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The clinical value of venous drainage in patients with spinal dural arteriovenous fistula

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ABSTRACT

Background: Spinal dural arteriovenous fistulas (sdAVF) with rapid deterioration are a known clinical phenomenon but have been rarely reported in the past. Clinical and radiologic features of these fistulas are analyzed for this study.

Material and methods: We retrospectively reviewed our medical records for sdAVF patients who were treated in our center between 2006 and 2017. Our cohort was dichotomized in two groups; a) patients with acute/ subacute onset and rapid deterioration within a period of ≤6 months, b) patients with chronic progressive deterioration within a period of > 6 months. MR findings at time of diagnosis were re-evaluated. All patients were treated microsurgically. Follow-up data were included.

Results: Data of forty patients were available for this study. Rapid deterioration was observed in 13/40 (32.5%) patients. AL-score at time of diagnosis did not differ between both groups (3.2 ± 1.2 vs 3 ± 2, $p = .78$). Patients with rapid deterioration showed significantly more prominent arterialized perimedullay veins at time of diagnosis ($p < .05$). At the last follow-up (53 ± 3 months), patients with rapid deterioration improved up to one point on AL-scores (from 3.2 ± 1.4 to 2 ± 1.6) and those with chronic progressive deterioration were unchanged (from 3 ± 1.6 to 3 ± 1.7).

Conclusion: Patients with rapid deterioration in our group (32.5%) presented with a significantly more prominent appearance of the arterialized perimedullry veins. This may reflect, in the earlier phase of the disease, a better compensation of the venous hypertension as well as the associated venous outlet disorder of the spinal cord. This may also explain the better outcome of these patients.

1. Introduction

In sdAVF, the arteriovenous (AV) shunt is usually located inside the dura mater close to the spinal nerve root where the arterial blood from a radiculomeningeal artery enters a radicular vein along its transdural course [1,2]. The associated venous hypertension of the spinal cord diminishes the arteriovenous pressure gradient and contributes to further disturbances of the medullar venous outflow [3,4]. This, in turn, could induce chronic hypoxia and slowly progressive congestive myelopathy.

Symptoms of congestive myelopathy are rather unspecific; they consist of hypo- and paraesthesias, paraparesis, spinal ataxia, impotence and sphincter disturbances [5]. This typical but unspecific slowly progressive clinical course of sdAVF has been reported in the vast majority of the representative studies in the literature [6–9]. Cases with acute/ subacute onset and rapid deterioration are a clinically known but not further examined phenomenon in the literature [10–12].

Based on our hypothesis that sdAVF patients with acute/subacute onset and rapid deterioration might differ from those with chronic progressive deterioration, we aimed to determine clinical and radiographic features that could correlate with this rapid deterioration and predict the long-term outcome in these patients.

2. Material and methods

The medical and radiological records of patients with a diagnosis of sdAVFs who were diagnosed and/or treated at the University Hospital Aachen from June 2006 until March 2017 were retrospectively reviewed.

All patients underwent a detailed neurological examination by a neurologist or neurosurgeon at the time of admission in our institution. All patients included in this study underwent surgical disconnection of

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Table 1
Modified Aminoff-Longue myelopathy score for gait.

Score	Gait
0	Normal
1	Leg weakness, abnormal walk or stance, but no restriction of activity
2	Restricted activity
3	Requiring 1 stick for walking
4	Requiring 2 sticks, crutches or walker
5	Confined to wheelchair

the fistula. After surgery, all patients had a detailed neurological examination on a daily basis. Early postoperative MR examinations were performed in all patients during the same inpatients stay. Moreover, all patients who showed any deterioration after surgery underwent postoperative spinal MRA and/or DSA examinations to document interruption of the AV shunt. Further MR examinations were performed, in the vast majority of the cases, three months after discharge and on annual basis during follow-up. In case of late deterioration, spinal MRA and DSA were performed.

Gait disabilities were graded using the modified Aminoff-Logue myelopathy scale (Table 1) and were rated as: 1) mild: AL-score 0–1, 2) moderate: AL-score 2–3, 3) severe: AL-score 4–5.

The clinical course was re-evaluated for this study based on patient's history and previous medical reports related to myelopathic symptoms. Patients were dichotomized according to the clinical course in two groups; a) sdAVF with acute/ subacute onset and rapid deterioration within a period of $\leq$6 months, and b) with chronic progressive deterioration within a period of $>$ 6 months. Clinical follow- up data based on examination at discharge and on postoperative visits were gathered and updated via telephone survey.

Radiologic data were analyzed blinded to all clinical data on standard PACS workstations by the authors. A reference standard for statistical analysis was established in a consensus reading.

We reviewed radiologic information from MR imaging, spinal MR angiography, and conventional catheter angiography at time of diagnosis.

Extension of medullar T2-signal hyperintensity and intramedullar contrast enhancement was qualified by the number of the affected vertebral levels. The alteration of the arterialized perimedullary veins was rated subjectively as prominent, mild or absent due to the tortuous and dilated appearance of these veins on T2-weighted MR images (Fig. 1). Results are presented using descriptive statistics. The study was approved by the local ethics board of the University Hospital Aachen.

3. Results

Clinical and radiologic data of forty patients were available for our current study. Nineteen patients were excluded from the current analysis because they were lost from follow-up due to unknown changes of address (n = 10) or due to incomplete clinical and/or radiologic data required for the current analysis (n = 7). Two patients died of causes not related to their sdAVF during follow-up and were also excluded from our analysis. Table 2 provides baseline characteristics of all included forty patients (Fig. 2).

3.1. Clinical and radiologic features

3.1.1. Patients with rapid deterioration

Thirteen (32.5%) patients presented with acute/ subacute onset and duration of symptom equal or less than six months with a mean age of 68 ± 10 years. Eight (62%) of them were male. Mean duration of symptom at time of diagnosis was 4 ± 2 months (median; 4, range: 1–6 months).

Mean AL-score at time of diagnosis in these thirteen patients was 3.2 ± 1.4. Gait disabilities and sensory disturbances in the lower extremities were documented in ten (77%) and nine (69%) patients, respectively. Micturition dysfunction was reported in six (46%) cases.

Twelve of theses fistulas were located in the thoracolumbar region and one fistula at level S1.

At time of diagnosis, medullar T2-signal hyperintensity was found in 12/13 (92%) patients with a mean extension of 5.8 ± 3.3 vertebral levels (median; 5, range 0–12). Intramedullar contrast enhancement was observed in 10/13 (77%) patients with a mean extension of 4.5 ± 3 vertebral levels (median; 5, range 0–8). Arterialized perimedullary veins appeared on T2-weighted MR images prominent in 8/13(62%) and mild in 5/13(38%) cases.

3.1.2. Patients with chronic progressive deterioration

Twenty-seven (67.5%) patients presented at time of diagnosis a chronic progressive deterioration with a mean duration of symptoms of 28 ± 3 months (median; 12, range: 7–120 months). The mean age was 70 ± 9 years. Twenty (74%) of them were male.

Mean AL-score at time of diagnosis was 3 ± 1.6 (median; 3, range: 0–5). Sensory disturbances were present in 22/27 (81.5%) patients followed by gait disabilities in 18/27 (67%) patients and micturition dysfunction in 10/27 (37%) patients.

Twenty-five fistulas were located in the thoracolumbar region, the remaining two in the sacral region. Medullar T2-signal hyperintensity was found in 23/27 (86%) patients with a mean extension of 5.2 ± 2.7 vertebral levels (median; 6, range 0–9). Intramedullar contrast enhancement was observed in 22/27 (82%) patients with a mean extension of 3.7 ± 2 vertebral levels (median; 4, range 0–7). Arterialized perimedullary veins appeared on T2-weighted images prominent in 6/27(22%), mild in 17/27(63%) and were absent in 4/27(15%) cases.

Concerning the MR findings at time of diagnosis, the extension of medullar T2-signal hyperintensity and intramedullar contrast enhancement assessed by the number of affected vertebral levels showed no significant differences between both patients groups. In contrast, arterialized perimedullary veins in patients with rapid deterioration appeared significantly more prominent than those in patients with chronic progressive deterioration at time of diagnosis ($p < .05$).

The occlusion rate based after initial surgical treatment was 98% in our current cohort. Only one patient was found to have a residual fistula on early postoperative DSA, which was occluded surgically whithin the same inpatients stay. Surgery-related complications were documented in 2 (5%) patients. One patients developed wound infection and one patient was treated for postoperative CSF leakage.

3.2. Follow-up analysis

The mean follow-up period was 53 ± 3 months (media; 51, range 3–156). At time of last follow-up, gait disabilities of patients with rapid deterioration were improved up to one point on AL-score (from 3.2 ± 1.4 to 2 ± 1.6). These remain, in contrast, unchanged in patients with chronic progressive deterioration (from 3 ± 1.6 to 3 ± 1.7). (Table 2) Additional follow-up MR examinations were available for 7 patients with rapid and 14 patients with chronic progressive deterioration, with a mean follow-up period of 14.5 ± 11.6 months (median, 12; range, 1–44). All twenty-one patients demonstrated a markedly regressed T2- signal hyperintensity.

4. Discussion

Even though sdAVF with acute clinical course are a known phenomenon in the clinical practice, mean duration of symptom less than one year from onset until diagnosis has never been reported in any of the large representative series in the past [6,8,13,14].

The relatively unusual large sample size of sdAVF with rapid deterioration in our current series could be explained by the more alarming severe and rapid functional deterioration in these patients. This more aggressive clinical course might have evoked the necessity of patient's

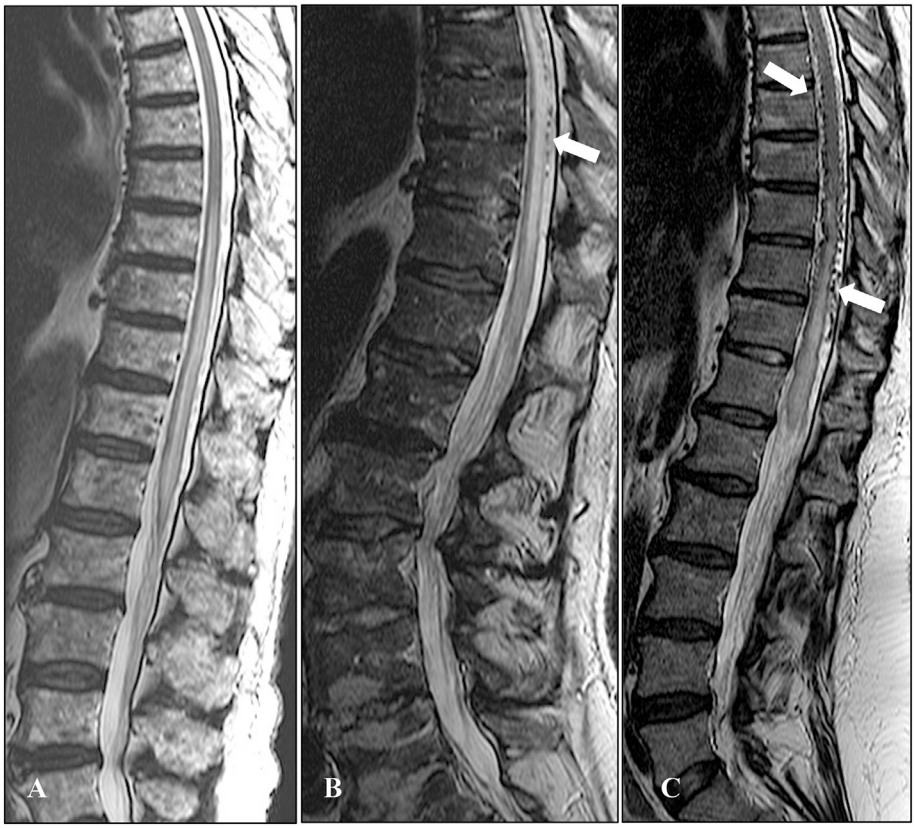

Fig. 1. Rating the appearance of altered perimedullary veins on T2-weighted images at time of diagnosis. A) T2-weighted images show medullar T2-signal hyperintensity from T9 to conus medullaris at L1 vertebral level, flow void signals dorsally to the thoracic spinal cord were rated as normal. B) Mildly dilated and elongated perimedullary veins (white arrow) are identified dorsally to the edematous thoracic spinal cord. C) Prominent perimedullary veins are located dorsally as well as ventrally to the thoracic spinal cord associated with medullar edema extending from T 9 to T12 vertebral level.

referral to specialized centers, whenever a vascular spinal disease was evident.

Nevertheless, even though duration of symptoms differed significantly between both groups in our current series, no significant differences between both patients groups were observed according to gait disabilities assessed by AL-score at time of diagnosis (Table 2).

Arterialized perimedullary veins were, however, significantly more prominent in patients with rapid deterioration than those in patients with the more common chronic progressive deterioration (Table 3). A markedly better gait improvement was determined in these patients in the follow-up analysis (Table 2).

In the presence of sdAVF, the shunting of arterial blood into perimedullary veins has been considered to be the basic mechanism of various pathophysiological conditions in the spinal cord [3,15–18]. Merland et al. assumed, additionally, that an insufficient venous outlet of the spinal cord may also play a significant role in the development and/or the persistence of these fistulas [19]. Moreover, various histopathological changes such like progressive venous microthrombosis, vessel wall hyalinization and calcification of the arterialized perimedullary veins in sdAVF patients were described in several anatomic studies [3,17,20]. Rodriguez et al. investigated in their histological study that intramedullar microvascular thrombosis are a common finding in patients with sdAVF [17]. Also pathological changes along the transdural course of radicular veins may occur in sdAVF patients in association with chronic arterial hypertension [3].

All these changes may result in course of the time in a progressive occlusion of the arterialized perimedullay veins. This chronic progressive vessel occlusion could induce, in turn, serious hemodynamic changes within the perimeduallary venous plexus reducing the venous spinal cord outlet and resulting in progressive congestive myelopathy [20].

An acute/ subacute myelopathy in association with spinal vascular malformations has first been described by Foix and Alajouanine in 1926 and was defined as “subacute necrotic myelitis syndrome” [21]. Since then, several pathological reports suggested an acute vascular thrombosis as a significant contributing factor in case of the former described Foix-Alajouanine syndrome [11]. It has been also speculated that, the rarely observed rapid deterioration in sdAVF patients may be a failure of still unknown autoregulation mechanisms of the spinal cord, comparable with more known mechanisms in the nervous system such like in the setting of cerebral edema or hydrocephalus [11].

Based on these observations one could assume, that in the early phase of the disease the more prominent appearance of the arterialized perimedullary veins in MR images may reflect a reactive dilation of

Table 2
Baseline characteristics of both patients group.

Baseline characteristics	Rapid deterioration (n = 13)	Chronic progressive deterioration (n = 27)
Sex	5f/8 m	7f/20 m
Age at time of diagnosis (years)	67.9 ± 10	69.9 ± 8.5
Fistula location	7 thoracic	19 thoracic
	5 lumbar	6 lumbar
	1 sacral	2 sacral
Duration of symptom (months)	4 ± 2	28 ± 1.6
AL-score at time of diagnosis	3.2 ± 1.2	3 ± 2
AL-score at follow-up	2 ± 1.6	3 ± 1.7

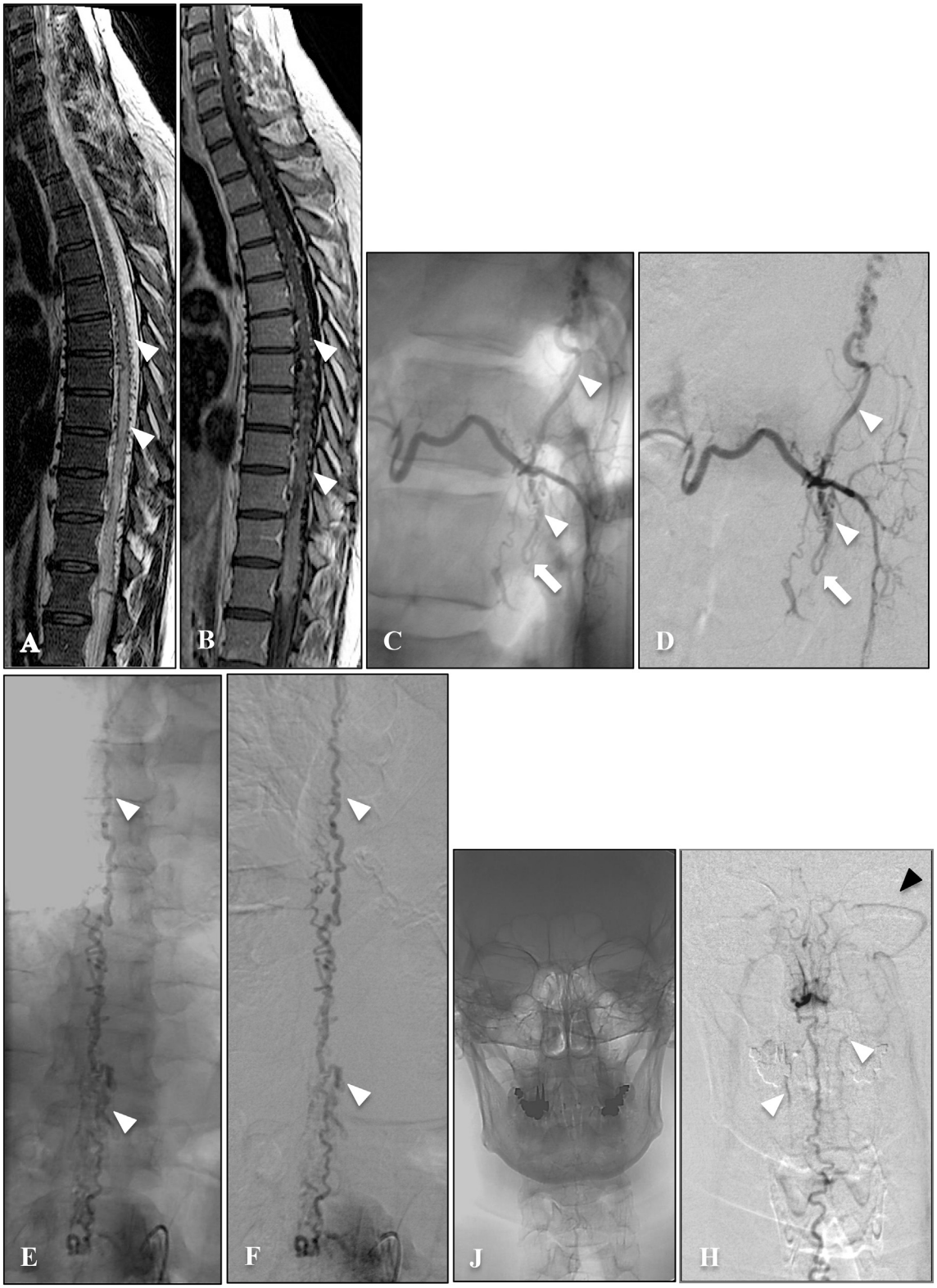

Fig. 2. 53-year-old man presented with subacute paraparesis and duration of symptom of 5 months. A-B) T2- and contrast enhanced T1-weighted images show prominent perimedullary veins (white arrowhead) with medullar T2-signal hyperintensity and intramedullary contrast enhancement. C-D) DSA (lateral projection) shows sdAVF (white arrow) supplied via the left T12 segmental artery and drained via the respective radicular vein (white arrowheads) *E*-F) prominent arterialized perimedullary veins extending along the spinal cord. J-H) Note the extraspinal venous drainage via the inferior petrosal vein (black arrowhead) as well as cervical epidural venous plexus (white arrowheads).

Table 3
MR findings at time of diagnosis. n.s.: no significance, significant p values marked with *.

Clinical deterioration	Extension T2-hyperintenstion (vertebral level)		Extension of intramedullr contrast enhancement (vertebral levels)		Appearance of the arterialized perimedullary veins					
					prominent		mild		absent	
Rapid (n = 13)	4.5 ± 3	n.s.	3.7 ± 2	n.s.	8 (62%)	$p = .017^*$	5(38%)	n.s.	0(0%)	n.s.
Chronic (n = 27)	5.8 ± 3.3		5.2 ± 2.7		6 (22%)		17(63%)		4(15%)	

these vessels to compensate the diminished arteriovenous pressure gradient. This extensive dilation of the arterialized perimedullary veins could help, in turn, to maintain the venous spinal cord outlet and to reduce the venous hypertension to some extent. However, a progressive occlusion of the arterialized perimedually veins in course of the time may irreversibly affect the venous spinal cord outlets and result in definite ischemic myelopathy [17,22].

In summary, the observed frequent prominent appearance of the arterialized perimedullary veins on MR images in sdAVF patients with rapid deterioration may prevent an ischemic myelopathy in the early phase of the disease. If the fistula remains undetected, several histopathological changes in the wall of the arterialiazed perimedullay veins can progress resulting in occlusion of these vessels, increased venous hypertension and ischemic/ necrotizing myelopathy.

It is still, however, unclear why medullar functional decompensation, in the presence of sdAVF and venous hypertension, occurs in some patients significantly earlier than in others.

5. Limitations

Our study has two major limitations; the relatively small sample size and the retrospective approach. Both of which could have been provoked a speculative interpretation of our data to some extent. Nevertheless, our observations may serve as a cornerstone for future anatomic and histopathologic studies to improve our understanding of this rare disease.

6. Conclusion

Acute/ subacute onset with rapid deterioration was present in 32.5% of sdAVF patients in our current series. The significantly more prominent appearance of the arterialized perimedullry veins on MR images in these patients may help, in the early phase of the disease, to maintain the venous spinal cord outlet and to reduce the venous hypertension. All which may prevent irreversible changes of the spinal cord and its vessels explaining the better clinical outcome of these patients after treatment.

However, it remains unclear why medullar functional decompensation, in the presence of sdAVF and venous hypertension, occurs in some patients significantly earlier than in others.

Conflict of interest

The authors report no conflict of interests.

References

[1] B.E. Kendall, V. Logue, Spinal epidural angiomatous malformations draining into intrathecal veins, Neuroradiology 13 (1977) 181–189.
[2] Jablawi F, Mull M. Double spinal dural arteriovenous fistulas. J. Neuroradiol. (in Press) https://www.sciencedirect.com/science/article/pii/S0150986117304960, 10.1016/j.neurad.2018.09.004.
[3] F. Jablawi, O. Nikoubashman, M. Mull, Arterial hypertension is associated with symptomatic spinal dural arteriovenous fistulas, World Neurosurg. 103 (July 2017) 360–363.
[4] A. Thron, T. Krings, J. Otto, M. Mull, J.M. Schroeder, The transdural course of radicular spinal cord veins-a microangiographical and microscopical study, Clin. Neuroradiol. 25 (2015) 361–369.
[5] T. Krings, M. Mull, J.M. Gilsbach, A. Thron, Spinal vascular malformations, Eur. Radiol. 15 (2005) 267–278.
[6] M.P. Steinmetz, M.M. Chow, A.A. Krishnaney, D. Andrews-Hinders, E.C. Benzel, T.J. Masaryk, et al., Outcome after the treatment of spinal dural arteriovenous fistulae: a contemporary single-institution series and meta-analysis, Neurosurgery 55 (2004) 77–87 (discussion 87-78).
[7] C. Sherif, A. Gruber, G. Bavinzski, H. Standhardt, G. Widhalm, D. Gibson, et al., Long-term outcome of a multidisciplinary concept of spinal dural arteriovenous fistulae treatment, Neuroradiology 50 (2008) 67–74.
[8] A. Saladino, J.L. Atkinson, A.A. Rabinstein, D.G. Piepgras, W.R. Marsh, W.E. Krauss, et al., Surgical treatment of spinal dural arteriovenous fistulae: a consecutive series of 154 patients, Neurosurgery 67 (2010) 1350–1357 (discussion 1357-1358).
[9] Jablawi F, Nikoubashman O, Schubert GA, Dafotakis M, Hans FJ, Mull M. Clinical and radiologic characteristics of deep lumbosacral dural arteriovenous fistulas. Am. J. Neuroradiol. 2017.
[10] M. Mull, Durchblutungsstörungen des rückenmarks- neurologische untersuchungen zur pathogenese und strategien der diagnosesicherung, Department of Diagnostic and Interventional Neuroradiology, University Hospital Aachen, 2004.
[11] G.R. Criscuolo, E.H. Oldfield, J.L. Doppman, Reversible acute and subacute myelopathy in patients with dural arteriovenous fistulas. Foix-alajouanine syndrome reconsidered, J. Neurosurg. 70 (1989) 354–359.
[12] M. Mull, A. Othman, M. Dafotakis, F.J. Hans, G.A. Schubert, F. Jablawi, Spinal epidural arteriovenous fistula with perimedullary venous reflux: clinical and neuroradiologic features of an underestimated vascular disorder, AJNR Am. J. Neuroradiol. 39 (2018) 2095–2102.
[13] L. Tacconi, B.C. Lopez Izquierdo, L. Symon, Outcome and prognostic factors in the surgical treatment of spinal dural arteriovenous fistulas. A long-term study, Br. J. Neurosurg. 11 (1997) 298–305.
[14] L. Symon, H. Kuyama, B. Kendall, Dural arteriovenous malformations of the spine. Clinical features and surgical results in 55 cases, J. Neurosurg. 60 (1984) 238–247.
[15] W. Hassler, A. Thron, Flow velocity and pressure measurements in spinal dural arteriovenous fistulas, Neurosurg. Rev. 17 (1994) 29–36.
[16] F. Jablawi, G.A. Schubert, F.J. Hans, M. Mull, Anticoagulation therapy after surgical treatment of spinal dural arteriovenous fistula. Effectiveness and long-term outcome analysis, World Neurosurg. 114 (June 2018) e698–e705.
[17] F.J. Rodriguez, B.A. Crum, W.E. Krauss, B.W. Scheithauer, C. Giannini, Venous congestive myelopathy: a mimic of neoplasia, Modern Pathol. 18 (2005) 710–718.
[18] R.W. Hurst, L.C. Kenyon, E. Lavi, E.C. Raps, P. Marcotte, Spinal dural arteriovenous fistula: the pathology of venous hypertensive myelopathy, Neurology 45 (1995) 1309–1313.
[19] J.J. Merland, M.C. Riche, J. Chiras, Intraspinal extramedullary arteriovenous fistulae draining into the medullary veins, J. Neuroradiol. 7 (1980) 271–320.
[20] W. Hassler, A. Thron, E.H. Grote, Hemodynamics of spinal dural arteriovenous fistulas. An intraoperative study, J. Neurosurg. 70 (1989) 360–370.
[21] C.H. Foix, Th. Alajouanine, La myelite necrotique subaigue, Rev. Neurol. (Paris) 2 (1926) 1–42.
[22] G. Di Chiro, Foix-alajouanine syndrome, AJNR Am. J. Neuroradiol. 11 (1990) 1286.