Progressive neurological damage due to a vascular disorder of the spine has been recognized for more than 40 years. The advent of selective spinal catheter angiography has allowed the identification of the most common type of spinal cord vascular malformation, the spinal dural arteriovenous fistula (SDAVF) or Type I spinal vascular malformation. These lesions are defined by abnormal connections between a radicular feeding artery and the coronal venous plexus of the spine without an intervening capillary bed. The actual fistula site is at the dural sleeve of the nerve root, and the pathophysiology underlying the neurological symptoms and signs is well understood. Arterial blood flow is shunted directly into the venous plexus, under arterial pressure. The venous plexus subsequently becomes “arterialized,” and obstruction of venous outflow leads to venous congestion, venous hypertension, and progressive ascending myelopathy (Figs. 1 and 2). If untreated, this can lead to venous infarction and irreversible neurological deficits. In this review, we provide an update on this disorder with special emphasis on more recent information about clinical signs and symptoms and prognostic factors after successful treatment.

Epidemiology

Spinal dural AVFs constitute approximately 70% of spinal arteriovenous malformations and affect about 5–10 cases per million people annually.17 These lesions are thought to be acquired conditions and affect predominantly middle-aged men; at least 80% of patients in most series are male.15,18,20,22,26,30 Aside from speculation about genetic influence, the reason for such a strong male predominance is unknown. The average age at diagnosis is 58–63 years, and more than two-thirds of patients are in the 6th or 7th decade of life at the time of diagnosis.27 It is very uncommon for an SDAVF to be diagnosed in a patient younger than 30 years.15
Because the disorder is rare, and initial symptoms can be nonspecific, SDAVFs are challenging to diagnose early, and misdiagnoses are frequent. The most common disorders that are incorrectly initially considered in patients who ultimately are found to have an SDAVF include spinal stenosis, demyelinating disease, and spinal cord tumors. More rarely, conditions such as Guillain-Barre syndrome, amyotrophic lateral sclerosis, or peripheral vascular disease are incorrectly considered. Diagnosis is delayed by an average of 11–18 months after symptom onset, and it is not unusual for patients to undergo invasive surgical procedures other than interruption of the fistula for symptoms that in retrospect are attributable to the SDAVF.

Although there are characteristic clinical presentations of SDAVF, the symptoms are not specific. The majority of patients develop myelopathic symptoms that start insidiously and progress gradually over time, or occur in a stepwise fashion. In about one-quarter of patients, superimposed episodes of acute neurological worsening punctuate this decline. Much more rarely, in approximately 5% of cases, the presenting symptom is acute in nature. It is well known that activities that increase venous pressure (for example, exercise, the Valsalva maneuver) may worsen symptoms, while resting often improves them.

Foix-Alajouanine syndrome is a classic but frequently misunderstood syndrome associated with spinal cord vascular malformations. This syndrome is characterized by sudden neurological deterioration attributed to spinal cord venous thrombosis related to an arteriovenous malformation, resulting in venous infarction and necrotic myelopathy. Spinal dural AVFs had not yet been described at the time of the original report in 1926 that described 2 young men with progressive myelopathy. In retrospect, it has been speculated that the patients in the original report by Foix and Alajounaine had SDAVFs. Pathological analysis of these initial cases did not show evidence of thrombosis, and symptoms may have been attributable to venous hypertension.

The most common early symptoms of SDAVF include gait disturbances and sensory changes. Lower-extremity weakness is also a frequent initial symptom, usually affecting approximately half of patients, ranging from 32% to 81%. Sensory levels to pinprick are described in 18%–37% of patients. In 1 series of 153 cases, the most common sensory level was at the first lumbar segment, but this did not correlate well with fistula level. Other types of sensory disturbances at presentation include impaired vibration sense in the legs (49%), a stocking-like pattern of sensory loss (16%), and perineal numbness (13%).

Clinical Symptoms and Signs

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Clinical features of spinal dural AVFs

Sphincter disturbances, including urinary or fecal incontinence or retention, are characteristic as the disorder progresses. Although a minority (4%–12%) of patients have sphincter disturbances as an initial symptom, the vast majority are affected by the time of diagnosis. About one-third of men with SDAVF have erectile dysfunction.

Pain afflicts one-quarter of patients with SDAVF and can be a disabling symptom. Pain is commonly dull in quality, centered in the lower back, and may radiate into a lower extremity, which sometimes is misinterpreted as being due to degenerative vertebral disease. Burning pain involving the lower extremities and perineum also may occur.

Disability from symptoms related to SDAVF is commonly classified in a modified disability scale (known as the Aminoff-Logue disability scale). Mobility is scored from Grade 1 (activity not restricted despite symptoms) through Grade 5 (unable to stand; confined to wheelchair or bed) (Table 1). The median score at time of diagnosis is 3 (require a cane for walking), with one-half to nearly two-thirds of patients depending on a walking aid or unable to ambulate.

### Diagnosis

The clinical presentation of a middle-aged man with gradual-onset, progressive pain, weakness or sensory changes in the legs, and micturition disturbance should thus raise suspicion for SDAVF, a diagnosis that can be established with neuroimaging. Magnetic resonance imaging is essential, and it should encompass the entire spine, as localizing physical examination findings (such as sensory level) do not correlate well with fistula level. Venous hypertension results in spinal cord ischemia or edema, which manifests as homogenous, longitudinally extensive T2 signal abnormality within the central spinal cord. This signal abnormality characteristically involves the conus medullaris in as many as 95% of patients. It should be noted that while MRI is invaluable for the diagnosis of SDAVF, T2 signal abnormality on MR images does not reliably predict postoperative outcomes, and should thus not be used for prognostic purposes. In addition to abnormal cord signal, the MR images typically show cord enlargement, and dilation of perimedullary veins may be seen, particularly on T2-weighted sagittal sequences. Following MRI, selective spinal angiography provides definitive diagnosis and allows localization of the fistula by identification of the feeding artery; it also allows evaluation of the venous drainage. Inability to detect the fistula on catheter angiography is not uncommon especially in older patients due to vessel tortuosity and in patients with more advanced disease because of the relative venous hypertension that may limit the degree of shunting. In the presence of typical clinical and MRI findings, PC-FIESTA MRI can be helpful in those cases in which catheter angiography fails to visualize the lesion.

### Treatment

Two effective treatment options—surgical disconnection and endovascular occlusion—are available for SDAVs. Surgical treatment of the fistula includes a targeted laminectomy, opening of the dura, and disconnection of the draining vein. Surgery is durable and safe, resulting in long-term shunt occlusion in 98% of cases, with a morbidity rate of less than 2%. In recent years, endovascular treatment has emerged as a tenable alternative for treatment of SDAVF. Complete obliteration of the proximal portion of the draining vein is key to prevent recurrences. Although endovascular procedures have achieved favorable outcomes with low morbidity rates, not all fistulas are amenable to endovascular therapy (which may be precluded by arterial feeders too small to catheterize or a common origin of the artery of Adamkiewicz, or not uncommonly a small posterior spinal artery, from the same segmental artery as the feeder), and long-term shunt occlusion rates may not be as high as those obtained with surgery.

### Prognosis

There are no prospective studies of the natural history of untreated SDAVs. Such studies would be difficult to justify considering that available treatments are simple, safe, and effective. Attempts have been made to deduce the natural history through retrospective analysis of patients with spinal vascular malformations who were studied before the introduction of selective spinal arteriography (and thus before a diagnosis or treatment of SDAVF). In 1974 Aminoff and Logue reported on a series of 60 cases involving men with a clinical diagnosis of spinal vascular malformations; one-fifth of the patients were nonambulatory or ambulatory with crutches after 6 months, half were severely disabled within 3 years of onset of gait impairment, and 91% were restricted in their activities within 3 years of symptom onset. In retrospect, the characteristics of the vast majority of these cases are consistent with SDAVF, and at present there is general agreement that myelopathy due to SDAVF is progressive without fistula treatment.

### Outcomes

Following successful surgical or endovascular treatment of SDAVs, almost 90% of patients experience stabilization of or improvement in their symptoms.
a meta-analysis of 9 studies, 55% of patients had symptom improvement after treatment, 34% had no change, and 11% had neurological deterioration. When improvement occurs, patients gain 1–2 points on average on the Aminoff-Logue disability scale for ambulation.6,9,20,27 This is largely accounted for by an improvement in motor symptoms, the symptoms that tend to respond best to treatment, which occurs in approximately two-thirds of treated patients (R. Muralidharan, unpublished data).8

Sensory symptoms such as numbness, dysesthesia, or burning pain tend to improve less than motor symptoms, but improvement has been reported in 12%–43% of patients (R. Muralidharan, unpublished data).6,9 While most patients at least have stabilization of sensory symptoms, these worsen in 14%–22% of patients, and can be a cause of significant pain.6,9 Sphincter disturbances tend to recover less well, remaining impaired in up to 73% of those affected and improving in only 15%.9

**Predictors of Outcome**

Physicians face a challenge when trying to predict whose symptoms will improve and whose will stabilize or worsen on an individual basis. Establishing accurate predictors has been limited by the small size of most published series and inconsistent results among studies. Clinical characteristics, rather than radiological findings, seem to have the most predictive value.

One consistent finding in the literature is that patients with severe preoperative neurological deficits have worse functional outcomes when compared with those with mild or moderate preoperative impairment (R. Muralidharan, unpublished data).7,8,21 Patients with preoperative gait disability scores of 2–3 improve more than those in other grade categories.6,31 Only 11% of patients who have severe preoperative disability (defined by a total score of 6–8 on the combined Aminoff-Logue disability scale for gait and micturition) have substantial improvement postoperatively, while 78% of those with mild disability (score 0–3) improve, and 29% of those with moderate disability (score of 4–5) improve.8 Nevertheless, clinical recovery is possible even for patients with severe deficits, including paraplegia. Treatments should not be withheld from patients who are severely affected, because they still may benefit from surgery (R. Muralidharan, unpublished data).22,29

One large retrospective study of 153 patients with SDAVF treated surgically at a single institution found that the presence of preoperative claudication without a pinprick level was associated with greater chances of independent ambulation after surgery (R. Muralidharan, unpublished data). The presence of a sensory level to pinprick stimulation on preoperative examination was associated with a lower likelihood of postoperative improvement, suggesting that this could be a marker of irreversible spinal cord ischemia (R. Muralidharan, unpublished data).

Other clinical findings are not as clearly associated with outcomes. The time elapsed from symptom onset to treatment is not predictive of outcome in most studies (R. Muralidharan, unpublished data). This may in part be explained by the variable progression of irreversible neurological injury, which occurs acutely in a minority of patients. Although results of 1 study showed that older age may be associated with worse functional outcomes,21 this finding has not been replicated in other studies, and there is general agreement that patients should not be excluded from treatment solely based on advanced age (R. Muralidharan, unpublished data).8,25,27

Radiological findings on MRI have been studied as possible predictors of outcome, but clinicians and patients should not necessarily be discouraged by a radiological finding of a longitudinally extensive myelopathy, as neither the extent of preoperative nor the change in postoperative T2 signal abnormality correlates with postoperative clinical disability (R. Muralidharan, unpublished data).26 Single studies have found other imaging associations. For example, one found that patients with fistulas located in the lower thoracic region had an increased chance of improvement compared with those with fistulas located in the upper thoracic to midthoracic segments. Only 66% of patients with a fistula above T-9 showed symptomatic improvement, whereas improvement was seen in more than 90% of patients with a fistula located between the T-9 and T-12 levels.9 Another study found that spinal cord atrophy may be a predictor of unfavorable outcomes.25 These associations were found in small single-center studies and still need to be replicated in other cohorts.

Finally, the success of the treatment procedure undoubtedly influences outcomes. Complete and permanent fistula obliteration provides the best chance for symptomatic improvement and a favorable outcome. In the past, endovascular treatment has been criticized because of low initial success rates and high fistula recurrence rates (up to 83% with the use of polyvinyl alcohol).11 More recent data indicate a higher success rate and lower recanalization rates with the use of liquid adhesive embolization. The initial success rate of embolization was 69%22 in 1 recent study and has ranged from 30% to 90% depending on whether penetration of the proximal vein is required.23,26,31 Recanalization—a complication more often seen in endovascular therapy compared with microsurgical clipping—is another consideration. In 1 recent study of 26 patients treated endovascularly, 19% had recanalization and all had accompanying worsening neurological symptoms.14

The majority of patients in both surgical and endovascular series improve after treatment, and postoperative imaging to confirm resolution of the fistula is not always performed. In addition, there are insufficient data detailing long-term outcomes for patients treated with endovascular therapy, and thus it is difficult to make direct comparisons of clinical outcomes between these patients and those treated with microsurgery. Nevertheless, once the fistula is obliterated, clinical evolution after the procedure is expected to be similar in those treated by endovascular means and those treated surgically.21

**Summary**

The most common type of spinal cord vascular malformation, SDAVF, is still overall a rare disorder. This acquired lesion affects mostly middle-aged men, who typically present with insidious symptoms of myelopathy and experience progressive or stepwise decline. Motor weakness is among the most common symptoms at pre-
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sentation and it is the symptom that responds best to treatment. After surgical or endovascular disconnection of the fistula, the prognosis is reasonably good, particularly if disability is not already severe at the time of treatment. Thus, early recognition, diagnosis, and treatment are important for patients to have the best possible chances of favorable recovery.

Disclosure

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