Overview of the current role of endovascular and surgical treatment in spinal dural arteriovenous fistulas

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Dural arteriovenous fistulas are the most common vascular malformations of the spinal cord. These benign vascular lesions are considered straightforward targets of surgical treatment and possibly endovascular embolization, but the outcome in these cases depends mainly on the extent of clinical dysfunction at the time of the diagnosis. A timely diagnosis is an equally important factor, with early treatment regardless of the type more likely to yield significant improvements in neurological functioning. The outcomes after surgical and endovascular treatment are similar if complete obliteration of the fistulous site is obtained. In the present study, the authors evaluated the current role of each modality in the management of these interesting lesions. (DOI: 10.3171/FOC.2009.26.1.E8)

KEY WORDS • dural arteriovenous fistula • endovascular embolization •
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SPINAL DAVFs are the most common vascular malformations of the spinal cord and its coverings.³ Despite their common occurrence, these lesions are not efficiently diagnosed.¹⁷ Although the presence of myelopathy is a distinct key point, the clinical features of a spinal DAVF and noninvasive imaging findings can be very nonspecific. Spinal DAVF is defined by an abnormal connection between the dural branch of a radicular artery and a radicular vein along the inner dural surface near the nerve root. Arterialization of the spinal perimedullary venous plexus results in myelopathy, and rarely, infarction due to venous congestion.^{2,16} The prognosis depends on symptom duration and the extent of ischemia and necrotizing myelopathy that is present at diagnosis.⁸ Timely recognition of the disease and exploration of the area of interest is therefore of paramount importance.

Treatment can be performed efficiently by endovascular or surgical disconnection of the enlarged shunting vein close to the point of its exit from the dura mater.^{1,21} Although successful surgical treatment has yielded significant neurological improvements in many patients,^{5,38,40} endovascular embolization is a less invasive treatment modality that has resulted in a comparable outcome whenever it is technically feasible.^{14,26,27,31}

In this overview, we evaluate the role of noninvasive imaging in the diagnosis of spinal DAVF, the implica-

tions of surgery and endovascular embolization in the treatment of these lesions, and the outcomes and complications.

Clinical Features

The clinical presentation of a spinal DAVF almost always includes the signs and symptoms of medullary dysfunction. Hemorrhage—a major presenting sign in cranial DAVFs or premedullary anterior spinal AVFs—virtually never occurs in spinal DAVFs, probably because of the slow flow characteristics of these lesions. Involvement of the lower thoracic spinal cord and the medullary conus causes anterior horn nuclei engagement in some cases, and therefore the congestive myelopathy can initially mimic the symptoms of lower motor neuron dysfunction and a peripheral nerve disorder.^{18,19} Venous congestion leading to hypoxia-induced ischemia is accepted as the theory of choice. This is supported by the histopathological findings of an occasional biopsy of the spinal cord¹⁶ and correlates well with the hypotheses of Foix and Alajouanine¹³ as well as to the findings in a recent description of a necrotizing myelopathy by Matsuo and colleagues.²⁴

Previously, published reports have clearly shown that there is a noticeable delay between the first signs of a spinal DAVF and the diagnosis.^{26,38} This delay is particularly important when the significant difference is compared between the rate of neurological disability at

Abbreviations used in this paper: AVF = arteriovenous fistula; DAVF = dural AVF.

FIG. 1. Sagittal thoracolumbar MR image (A) shows hypersignal intensity suggesting myelopathy in a 62-year-old man with progressive mild paraparesis. The MR ATECO (auto-triggered elliptic centric-ordered) angiographic views in the sagittal (B) and coronal planes (C and E) suggest unusual dilation of perimedullary vessels and a spinal fistula at the left T-12 level. On axial Gd-enhanced MR angiography (D) the exact level of the fistula at the proximal arterialized vein is shown. Digital subtraction spinal angiogram (F) at the left T-12 level confirms the presence of the fistula, and the fistula is identified after a surgical T11-12 unilateral laminectomy (G).

symptom onset and at presentation at the time of diagnosis. Van Dijk et al.³⁸ from our study group reported motor, sensory, and bladder impairment in 55, 47, and 10%, respectively, of patients with spinal DAVFs at onset. At diagnosis, however, these rates had increased to 96, 90, and 82%, respectively. Narvid and colleagues²⁶ have recently reviewed their experience in the treatment of 63 patients with spinal DAVFs. The rates of lower extremity motor and sensory dysfunction increased from the first presentation to the time of diagnosis from 52 and 30%, respectively, to 92 and 65%, respectively; urinary symptoms dramatically worsened from 6 to 83%. These findings confirm that significant impairment of neurological function progresses during the interval between the first presentation and the final diagnosis.

Diagnostic Imaging

Conventional spinal digital subtraction angiography is still considered the modality of choice to confirm a spinal DAVF diagnosis. Since 1999, Gd-enhanced MR an-

FIG. 2. *Upper:* Magnified surgical view of the fistula in the inner surface of the dura at the left T-12 nerve root. *Lower:* Intraoperative view after coagulation of the arterialized vein. The patient made a significant recovery at 16 months follow-up.

giography has proven useful in revealing the level of the fistula before angiography.¹² This is performed once there is suspicion of a spinal DAVF based on the spinal MR imaging results (Figs. 1A). In our practice, Gd-enhanced MR angiography has replaced diagnostic angiography, and we currently use it to localize the fistula; angiography is then performed for treatment planning of the fistula. Gadolinium-enhanced MR angiography is a much faster modality than standard multilevel angiography, and allows the diagnostic procedure to be possibly combined with treatment. Multidetector row CT is also considered a useful tool in the diagnosis of spinal DAVFs and perimedullary AVFs.^{22,23}

Spinal DAVF Location

The authors of most case series have shown that spinal DAVFs arise from lower thoracic and lumbar vertebral segmental arteries; the remainder are from the high thoracic region. Fistulas at cervical levels are rare; the highest encountered level in a previously published series was C-7.³⁸ There are only 2 reports of patients with cervical DAVFs in the literature: 1 patient presented with radiculopathy²⁰ and, remarkably, the other presented without medullary dysfunction.⁹ The rare but possible occurrence of a cervical DAVF requires that the entire length of the spinal dura mater be examined on Gd-enhanced MR and spinal angiography. Furthermore, an intracranial DAVF with spinal drainage should also be suspected when appropriate.^{6,37} Dural AVFs are preponderantly located on the left side.⁴⁰

Another rare but possible scenario is the presence of multiple spinal DAVFs. Double or multiple spinal DAVFs are rare but have been described by several authors,^{10,28,34} and their existence emphasizes the need for detailed an-

FIG. 3. *Left:* Left T-11 angiographic exploration showing a spinal DAVF causing progressive gait disturbance in a 71-year-old man. *Right:* Supraselective injection identifies a common supply to the posterior spinal artery (arrows) and the fistula, making an unsuitable condition for endovascular embolization.

giography in patients in whom spinal DAVF treatment does not result in neurological improvement, or in whom there is subsequent secondary deterioration. At our institution, 2–3% of patients with DAVFs have more than 1.³⁹

Treatment

Endovascular Treatment

In our management strategy, endovascular treatment with liquid adhesive material (mixture of *N*-butyl-2-cyanoacrylate and lipiodol) is attempted only if access is deemed possible on the basis of diagnostic imaging, and if a cure is expected after embolization. An additional important factor is the penetration of embolization materials into the proximal vein. Failure of penetration into the proximal vein results in a high rate of fistula persistence or recurrence.

There are several limitations to endovascular treatment. If the spinal DAVF contains a common segmental artery that supplies both the anterior spinal artery (or the posterior spinal artery) and the fistula, the risk in this particular situation should be assessed on diagnostic angiography, and a surgical treatment might be preferable (Fig. 3). A tortuous radicular artery can also limit endovascular access to the fistula (Fig. 4), and excessive endovascular maneuvers to advance the microcatheter to the target point may predict abandoning endovascular treatment in favor of surgery.

Endovascular treatment has been criticized in the past because of its low initial success rate and particularly high recurrence rate of up to 83% with the use of polyvinyl

alcohol.^{15,25} Recent data have suggested a higher success rate and a lower rate of recanalization after endovascular treatment with liquid adhesive embolization. The initial success rate of embolization was 25% in our patients in a previous study (11 of 44 attempts at embolization were successful),³⁸ 39% in the Eskandar series¹² (9 of 23 attempts), and 69% (27 of 39 attempts) in the study from Narvid et al.²⁶ Depending on whether the penetration of the proximal vein is required, the initial success rate in endovascular series varies from 30 to 90%.^{27,32,40}

In studies that did not require proximal vein penetration, recurrence is reportedly as high as 23%.²⁷ In the report by Van Dijk et al. recanalization was not encountered in the 11 of 48 patients who received a cure by embolization alone. There was a 19% recurrence rate (5 of 27) in the recent series of spinal DAVFs treated endovascularly by Narvid et al.²⁶ at the University of California at San Francisco.

The advantages to endovascular therapy include its noninvasiveness, the possibility for immediate angiographic control of treatment, and a shorter hospital stay.²⁶ The disadvantages are radiation exposure and the higher rate of recurrences. It is, however, accepted that, once definitive fistula obliteration is achieved, the same clinical evolution will be seen after endovascular embolization as after surgery.

Surgical Treatment

Symon et al.³⁵ and Oldfield and colleagues³⁰ have made significant contributions to the understanding and the management of spinal DAVF. Surgical disconnection of the fistula is not a difficult procedure in itself (Fig. 2).

FIG. 4. Right T-11 catheterization depicts a spinal DAVF. The radicular artery is tortuous and an attempt at endovascular embolization failed due to the difficult access.

Correct identification of the spinal level of the fistula is probably more challenging than the actual exposure or disconnection of the fistula itself. Intraoperative fluoroscopy, preoperative localization in the angiographic suite, and possibly neuronavigation can all be used to correctly identify the level of interest. There is no proven superiority, however, of any of these preoperative localization techniques. The authors of a meta-analysis of surgical series estimated an initial success rate of 98% after surgical obliteration of spinal DAVFs.³³

Complication Rates

Complication rates are low for both treatment modalities. In the meta-analysis performed by Steinmetz et al.,³³ the rate was slightly lower after surgery than embolization (1.9 vs 3.7%).

Postoperative extension of the thrombosis can cause worsening of neurological symptoms. This is not a direct complication but a rare consequence of the arterialized vein disconnection. This phenomenon has also been reported after endovascular embolization.²⁹ The few complications related to microsurgery include pseudomeningocele, instability after laminectomy, and infection.

The most striking feature of endovascular treatment is its relatively high failure rate. On the other hand, inadvertent injection of embolization materials into the perimedullary vessels can cause neurological worsening.

Outcome Evaluation

Data are insufficient with regard to long-term clinical outcome after endovascular embolization. It is therefore difficult to directly compare the clinical outcome after surgery to the outcome after embolization. The authors of most recent series have adopted a multidisciplinary approach to these lesions. In a recent endovascular series, 26 patients underwent successful embolization of their spinal DAVFs.¹⁴ At a median follow-up of 21 months, there were 5 patients (19%) with recanalization and symptom worsening, and the remaining 21 patients showed marked im-

provements from their preoperative neurological status.

When a fistula is cured, the outcome is probably the same regardless of treatment type. The authors of few surgical series have focussed specifically on long-term outcome after surgery. The majority of series with at least 12 months of follow-up show an improvement or stabilization of symptoms after treatment. Surgery has shown to have a low rate of recurrence or persistent fistula. Behrens and Thron⁵ reported on the long-term functional outcome in 21 patients after surgery for spinal DAVFs. At an average of 50 months postoperatively, 67% of patients demonstrated improvement in motor activity, 71% had resolution or stabilization in their preoperative pain, and 28% of male patients demonstrated deterioration in potency. All patients seen at a mean follow-up of 33 months after treatment remained clinically stable or had improved in the van Dijk et al. report.³⁸ The median Aminoff scores for gait and bladder function⁴ improved by 1 point in both gait and bladder assessment. Significant improvements in Aminoff scores were also found in both the endovascular and surgical groups in the study by Narvid et al.²⁶ at a mean follow-up of 49 months. The study by Tacconi and colleagues³⁶ is the only surgical series of 20 patients that has a controversial long-term outcome. At 18–36 months after treatment, surgical interruption of spinal DAVF produced improvement or stabilization of neurological disability in 84% of patients. However, after a mean follow-up of 147 months, this amelioration dropped to 35%. This degree of delayed deterioration was not seen in other series. Cenzato et al.⁸ examined the predictors of outcome and found that the type of onset of symptoms (motor deficit) and location of the fistula (lower thoracic) were both considered significant predictors of better functional outcome.

Conclusions

The current approach to spinal DAVF is multidisciplinary, and prompt diagnosis is the most important factor in its management. Outcome is directly affected by a efficient diagnosis and early treatment. Although surgery has superior overall effectiveness, endovascular embolization may be offered first if safely feasible with the objective of reaching the proximal arterialized vein. We believe that if the fistula is totally obliterated, the outcome is similar regardless of the treatment modality. Surgery or endovascular embolization can both achieve a cure and significant improvement in terms of mobility and functional and neurological outcomes.

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