Intraoperative microvascular Doppler monitoring of blood flow within a spinal dural arteriovenous fistula: a precious surgical tool

Case report

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The authors describe a case of spinal arteriovenous fistula (AVF) treated by a microvascular Doppler–assisted surgical interruption of the arterialized vein. Microvascular Doppler monitoring represents a valid, widely available, noninvasive tool that enables identification, through flow spectrum analysis, of components of this type of vascular malformation. In this case because the location of the fistula was identified prior to opening the dura only minimally invasive surgery was required. Direct recordings of the arterialized draining vein and the nidus of the fistula demonstrated a pathological spectrum caused by the arterial supply and the disturbed venous outflow in which a high-resistance flow pattern and low diastolic flow resembling an arterial-like flow velocity were observed. The fistula was obliterated by interruption of the draining vein, and Doppler measurements provided information on flow velocity changes in the medullary veins from an arterial to a venous pattern. The absence of any residual flow in the AVF confirmed successful hemodynamic treatment.

Intraoperative microvascular Doppler recording during surgical closure of spinal AVF is a widely available and reliable monitoring modality that helps to produce excellent clinical results.

KEY WORDS • dural arteriovenous fistula • spine • ultrasonography • intraoperative monitoring

Spinal dural AVFs are rare, insidious but curable acquired malformations that represent 3 to 4% of all spinal cord lesions and 80 to 85% of spinal AVFs, which primarily involve the dorsal aspect of the thoracolumbar region. Typically they manifest in the fourth and fifth decades of life, more often in men than in women. These fistulas usually represent an abnormal connection between the segmental dural arterial supply of the root sleeve and the underlying medullary vein. Clinical symptoms relate to the reversal of flow in the perimedullary veins, resulting in venous hypertension.

Because of their insidious onset, they frequently remain undiagnosed for long periods of time. Patients with these lesions can actually present with a plethora of clinical syndromes mimicking many other neurological disorders that range from multiple sclerosis to spinal cord tumors to lumbar spondylosis with neurogenic claudication. Unfortunately, the disease can develop long before the neurological clinical signs are adequately interpreted and appropriate diagnostic and therapeutic measures are taken. The prognosis of patients with spinal dural AVFs is very serious: within 5 years of developing significant neurological deficits, the great majority of patients are paraplegic.

On T2-weighted MR images an increased central cord signal intensity is observed, which can be misinterpreted to indicate myelitis, medullary ischemia, and sometimes intramedullary glioma. The emergence of gadolinium-enhanced MR imaging and MR angiography technology has helped in the differential diagnosis.

The most important goal in the treatment of spinal dural AVFs is to achieve complete obliteration of the fistula without aggravating spinal cord venous drainage because recurrence of the fistula is associated with an extremely high risk of progressive myelopathy.

In this article, we present a simple, noninvasive, intraoperative monitoring method, in which 16-MHz pulsed microvascular Doppler ultrasonography with a 1-mm-diameter probe, is used for easy and immediate assessment of blood flow. The goals of this report were to veri-
fy whether it is possible to differentiate the epidural arterialized veins draining from the normal venous drainage pathway; to localize precisely the intradural fistula, thereby allowing a minimally invasive surgical approach; and to confirm the disappearance of the arterial spectrum after interruption of the fistula.

CASE REPORT

Presentation. This 51-year-old woman was admitted to our neurosurgical department with a 6-month history of progressive lower-limb weakness, bilateral lower-extremity hypesthesia and paresthesia, loss of vibratory sense, and spastic–ataxic gait.

Examination. A spinal MR imaging examination revealed high intramedullary signal intensity in the T7-weighted images at the T-7 level and a slightly enlarged spinal cord simulating an intramedullary tumor (Fig. 1). Selective spinal arteriography demonstrated a dural AVF at the T7–8 level, which was fed by a single radicular artery, as well as a tortuous and ectatic venous plexus, grossly developing downward to the lumbar region (Fig. 2).

The patient underwent surgery in which the AVF was obliterated by a microvascular Doppler-assisted surgical occlusion of the arterialized vein.

The surgical treatment consisted of a limited unilateral approach: under fluoroscopic control a right-sided T7–8 hemilaminectomy and partial facetectomy were performed after making a midline skin incision. Using a microvascular Doppler device, transdural localization of the fistula was performed (Fig. 3) allowing a minimal (3-cm) dural incision centered over the lesion. An abnormal intradural vessel was noted adjacent the right-sided T-7 nerve root. The nidus of the fistula was comprised of large, dilated, tortuous vessels developing on the dorsal surface of the cord. Additional Doppler ultrasonography measurements were acquired to identify the arterialized intradural draining vein (Figs. 4 and 5), which was then closed using vascular clips. After these procedures, the distended perimedullary veins became darker in color and collapsed within 5 to 10 minutes, and the absence of flow signal confirmed interruption of the abnormal shunt.

Follow-Up Course. The follow-up examination showed improving motor and sensory functions at 1, 3, and 6 months postoperatively.

Doppler Monitoring

A high-frequency 16-MHz pulsed doppler device (Ex-
Intraoperative microvascular Doppler monitoring

Fig. 3. Doppler measurements performed over the dura at T-7 for the localization of the intradural spinal AVF at that level. The signal, ascribable to the arterialized vein, was detected at a 5-mm depth. Blood flow velocities were 8 cm/second (systolic), 3 cm/second (diastolic), and 4.7 cm/second (MV). The RI was 0.62 and the PI 1.06. D = diastolic; HR = heart rate; S = systolic; STI = systolic time interval; Vdia = velocity during diastole; Vsys = velocity during systole.

Fig. 4. Doppler measurements of the arterialized draining vein of the AVF. Recordings were performed directly over the fistula, after dural opening, at a 2-mm insonation depth with a sample volume of 1.1 mm. Registered flow velocities were 14 cm/second (systolic), 5 cm/second (diastolic), 8 cm/second (MV); the RI was 0.64 and the PI was 1.12. The reduced angle of insonation resulted in a higher velocity, which more closely reflects the real blood flow velocity in the examined vessel.
incidence of complications and a zero mortality rate have been achieved in most reported cases. A low-perfusion of the spinal cord, as well as the need to obliterate the arterialized vein, into the coronal venous plexus of the spinal cord. Because the normal veins of the coronal plexus become arterialized, the venous pressure in the spinal cord increases and pathological changes, with consequent progressive myelopathy, develop as a result of venous hypertensive ischemia.3,19 Measurements of intravascular pressure in the draining veins have, in fact, confirmed this assumption.15 In our case it was possible to minimize the extent and soundwave when the transmitter, the receiver, and the reflecting object move in relation to one another. This change in frequency is proportional to the velocity of the movement. The Doppler effect is the difference in frequency of transmitted and received soundwaves and is proportional to blood flow velocity.12 Doppler ultrasonography recording of blood flow velocities in the extracranial arteries supplying the brain has been used to investigate cerebral hemodynamics since the first description in the early 1960s.17 The technique was then modified for the purpose of transcranial Doppler ultrasonography.1 The use of intraoperative microvascular Doppler ultrasonography for hemodynamic evaluation in cerebrovascular arteries was first described by Nornes and colleagues.24,25 By using a higher transmission frequency of 20 MHz, Gilsbach was able to decrease the size of the transmitter crystal and thus make the Doppler probe 3 mm in diameter. They explained that the fistula was epidural in location and usually related to a lower thoracic nerve root dural sheath. The lesion generally remains asymptomatic until drainage becomes possible, usually through a single arterialized vein, into the coronal venous plexus of the spinal cord. Because the normal veins of the coronal plexus become arterialized, the venous pressure in the spinal cord increases and pathological changes, with consequent progressive myelopathy, develop as a result of venous hypertensive ischemia.3,19 The goal in treating a spinal dural AVF is to eliminate the venous congestion of the spinal cord. Surgery or endovascular embolization is performed to interrupt of the connecting veins from the fistula to the perimedullary venous plexus.2,3,7,16,32,33 Preserving normal perfusion of the spinal cord, as well as the need to obliterate completely the AVF, cannot be emphasized enough.

The results of open surgery for spinal dural AVFs are generally excellent: complete obliteration and permanent cure have been achieved in most reported cases. A low incidence of complications and a zero mortality rate have been reported.13,26 Embolization is associated with a 60 to 90% obliteration rate.13,23 In general, surgical ligation of the intrathecal arterialized draining vein can lead to a cure with minimal complications.

The necessity of using an intraoperative monitoring system during these procedures has been previously emphasized.14 The monitoring techniques used in the past included intraoperative angiography and local invasive intravascular pressure measurement. The main advantage of the Doppler technique is that the system is noninvasive and widely available.

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It is well known that the velocity patterns of arterial compared with venous flow, as detected by Doppler ultrasound, are very different. According to Proucelot, the relationship between the systolic peak flow velocity and the end-diastolic velocity of an artery is indicative of the vascular resistance in the peripheral distribution of the vessel. The RI depends mainly on the relative magnitude of the end-diastolic velocity. A low value corresponds to a low resistance, and relatively elevated end-diastolic flow velocities indicate low peripheral vascular resistance. Normally, the arterial flow is a high-resistance, pulsatile flow that is detected by Doppler examination with a characteristic velocity spectrum pattern, whereas venous flow is a low-resistance nonpulsatile flow.

The direction and velocity of the shunt flow were also examined during surgical clipping, and a dramatic hemodynamic change was detected. As the fistula was closed at is entrance within the dura, the arterialized flow completely disappeared on the medullary veins, whereas, on visual inspection, the vascular tangle was observed to grow darker within a few minutes.

In conclusion, intraoperative microvascular Doppler monitoring during surgical closure of spinal AVF is a widely available and noninvasive modality that may help to produce excellent clinical results.

References


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