A 52-year-old physically active man with a medical history of coronary artery disease, hypertension, and hyperlipidemia presented with numbness and tingling in the legs. His symptoms were intermittent initially, triggered by running or playing soccer and relieved by rest. Symptoms progressed during 1 year. The numbness became more constant, and he developed leg pain radiating from the popliteal fossa to the heel bilaterally (pain was more severe in the left leg compared with the right leg). Recently, he had noted some constipation as well as difficulty in initiating urination.

On physical examination, he had normal higher cortical function. Cranial nerve examination findings including funduscopia were normal. Upper extremity strength was normal; lower extremity strength was diffusely reduced (Medical Research Council grade 4/5) in all muscle groups. Reflexes were normal in the upper extremities (1+) but absent in the lower extremities. The plantar responses were flexor. Perception of light touch and superficial pain was normal in the upper extremities but impaired in a stocking distribution in the lower extremities. Vibrations sensation was impaired in the left foot more than in the right foot. His gait was unsteady and cautious.

INITIAL LABORATORY AND IMAGING STUDIES

Routine laboratory study findings (metabolic panel and blood counts) were normal. Cerebrospinal fluid (CSF) examination findings were normal. Magnetic resonance imaging (MRI) of the spine revealed abnormal enhancement and expansion of the distal spinal cord (Figure 1).

CLINICAL DISCUSSION

This patient presented with slowly progressive paraparesis, hypoesthesia, paraesthesias, and pain limited to the lower extremities. Symptoms were initially present only with exercise. These features along with evolving symptoms of bowel and bladder sphincter impairment suggest a localization involving multiple lumbosacral roots (cauda equina), conus medullaris, or both. Neuroimaging showed an enhancing, expansile intramedullary lesion of the conus medullaris.

The differential diagnosis is fairly broad and includes neoplasms, vascular disorders, demyelinating disease, infections, and other inflammatory conditions. Primary spinal cord neoplasms are rare, representing only 4% to 10% of all central nervous system neoplasms.1 The most common intramedullary neoplasms of the cord are ependymomas, astrocytomas, and hemangioblastomas. The myxopapillary ependymoma is the most common neoplasm found in the conus medullaris, representing 83% of distal cord tumors.1 Other neoplasms that could rarely involve the distal cord include metastases (especially melanoma), lymphoma, ganglioglioma, paraganglioma, subependymomas, and primitive neuroectodermal tumors. Enhancement, expansion of the spinal cord, and cystic changes are imaging features suggestive of intramedullary spinal cord neoplasms. With intramedullary spinal cord neoplasms, the

For editorial comment see page 1509
spinal fluid is typically abnormal. In a review of 503 cases of intramedullary spinal cord neoplasms, only 6% had both normal cell count and protein level.\(^2\)

Demyelinating disease (multiple sclerosis or neuromyelitis optica) must be included in the differential diagnosis of intramedullary spinal cord lesions. Acute, active inflammatory demyelinating lesions may show edema and contrast enhancement and may mimic a neoplastic mass lesion. In this case, the protracted 1-year history of progressive symptoms and normal CSF indices makes the diagnosis of demyelinating disease less likely.

Spinal neurosarcoidosis is another diagnosis to consider. Although rare, approximately 5% of patients with sarcoidosis will have clinical involvement of the central or peripheral nervous system. At autopsy, about 14% of patients will have pathological involvement of the central nervous system.\(^3\) In a review of 172 cases, spinal cord disease was the presenting manifestation in 56.9% of neurosarcoidosis cases, and it was the only manifestation in 15.6%.\(^4\) Patient age ranged from 17 to 71 years, with a mean age of 42.8 years. Cervical spinal cord was the most commonly affected site, and lumbar cord was the least common. Analysis of CSF in neurosarcoidosis will typically show pleocytosis and an elevated protein level. About 50% of patients will have an elevated angiotensin-converting enzyme level in the CSF. Enhancement and expansion of the cord as well as leptomeningeal enhancement may be seen on MRI.\(^4\)

There are many infectious etiologies that can lead to myelopathy, including tuberculosis, Lyme disease, schistosomiasis, toxoplasmosis, cysticercosis, and viruses (notably cytomegalovirus, herpes simplex virus, human herpesvirus 6, human T-cell lymphotropic virus type 1, and human immunodeficiency virus). In this case, there was no history of immunosuppression or travel. The CSF was normal and there was no history of fever. Taken together with the slow progression of this patient’s symptoms, these diagnoses are less likely.

Spinal cord infarction may occasionally appear as an enhancing mass lesion. Infarction due to arterial occlusion classically affects the anterior portion of the thoracic cord because the blood supply to that area is most vulnerable to disease affecting large radicular artery branches from the aorta. The distal spinal cord is supported by a rich anastomotic arterial supply and is therefore less susceptible. One case of fibrocartilaginous embolization affecting the distal cord and producing swelling and increased signal in the conus medullaris was reported.\(^5\) In general, arterial infarction of the cord produces sudden onset of paraparesis, which does not fit with the clinical presentation of this case.

Spinal dural arteriovenous (AV) fistulas can cause slowly progressive myelopathy with symptoms that are exacerbated by exercise or the Valsalva maneuver. This condition is more common in men and typically presents in patients aged 40 to 60 years. Neurological symptoms may progress gradually during months or years with pain, weakness, sphincter dysfunction, and prominent sensory symptoms. Enhancement and expansion of the cord may be seen on MRI. With high-quality MRI, dilated and tortuous spinal veins may be seen along the dorsal surface of the cord as T2 flow voids.\(^6\)

The initial clinical diagnosis in this case was intramedullary spinal cord tumor, and a resection of the spinal cord mass was planned. Very near the beginning of the approach to the mass, intraoperative electrophysiological monitoring detected loss of the tibial somatosensory evoked potential and loss of the motor evoked responses from the anal sphincter. The neurosurgeon elected not to attempt resection, and a biopsy was performed instead.

**NEUROPATHOLOGY**

Histologic sections of the spinal cord showed abnormal clusters of small-caliber blood vessels with unusually thick, fibrous walls (Figure 2A and B). Immunohistochemical stains revealed fragmented axons and infiltration of the neuropil by lymphocytes and macrophages. The findings suggested axonal injury due to ischemia. Thickening and proliferation of vessels raised the possibility of an associated AV fistula.

**NEUROIMAGING**

Closer review of the spinal MRIs in this case revealed an increased number of vessels along the posterior aspect of the thoracic cord (Figure 1A). Diagnostic spinal angiography was performed, which revealed a spinal dural AV fistula arising from a radicular branch of the T5 intercostal artery (Figure 2C and D). Dilated perimedullary veins extended from thoracic levels down to the conus medullaris. A few days after the diagnostic angiogram was obtained, the patient was treated with transarterial embolization of the fistula using liquid embolic agent.
Following embolization, repeated angiography showed no further filling of medullary veins. The patient tolerated the procedure well. After 5 days of inpatient rehabilitation, he was discharged using a rolling walker. Two and a half months after treatment, he was walking without assistance and the pain in his lower extremities had mostly resolved. Repeated MRI showed improvement in the cord edema and enhancement.

**CONCLUSIONS**

In 1926, Foix and Alajouanine described 2 young men with subacute myelopathy and reported autopsy findings of spinal cord necrosis with abnormally dilated and tortuous vessels situated primarily on the spinal cord surface. The underlying pathology of those cases is now believed to be a spinal dural AV fistula. In addition to the eponymic designation, the syndrome is also known as angiodyssgenetic necrotizing myelopathy, subacute necrotizing myelopathy, and venous congestive myelopathy.

The pathology is attributed to a venous congestive myelopathy. This occurs when a radicular artery connects directly to a spinal medullary vein, leading to increased venous pressure and a decrease in the AV pressure gradient. This results in venous congestion and intramedullary edema with ischemia and progressive myelopathy. Although the vascular malformation is most commonly found in the thoracic spine, venous congestion is often most severe in the distal cord, perhaps due to an orthostatic gradient in venous pressure. Involvement of the cervical cord is rare.

Pathological findings include necrosis of the affected cord regions. Gray matter structures (as compared with white matter)
Masses of enlarged, tortuous, and thick-walled subarachnoid veins are observed overlying the surface of the cord (primarily on the posterior aspect). Smaller blood vessels with thickened fibrotic walls also are present within the affected spinal cord segments. The mechanism of fistula formation remains unknown, but this is thought to be an acquired condition.7

Patients typically present with slow or stepwise progression of lower extremity weakness, numbness, and parasthesias. Neurogenic bladder and bowel and sexual dysfunction may occur later. Symptoms are frequently exacerbated by exercise. On neurological examination, patients may exhibit signs of involvement of upper motor neurons, lower motor neurons, or a combination.9

Spinal MRI is often useful in making the diagnosis. The T2-weighted images show hyperintense signal, almost always involving the conus medullaris (regardless of the location of the fistula). On axial images, the hyperintensity typically involves the center of the cord, often surrounded by a hypointense rim. There may be cord expansion and enhancement as well, often leading to an incorrect diagnosis of neoplasm. Frequently, multiple flow voids may be seen along the dorsal surface of the cord, representing dilated serpiginous dural veins.10 Myelography will usually demonstrate tortuous veins (appearing as large filling defects) along the surface of the cord.

Treatment is either surgical, by ligating the fistula, or endovascular injection of an embolic agent into the feeding artery.11 With successful treatment, progression of the disease can be stopped and most patients experience improvement in their symptoms.9,11

This case highlights the importance of a thoughtful approach to properly correlate clinical, radiological, and pathological findings. Although an enhancing expansile mass lesion with slowly evolving symptoms immediately raises concern for neoplasm, features of this clinical presentation should have pointed toward the correct diagnosis. The diagnosis of spinal dural AV fistula should be considered in any lower spinal cord syndrome, especially when the symptoms fluctuate with exertion. A careful review of MRI studies including higher spinal levels may reveal increased numbers of perimedullary vessels as evidence of this treatable diagnosis.