the problems encountered with these complex vascular lesions.¹¹

Our case presented some interesting therapeutic challenges: Due to the difficulty encountered with antegrade catheterization of a complex, high-flow fistula and a fragile, dysplastic vertebral artery, we used a retrograde approach from the contralateral side, in essence “saddling” the vertebral–basilar junction. We believe this approach to the lesion was justified considering the life-threatening situation. Although GDCs would have allowed for more precise coil placement and a better selection of appropriate-sized coils during the initial pro-

Figure 5. (A) "Scout" digital radiograph allows visualization of the cervical bony abnormalities associated with NF1 and the previously placed microcoils. (B) Follow-up aortogram done 6 months after direct-puncture embolization and surgery shows retrograde filling of the distal left vertebral artery to the level of the surgical clip (arrow) without AV shunting or aneurysm filling. There was a normal appearance to the anterior and posterior intracranial circulation, and the study was otherwise without change. (C) Venous phase of the contrast injection is consistent with complete treatment of the lesion.

cedure, the tortuous course of the catheter made coil stretching probable. The more thrombogenic fibered microcoils served to rapidly decrease shunt flow and treated the patient's acute hemorrhage.

Given the acute presentation and the lack of a carotid steal or posterior circulation ischemia, we were not compelled to perform a staged occlusion. However, despite the initial angiographic occlusion, there was a rapid recurrence of an AVF, with only difficult and dangerous options for endovascular or surgical access. We felt that approaching the recurrent lesion endovascu-

larly in a retrograde fashion would have been much more difficult with the coil masses present. In our patient, additional surgical challenges were anticipated related to NF-associated bone dysplasia (Fig. 5A).

Initially described for preoperative or palliative embolization of hypervascular tumors,¹² direct-puncture acrylic embolization has been used to treat extracranial vascular malformations.¹³ Although unconventional, this technique was successful in treating life-threatening pseudoaneurysm hemorrhage in a patient with recurrent carotid blowout.¹⁴ We used the direct-

puncture procedure to permit embolization of a vascular lesion that was inaccessible by a conventional transarterial route, and to decrease the risk of complications during surgical ligation. Of interest, we found that despite both coil and direct-puncture embolization preoperatively, many abnormal vessels were encountered at surgery. Although this suggests persistent shunting, it may represent collateral supply to the upper extremity in this patient with a dysplastic left subclavian artery.

The patient remained asymptomatic and had follow-up angiography 6 months after the direct-puncture embolization and surgical ligation procedure, approximately 1 year from initial presentation (Fig. 5). This showed retrograde filling of the left vertebral artery to the level of the surgical clip, without AV shunting or recanalization of the coil masses/aneurysms. We are cautiously optimistic about the early durability of our multimodality treatment and plan continued clinical and angiographic follow-up.

Our case illustrates how difficult it can be to completely treat the complex vascular lesions in patients with NF, and points to the need for an aggressive multidisciplinary approach and close follow-up. We have described a novel but well-conceived, combined neuro-interventional/neurosurgical strategy that proved safe and effective in treating a lesion that may have otherwise been fatal.

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