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Angiographic and Clinical Characteristics of Thoracolumbar Spinal Epidural and Dural Arteriovenous Fistulas

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Background and Purpose—The purpose of this study is to compare the angiographic and clinical characteristics of spinal epidural arteriovenous fistulas (SEAVFs) and spinal dural arteriovenous fistulas (SDAVFs) of the thoracolumbar spine.

Methods—A total of 168 cases diagnosed as spinal dural or extradural arteriovenous fistulas of the thoracolumbar spine were collected from 31 centers. Angiography and clinical findings, including symptoms, sex, and history of spinal surgery/trauma, were retrospectively reviewed. Angiographic images were evaluated, with a special interest in spinal levels, feeders, shunt points, a shunted epidural pouch and its location, and drainage pattern, by 6 readers to reach a consensus.

Results—The consensus diagnoses by the 6 readers were SDAVFs in 108 cases, SEAVFs in 59 cases, and paravertebral arteriovenous fistulas in 1 case. Twenty-nine of 59 cases (49%) of SEAVFs were incorrectly diagnosed as SDAVFs at the individual centers. The thoracic spine was involved in SDAVFs (87%) more often than SEAVFs (17%). Both types of arteriovenous fistulas were predominant in men (82% and 73%) and frequently showed progressive myelopathy (97% and 92%). A history of spinal injury/surgery was more frequently found in SEAVFs (36%) than in SDAVFs (12%; P=0.001). The shunt points of SDAVFs were medial to the medial interpedicle line in 77%, suggesting that SDAVFs commonly shunt to the bridging vein. All SEAVFs formed an epidural shunted pouch, which was frequently located in the ventral epidural space (88%) and drained into the perimedullary vein (75%), the paravertebral veins (10%), or both (15%).

Conclusions—SDAVFs and SEAVFs showed similar symptoms and male predominance. SDAVFs frequently involve the thoracic spine and shunt into the bridging vein. SEAVFs frequently involve the lumbar spine and form a shunted pouch in the ventral epidural space draining into the perimedullary vein. **(*Stroke*. 2017;48:3215-3222. DOI: 10.1161/STROKEAHA.117.019131.)**

Key Words: angiography ■ arteriovenous malformations ■ drainage ■ male ■ spinal injuries

Spinal dural arteriovenous fistulas (SDAVFs) are the most common vascular shunts of the spine. They occur predominantly in men (80%), commonly involve the thoracolumbar spine, and usually cause progressive myelopathy because of venous congestion of the spinal cord.[1,2] It is widely accepted that SDAVFs is fed by the radiculomeningeal artery, located on the dura mater of the spinal nerve root sleeve, and drains into the radiculomedullary vein.[2,3] In contrast, spinal epidural arteriovenous fistulas (SEAVFs) are rare vascular shunts that have been thought to present with benign symptoms, such as radiculopathy. The shunt is located in the epidural space and drains into epidural veins.[3–5] However, their angiographic and clinical features have not been well investigated in a large number of cases. Some investigators regard SDAVFs as lateral SEAVFs, in which the arteriovenous shunts develop in the lateral epidural space, although the arteriovenous shunt of an SDAVF is located on the dura mater.[3,5] Therefore, SEAVFs are poorly understood and may be misdiagnosed as SDAVFs.

The aim of this study was to compare the angiographic and clinical characteristics of SEAVFs and SDAVFs of the thoracolumbar spine based on a retrospective multicenter cohort study.

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This study is approved by the institutional review boards of all collaborative institutions.

Materials and Methods

We will not make our data and study materials available to other researchers.

Patients

A total of 207 consecutive patients with a diagnosis of SDAVFs, SEAVFs, or paravertebral arteriovenous fistulas (AVFs) of the thoracolumbar spine between 2005 and 2016 were enrolled from 31 neurovascular centers in Japan. All participating centers were neurosurgical or neuroendovascular training centers certified by the Japan Neurosurgical Society and the Japanese Society of Neuroendovascular Therapy and expressed interest in study participation (Table I in the online-only Data Supplement).

Data Collection

Data were collected retrospectively using a standardized form, including age, sex, symptoms, history of spinal surgery or trauma, treatment methods, treatment results, and angiography and magnetic resonance imaging in DICOM (digital imaging and communications in medicine) data format. Symptoms included myelopathy because of venous congestion, radiculopathy, intramedullary hemorrhage, subarachnoid hemorrhage, and others. All datasets were organized by 3 researchers (S.Y., K.T., and T.T.) at the coordinating center.

Image Interpretation

All images collected were reviewed by 6 reviewers (H.K., Y.M., Y.N., K.T., T.I., and M.H.) on a viewer using DICOM viewer software (Osirix) at the coordinating center. Each reviewer had >10 years of experience in spinal angiography. Five are neurointerventionalists certified by the Japanese Board of Neuroendovascular Therapy, and one is a spine neurosurgeon certified by the Neurospinal Society of Japan. After the preliminary review, 38 patients were excluded because of poor image quality (low spatial or temporal resolution) precluding analysis of the details of the angioarchitecture (n=20), sacral or cervical levels (n=12), intradural AVFs (n=5), and AVFs associated with spinal tumors (n=2). Ultimately, 168 lesions in 168 patients were analyzed in detail.

An anteroposterior view of selective angiography of each segmental artery was reviewed. In addition, lateral and oblique views were also interpreted when the AVF was detected in the anteroposterior view. Three-dimensional angiography, including cone beam computed tomography and multiplannar reconstruction images of rotational angiography, superselective angiography of the feeding arteries, video, and photographs taken during the surgical procedure were also reviewed when available.

All images were reviewed by the 6 reviewers to reach a consensus about the feeding artery, the location of the AVFs, the presence and location of a shunted venous pouch in the epidural space, and the drainage vein. At the end of each case review, the final diagnosis of AVF was made by a consensus among all the 6 readers, and it was compared with the initial diagnosis at the participating center.

An SDAVF was defined as an arteriovenous shunt located on the dura and draining to the intradural vein alone. An SEAVF was defined as an arteriovenous shunt located outside the dura, draining to the epidural vein with the formation of an epidural venous pouch, and then into the paravertebral vein or the intradural vein (radiculomedullary vein).

For the cases of SDAVF, the location of the shunt point in relation to the thecal sac on the anterior view of the spinal angiography was evaluated using the medial interpedicle line as the estimated lateral margin of the thecal sac. The medial interpedicle line is the tangent line connecting the most medial point of the pedicle circles between the upper and lower spinal levels (Figure 1). The location of the shunt point was classified into 3 types: lateral, on line, and medial. Lateral type suggests that the AVF is located on the dural sleeve and drains into the radiculomedullary vein, whereas medial type suggests an AVF located on the spinal dura mater (thecal sac) and draining into the bridging vein. The location of the shunt point is undetermined for the on line type.

For the cases of SEAVF, the location of the shunted epidural venous pouch was classified as ventral, lateral, or dorsal based on the anterior and lateral views of the spinal angiography. A lateral epidural

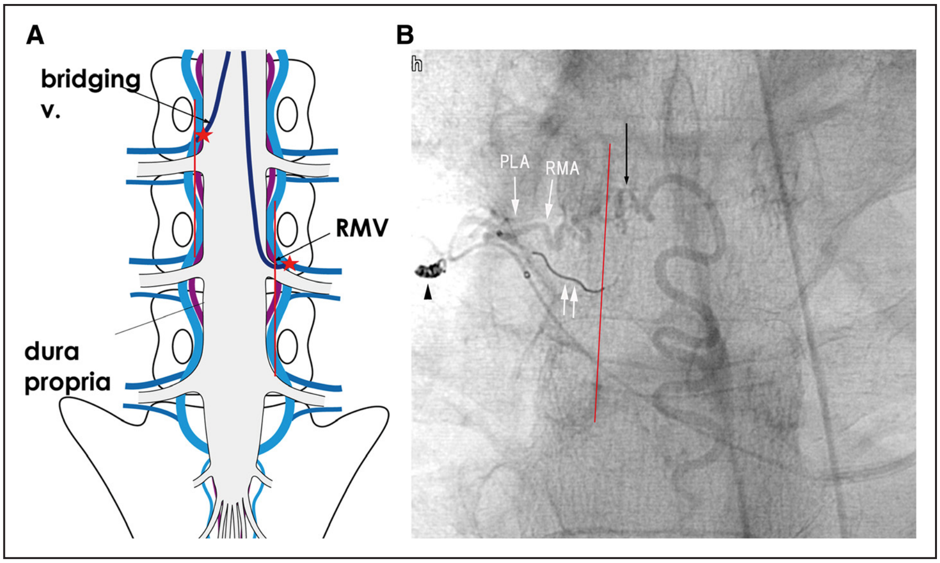

Figure 1. Relationship of the medial interpedicle line with the location of the shunt point in spinal dural arteriovenous fistulas. **A**, Schematic drawing of the medial interpedicle line (red line) and its relation to the location of the shunt point (star) of the spinal dural arteriovenous fistulas (SDAVFs). The SDAVF shunts to the bridging vein on the dura mater of the spinal cord when the shunt point is medial to the medial interpedicle line (right side). The SDAVF shunts to the radiculomedullary vein (RMV) on the dura mater of the spinal nerve root sleeve when the shunt point is lateral to the medial interpedicle line (left side). **B**, Superselective angiography of the radiculomeningeal artery (RMA) in a patient with SDAVF during an embolization procedure. The red line represents the medial interpedicle line. The shunt point (arrow) of the SDAVF is medial to the medial interpedicle line, suggesting that the SDAVF shunts to the bridging vein on the dura mater of the spinal cord. Lateral muscular artery (arrowhead) and the dorsal somatic branch (double with arrows) are embolized with coils. PLA indicates prelaminar artery.

AVF was defined as a shunted pouch lateral to the medial interpedicle line on the anterior view. The shunted pouches of the ventral and dorsal epidural AVFs are medial to the medial interpedicle line and are located on the ventral side and dorsal side in the spinal canal on lateral view, respectively.

Data Analysis

Clinical and angiographic data, which included types of AVFs, angiographic findings (spinal levels, laterality, main feeding arteries, and drainage types of AVFs [perimedullary drainage, paravertebral drainage, or both]), and clinical findings (symptoms, age, sex, and history of spinal injury or surgery), were summarized using descriptive statistics.

All statistical analyses were performed using XLSTAT software. Correlations of types of AVFs with spinal levels, laterality, bilateral supply, symptoms, sex, and history of spinal surgery/trauma were statistically analyzed using the χ^2 test. The statistical level of significance was set at P=0.05. Vascular anatomy related to SDAVFs and SEAVFs and anatomic terms used in this article are demonstrated in Figures I and II in the online-only Data Supplement.

Results

The initial diagnoses of the AVFs at the 31 individual centers were SDAVFs in 135, SEAVFs in 31, and paravertebral AVFs in 2 patients. The final diagnoses after precise review of the imaging data by 6 readers were SDAVFs in 108, SEAVFs in 59, and paravertebral AVFs in 1 patient. Twenty-nine cases (49%) of SEAVFs were misdiagnosed as SDAVFs at the individual centers. After exclusion of 1 case of a paravertebral AVF, the remaining 168 cases were further analyzed.

Clinical Findings

The median ages at presentation in patients with SDAVFs (SDAVF group) and SEAVFs (SEAVF group) were 64.4 and 66.6 years, respectively. Both groups predominantly contained men (89 of 108 in SDAVF group and 43 of 59 in SEAVF group). The most frequent symptom of the SDAVFs was progressive myelopathy (105 patients; 97.2%), followed by radiculopathy (5 patients) and back pain (4 patients). Subarachnoid hemorrhage and intramedullary hemorrhage were found in 1 patient each. The most frequent symptom of the SEAVFs was also progressive myelopathy (54 patients; 91.5%), followed by radiculopathy (7 patients) and back pain (1 patient). Mean value of the modified Rankin Scale at presentation was 2.9 (1–5) in SDAVFs group and 3.1 (0–5) in SEAVF group, respectively. There were no significant differences in age, sex, or symptoms between the 2 groups. A history of spinal surgery or trauma was more frequently observed in the SDAVF group (13 patients; 12%) than the SEAVF group (21 patients; 36%) with statistical significance (P=0.001; Table II in the online-only Data Supplement).

Angiographic Findings

Spinal Levels

SDAVFs were much more frequent at the thoracic spine levels (94 of 108 cases; 87%) than at the lumbar spinal levels, whereas SEAVFs were frequently located at the lumbar spinal levels (49 of 59 cases; 83%). There were significant differences in frequency between SDAVFs and SEAVFs at the T5 to T8 levels (P<0.001) and L2 to L5 levels (P<0.001; Figure III in the online-only Data Supplement; Table).

Laterality

There was no overall laterality for SDAVFs or SEAVFs. SDAVFs were located on the right side in 56 patients and the left side in 52 patients. SEAVFs were located on the right side in 22 patients and the left side in 31 patients. Six of 59 cases of SEAVFs showing diffuse epidural AVFs were located bilaterally.

Main Feeding Arteries

SDAVF

Meningeal branches of the radiculomeningeal artery were the main feeding arteries in 99 of 108 cases (91.7%) of SDAVFs. Meningeal branches from the prelaminar artery often fed the SDAVFs as an additional feeder (n=28; 26%) or the main feeder (n=9; 8.3%). The feeding arteries arose from 2 ipsilateral segmental arteries at serial spinal levels in 14 (13%) or from the bilateral segmental arteries in 5 cases (4.6%). These feeding arteries ran medially on the surface of the dural sleeve and turned longitudinally along the thecal sac. Then they gathered and joined the single vein on the inner dural surface. In typical cases, these longitudinal meningeal feeders and a drainage vein showed horizontal T sign in an anteroposterior view of angiography (Figure 2).

SEAVF

SEAVFs were mainly supplied from the dorsal somatic branches in 54 patients (91.5%), the prelaminar artery

Table. Characteristic Angiographic Findings of SDAVFs and SEAVFs

	SDAVFs (n=108)	SEAVFs (n=59)	
Spinal levels			P<0.001
Thoracic spine	94	10	
Lumbar spine	14	49	
Main feeding artery			P<0.001
Radiculomeningeal artery	99	1	
Dorsal somatic branch	0	54	
Prelaminar artery	9	4	
Bilateral feeders	5	29	P<0.0001
Shunt points of SDAVFs to the medial interpedicle line			
Medial	68		
On the line	16		
Lateral	4		
Nonassessable	30		
Locations of SEAVFs			
Ventral		52	
Lateral		6	
Dorsal		1	
Drainage pattern of SEAVFs			
Perimedullary drainage		44	
Paravertebral drainage		6	
Combined drainage		9	

SDAVF indicates spinal dural arteriovenous fistula; and SEAVF, spinal epidural arteriovenous fistula.

in 4, and the radiculomeningeal artery in 1. The ventral somatic branches also fed the SEAVF as accessory feeders in 14 patients. Multiple feeders joined to an epidural venous pouch at the multiple fistulous points (Figure 3). The feeders arose from ipsilateral multisegmental arteries at serial spinal levels in 15 (25.4%) cases. The SEAVFs were more frequently supplied from bilateral segmental arteries (n=29; 49.1%) than the SDAVFs with statistical significance (*P*<0.0001).

Locations of the Shunt Point in SDAVFs

Twenty cases were excluded from this analysis because of lack of the images depicting the pedicle circle. In the remaining 88 cases, the shunt point of the SDAVF was more frequently located medial to the medial interpedicle line (n=68; 77%) than any other position (on line in 16 cases, 18%; lateral in 4 cases, 5%; Figures 1B and 4).

Locations of the Shunted Venous Pouch in SEAVFs

The shunted venous pouch of the SEAVFs was located much more frequently in the ventral epidural space (52 cases; 88.1%) than the lateral epidural space (6 cases; 10.2%) or the dorsal epidural space (1 case; 1.7%; Figures 3 and 4).

Drainage Types of SEAVFs

Every SEAVF formed an epidural venous pouch, and it drained into the perimedullary vein in 44 cases (75%), the paravertebral veins in 6 (10%), or both in 9 (15%; Figures 3, 4, and 5). In the cases of ventral SEAVFs, the drainage route from the epidural venous pouch to the radiculomedullary vein typically formed an acute angle, characteristic of J turn sign.

Treatments

SDAVFs

In 108 patients with SDAVFs, 107 patients were treated by surgical interruption of the intradural draining vein (n=39), transarterial embolization (TAE) using n-btyl 2 cyanoacrylate (n=47), or combination of open surgery and TAE (n=19). One patient was observed without treatment. Disappearance of SDAVF was obtained in 102 patients (95%), which includes 44 of 49 patients treated by TAE alone and all 58

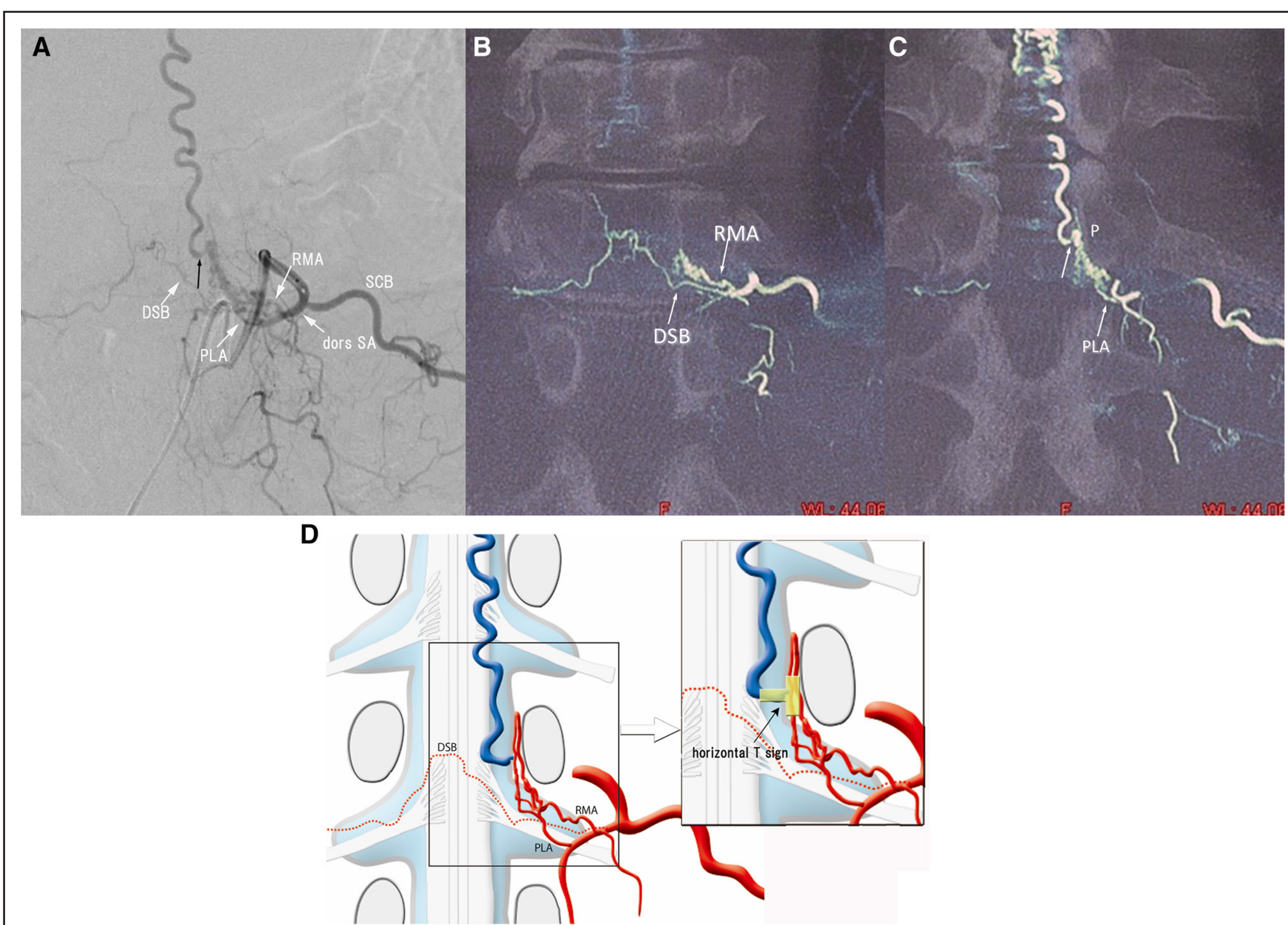

Figure 2. Typical angiographic features of spinal dural arteriovenous fistulas (SDAVFs) in a 63-year-old man who presented with progressive myelopathy. **A**, Anterior view of the left subcostal angiography shows an SDAVF fed by multiple meningeal branches. The meningeal branches mainly originate from the radiculomeningeal artery (RMA) and turn longitudinally to gather and join the single vein (arrow) that continues to the perimedullary vein. **B**–**D**, Coronal maximum intensity projection images reconstructed from rotational angiography of the sub To Reviewer #1: 3costal artery and schematic drawing of the angioarchitecture (**D**). Multiple meningeal branches originating from the RMA and the prelaminar artery (PLA) join and continue to the bridging vein on the dura mater of the spinal cord (white arrow). Longitudinal meningeal arterial feeders and a drainage vein form horizontal T sign (yellow color in **D**). The dorsal somatic branch (DSB) does not feed the SDAVF. dors SA indicates dorsal spinal artery; and SCB, subcostal branch.

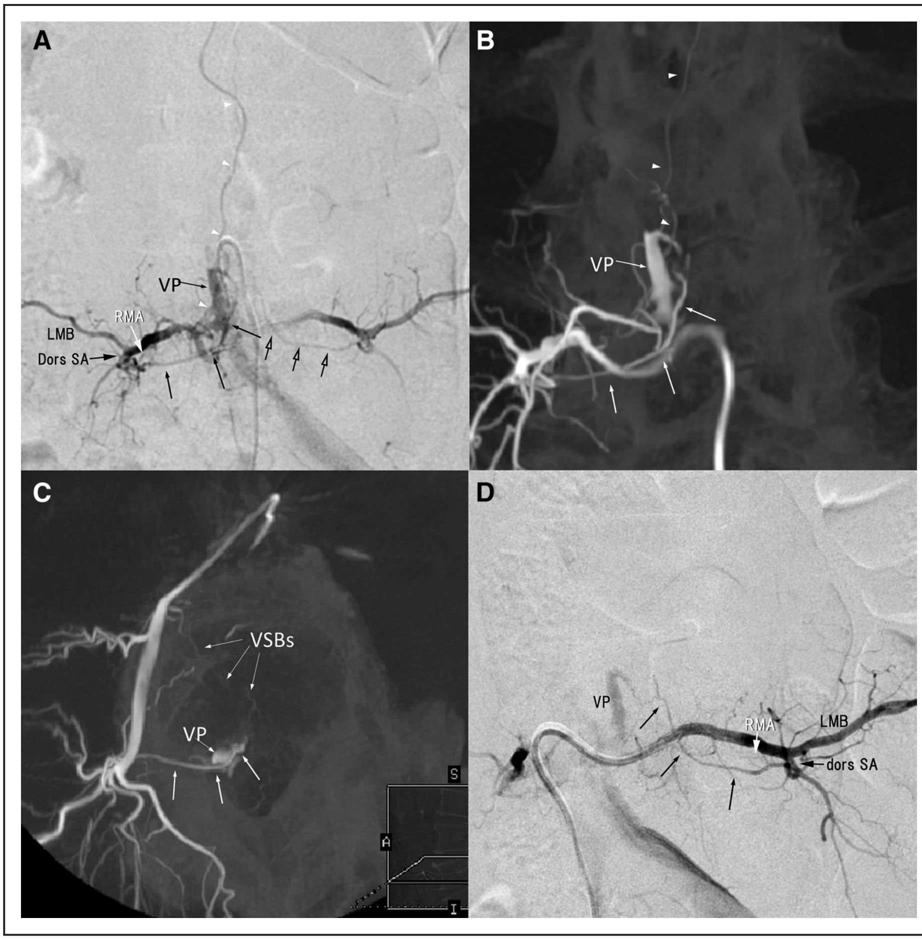

Figure 3. Typical angiographic features of spinal epidural arteriovenous fistulas in a 69-year-old man who presented with progressive myelopathy. **A**–**C**, Anteroposterior view (**A**) and coronal (**B**) and axial (**C**) maximum intensity projection images of the right fourth lumbar angiography shows an epidural arteriovenous fistula with an epidural venous pouch (VP) fed by the right dorsal somatic branch (arrows) and the left dorsal somatic branch (open arrows). The arteriovenous fistula drains into the perimedullary vein (white arrowheads). Axial maximum intensity projection image (**C**) shows that the ventral somatic branches (VSBs) and the dorsal somatic branch shunt to the VP located in the ventral epidural space. **D**, Anteroposterior view of the left fourth lumbar angiography shows that the left dorsal somatic branch (arrows) also shunts to the epidural VP. dors SA indicates dorsal spinal artery; and LMB, lateral muscular branch.

patients treated by open surgery or combined treatment. Complications related to the procedure were encountered in 6 patients, which include arterial injury during catheterization (n=3), delayed spinal venous thrombosis after embolization (n=2), and wound infection after open surgery (n=1). Ninety-eight patients could be followed for 3 months, and modified Rankin Scale at 3 months after treatment was improved in 59 patients (60%), unchanged in 37 patients (38%), and worsened because of delayed spinal venous thrombosis in 2 patients (2%). Recurrence of SDAVF was observed in 3 patients (3%). All the 3 patients were initially treated by TAE alone, and they were retreated by open surgery.

SEAVFs

Among the 59 patients with SEAVFs, 45 patients (76.3%) were treated by endovascular technique alone, including TAE, using n-btyl 2 cyanoacrylate (n=43) and transvenous embolization (n=2). Nine patients were treated by surgery of interruption of the intradural draining vein with or without surgical devascularization of the feeders, and 4 patients were treated by combination of open surgery and TAE. One patient was observed without treatment. Disappearance of SEAVF was obtained in 43 patients (74%), which includes 31 of 43 patients treated by TAE alone, 2 of 2 patients treated by transvenous embolization, and 10 of 13 patients treated by open surgery or combined treatment. Complications were encountered in 2 patients, which were arterial injury during catheterization. Fifty-one patients could be followed for 3 months. The modified Rankin Scale at 3 months after treatment was improved in 33 patients (65%), unchanged in 17 patients (33%), and worsened in 1 patient (2%). Recurrence of SDAVF was observed in 3 patients (6%), which were 2 cases initially treated by TAE alone and 1 treated by open surgery.

Discussion

SEAVF is an entity consisting of a spinal arteriovenous shunt draining primarily into the epidural venous plexus, and it can also involve the bony structure adjacent to the epidural space.[3,4,6] SEAVFs had been diagnosed as paravertebral AVFs or SDAVFs with epidural venous drainage before the recognition of this entity.[7,8] SEAVFs are classified into 3 types according to their venous drainage, including intradural/perimedullary drainage,

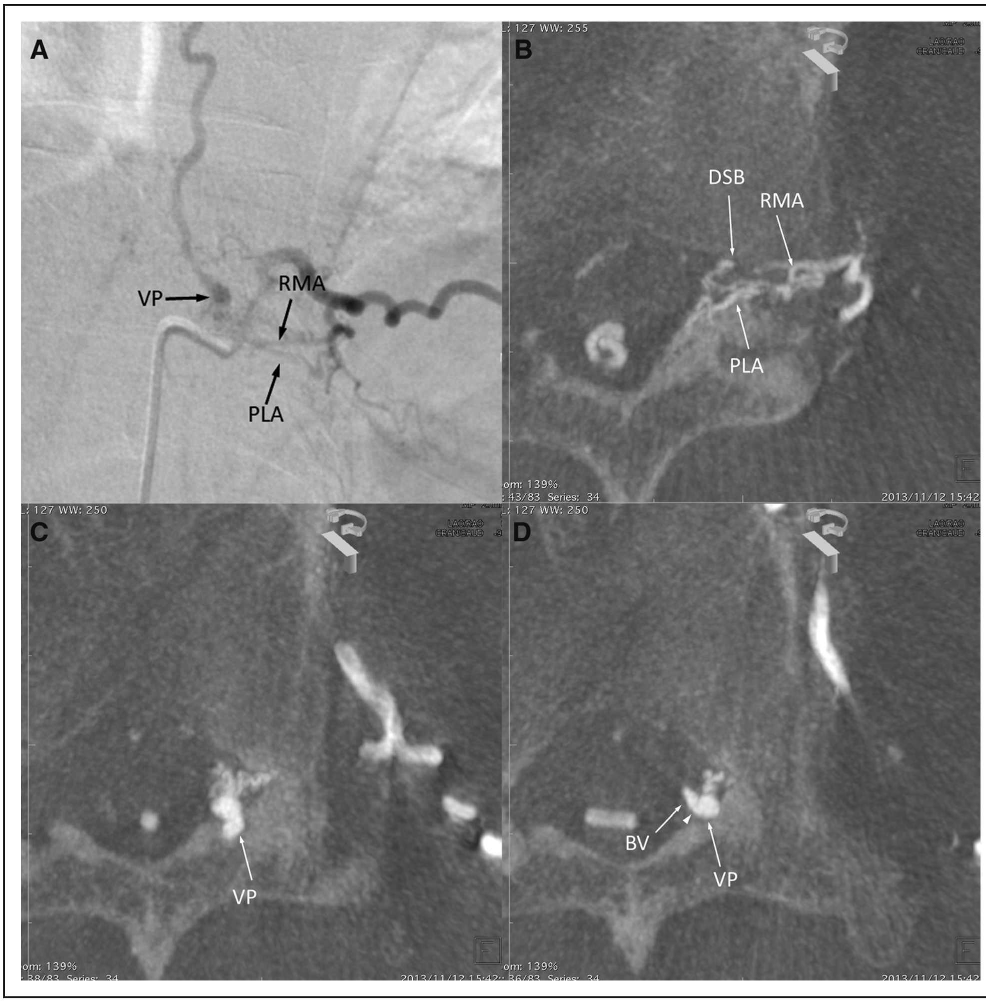

Figure 4. Spinal epidural arteriovenous fistulas located in the lateral epidural space in a 76-year-old man who presented with progressive myelopathy. **A**, Anteroposterior view of the left second lumbar angiography shows that multiple feeding arteries from the radiculomeningeal artery (RMA) and the prelaminar artery (PLA) converge on a venous pouch (VP), which continued to the perimedullary vein. **B**–**D**, Axial reformatted images of the rotational angiography of the left second lumbar artery show multiple feeding arteries arising from the PLA, the dorsal somatic branch (DSB), and the RMA converge on a VP, which were located in the lateral epidural space and partially in the vertebral arch. The VP continues to an intradural vein (bridging vein [BV]). A slit-like stricture (arrowhead) is seen at the junction of the epidural VP and the BV.

paravertebral drainage, and combined perimedullary and paravertebral drainage.[9,10] SEAVFs with paravertebral drainage can be diagnosed because of their typical drainage to the outside of the spinal canal. However, even now, SEAVFs with perimedullary drainage alone are often incorrectly diagnosed as SDAVFs. In this study, 29 cases(49%) of SEAVFs were incorrectly diagnosed as SDAVFs at the individual centers.

Clinical Findings

Geibprasert et al[5] classified SEAVFs and SDAVFs into 3 groups according to the location (ventral, lateral, and dorsal). According to their classification, SDAVF was classified as lateral epidural group, which frequently showed aggressive symptoms. They demonstrated that the ventral epidural group showed benign clinical presentations, a lower rate of spinal venous reflux, and predominantly female demographics.[5] However, a few reports demonstrated high frequency of spinal venous reflux in ventral SEAVFs at thoracolumbar spine.[9,10] The results of the present study showed no significant differences between the SDAVF and the SEAVF in sex, age, or clinical presentations. Both showed predominantly male demographics, frequent symptoms of progressive myelopathy, and frequent spinal venous drainage. This discrepancy may be because of the difficulty of diagnosing SEAVFs correctly.

Angioarchitecture

Several differences in angioarchitectural features are observed between the SDAVFs and SEAVFs.

First, ventral SEAVFs with perimedullary drainage show a characteristic J turn sign consisting of the epidural pouch and the radiculomedullary vein.

Second, several differences in other angioarchitectural features, including the main feeding artery and frequency of bilateral feeders, are also observed. The majority of the SDAVFs are mainly supplied by meningeal branches from the radiculomeningeal artery. These meningeal branches anastomose vertically and drain into the single intradural vein, which

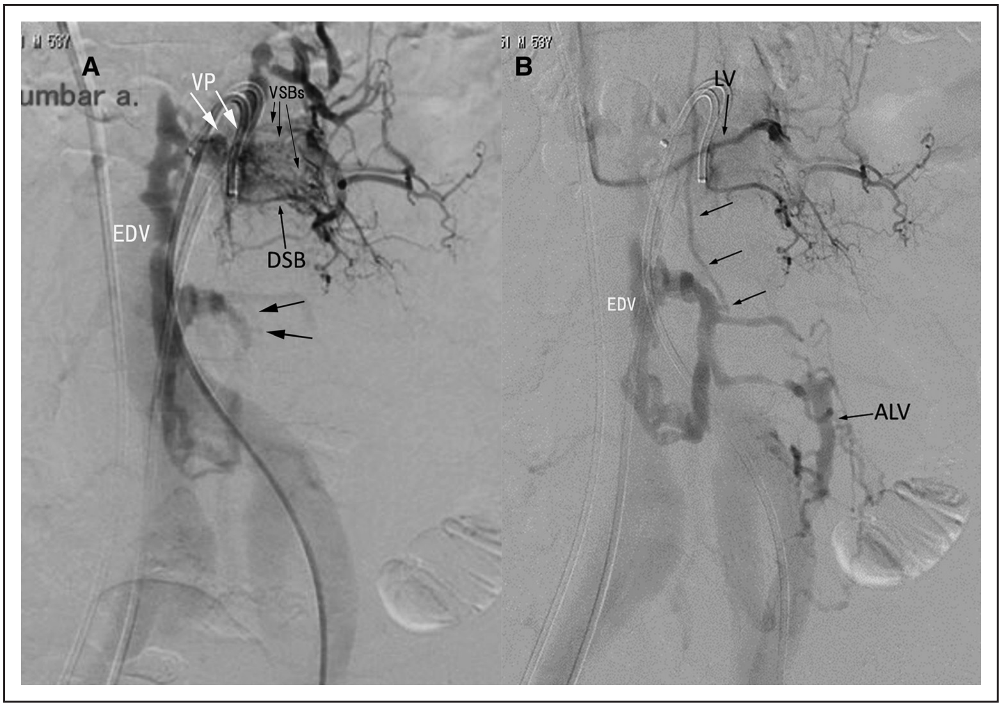

Figure 5. Spinal epidural arteriovenous fistula with perimedullary and paravertebral venous drainage in a 53-year-old man presented with progressive myelopathy. **A** and **B**, Anteroposterior view of the left third lumbar angiography at early arterial phase (**A**) and late arterial phase (**B**) show epidural arteriovenous fistulas fed by multiple feeding arteries mainly from the dorsal somatic branch (DSB). Numerous feeders from ventral somatic branches (VSBs) also converge on an epidural venous pouch (VP). The AVF drains via the epidural venous plexus (EDV) into the paravertebral vein, the third lumbar vein (LV), and the ascending LV (ALV). Perimedullary venous drainage via the left L4 radiculomedullary vein (arrows) is also noted.

typically forms horizontal T sign on a frontal view of spinal angiography.[11] On the contrary, SEAVFs are almost always supplied by epidural arteries, especially the dorsal somatic branch, often bilaterally.[9]

Third, the spinal levels involved are significantly different. SEAVFs should be primarily suspected for cases of spinal AVF at the lumbar spinal levels because SEAVFs were much more frequently located at lumbar spinal levels than SDAVFs.

These angiographic findings can help to differentiate SEAVFs from SDAVFs.[9–11] Three-dimensional angiography, particularly cone beam computed tomography and multiplanar reconstruction images, is useful for evaluation of these angioarchitecture.[9,12]

Bridging Venous Drainage of SDAVFs

It is generally thought that SDAVFs are located at the dura mater of the spinal nerve root sleeve and drain into the radiculomedullary vein.[2,3] In healthy anatomy, the drainage veins from the spinal cord, called radiculomedullary veins, run along the nerve root and pierce the dura at the spinal nerve root sleeve; radiculomedullary veins are found in 60% of healthy subjects.[13] The remaining 40% shows venous drainage of the spinal cord via the bridging vein, which runs apart from the nerve root and pierces the dura mater of the spinal cord to join the epidural venous plexus. SDAVFs can involve either the radiculomedullary vein or the bridging vein.[3] However, the bridging venous drainage has not been clearly noted. In our results, the shunt point of the SDAVF was lateral to the medial interpedicle line in only 5% of cases. This indicates SDAVFs commonly shunt to the bridging vein.

Therapeutic Relevance

It is important to differentiate SEAVFs from SDAVFs in selection of treatment strategy. TAE using liquid embolic materials is an effective and less-invasive technique for the treatment of SDAVFs.[14] SDAVFs can cure when n-btyl 2 cyanoacrylate or Onyx reaches into the proximal portion of the intradural draining vein. However, it is often difficult to navigate a microcatheter into a proper feeding artery because the main feeders of SDAVFs from the radiculomeningeal artery usually originate at acute angle and run tortuously. Furthermore, radiculomedullary artery or radiculopial artery often originates from the radiculomeningeal artery together with feeders of SDAVFs. In this study, less than half of cases were treated by TAE alone. Surgical interruption of the intradural draining vein is a promising method for the treatment of SDAVFs although it is more invasive technique. In our series, 54% of the cases of SDAVFs were treated by open surgery alone or combined with TAE, and all of them disappeared without recurrence. The majority of SDAVFs shunt to the bridging vein, which penetrates the dorsal spinal dura matter, and, therefore, shunted bridging vein can be easily identified during surgical procedure. On the contrary, primary surgical treatment is less frequently undergone for the SEAVFs.[15] Interruption of the intradural draining vein can cause remnant of epidural AVF, and recruitment of the retrograde intradural drainage may occur via radiculomedullary vein at another spinal level.[16] Surgical approach to the arterized venous pouch has a risk of massive bleeding, and it is difficult because the venous pouch is usually located at ventral epidural space. Therefore, endovascular technique is preferred to use for the treatment of SEAVFs in resent reports.[9,10,15] Nasr et al[15] recently reported a case series of SEAVF at a single center. In their series, 18 of 24 patients (75%) were treated by endovascular technique, 4 (16.7%) by open surgery, and 2 (8.3%) by combination of both. Similarly, our study shows open surgery was less frequently performed approximately in 13 cases (22%) of SEAVFs. Three of the 13 SEAVFs persisted after surgical treatment. Regarding endovascular treatment of SEAVFs, curative rates of SEAVFs by endovascular treatment varied from 59% to 100%.[9,10,15] SEAVFs can be completely obliterated when a liquid embolic material fills in the venous pouch and partially in the drainage vein. Catheterization to the proper feeders of SEAVF is easier than that for SDAVF because the main feeder of the dorsal somatic branch usually runs straight, and, therefore, complete obliteration of the SEAVFs can be easily obtained when the SEAVFs have a small epidural venous pouch with few feeders. However, complete filling of the embolic materials in the entire venous pouch and draining veins is often difficult for the cases with a large epidural venous pouch fed by numerous feeders and with paravertebral drainage.[9] Combined techniques or transvenous embolization should be applied for such cases.

Limitations

There are different protocols for spinal angiography using different angiographic machines because of the retrospective multicenter cohort study design. Therefore, it is difficult to analyze the angioarchitecture of numerous small feeders precisely based on conventional angiography in some cases. We excluded 20 cases from this study because of poor image quality. Three-dimensional rotational angiography with multiplanar reformatted image reconstruction, cone beam computed tomography, and superselective angiography are useful for precise evaluation by providing detailed angioarchitecture. Therefore, a prospective study with a large number of cases using the same angiographic protocol with 3-dimensional angiography would be required for further evaluation.

Conclusions

SDAVFs and SEAVFs showed similar symptoms of myelopathy and male predominance. SDAVFs frequently involve the thoracic spine and are commonly fed by the radiculomeningeal artery and drained into the bridging vein. SEAVFs frequently involve the lumbar spine and form a shunted pouch in the ventral epidural space, draining into the perimedullary vein or paravertebral vein. Recognition of these differences is helpful for correct diagnosis.

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Disclosures

None.

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