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ORIGINAL ARTICLE

Single center experience with treatment of spinal dural arteriovenous fistulas

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Abstract Spinal dural arteriovenous fistulas (SDAVFs) are rare pathologies with a yearly incidence of 5–10 new cases/million, constituting 60–80 % of spinal arteriovenous malformations. Clinical symptoms include progressive paraparesis, paresthesias, bladder, and bowel disturbances. The pathophysiology of SDAVFs is not well elucidated. Microneurosurgery and endovascular techniques are established treatment modalities for permanent fistula occlusion, which are oftentimes accompanied by an amelioration of neurological deficits in the long run. Here, we report our interdisciplinary neurosurgical/neuroradiological management strategy of SDAVFs in 32 patients who were evaluated retrospectively. We focused on clinical presentation, microneurosurgical and interventional technique, early, and late neurological results. Quality of life (QoL) was additionally assessed in 12 patients at last follow-up. We discuss the results against the background of the current literature. Our series and the literature indicate that clinical outcome after treatment of SDAVF is favorable in general. Both neurosurgical and neurointerventional therapies appear to be safe and effective, but short-term neurological deterioration after the intervention constitutes an as-of-yet unsolved problem. Beyond age and preoperative neurological state, presence of comorbidities had a significant influence on neurological outcome in our study sample. Self-assessed physical and mental QoL at long-term follow-up was reduced in quite a number of patients and was associated with a poorer neurological result as well as presence of comorbidities. The patients' perspective in terms of QoL was first investigated in this study, but further research on QoL and psychosocial impairment of SDAVF patients is needed to enable individualized counseling and rehabilitation strategies.

Keywords Spinal dural arteriovenous fistula · Spinal vascular malformation · Venous congestion · Progressive myelopathy · Spinal cord disease

Introduction

Spinal dural arteriovenous fistulas (SDAVF), are rare pathologies with an incidence of only 5–10 new cases per million inhabitants per year [43]. Yet, these lesions constitute 60–80 % of spinal arteriovenous malformations. Most of SDAVF are located in the thoracolumbar region of the spine and usually become symptomatic in the sixth decade of life [9, 34, 47]. Diagnosis of SDAVF is generally difficult in clinical practice because of the rarity of the disease and the unspecific initial clinical presentation. First symptoms include gait disturbance and paraparesis, whereas in the later course bladder and bowel dysfunction can also be observed [12, 33, 34]. In contrast to the well-established traumatic and thrombotic pathogenesis of cranial dural arteriovenous fistulas [26, 28, 31], the pathomechanisms responsible for the development of SDAVFs are still not well elucidated. However, diagnosis and treatment of SDAVF are well known and described in the current literature [1, 9, 18, 34].

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Microneurosurgical occlusion of the fistula was for many years the method of choice, but more recently, endovascular techniques have augmented the therapeutic armamentarium. It is, therefore, not surprising that studies on SDAVFs focus on the comparison of surgical and endovascular therapies [13–15, 19, 23, 35, 39] whereas the influence of clinical parameters (such as age, length of duration of symptoms and initial neurological presentation) on outcome and the patient's perspective in terms of quality of life (QoL) have not been so comprehensively investigated.

The aim of our retrospective study was to identify potential clinical variables influencing outcome after treatment in our own series of 32 patients with spinal dural fistulas, treated interdisciplinary in cooperation with the Department of Neuroradiology and to fit them into the current literature. Moreover, we assessed the impact on functional impairment at late follow-up on health-related quality of life (QoL) in order to gain an insight on the patients' perspective of the sequelae of this life-changing disease.

Patients and methods

A chart review was undertaken of all patients treated for spinal vascular diseases between January 2001 and December 2013 at our institution. All patients presenting with SDAVFs and treated at our institution were included in this retrospective survey, whereas patients with perimedullary fistulas and intramedullary AVMs as well as patients who refused treatment were excluded from this study.

Demographic and clinical data including age, gender, comorbidities, pre- and postoperative neurological state, radiological findings (i.e., level of SDAVF, extent of edema), surgical or endovascular technique, intraoperative findings (if applicable), and complications were obtained. All patients received a clinical follow-up examination at the neurosurgical outpatient department 3 months after therapy and had a second long-term follow-up. Motor impairment immediately before fistula occlusion, at 3-month follow-up and at last follow-up was classified according to the modified Aminoff-Logue myelopathy scale (Table 1) [36].

Table 1 Aminoff-Logue disability scale

0	Normal
1	Leg weakness, abnormal stance or gait, but no restriction of local motor activity
2	Restricted exercise tolerance
3	Requiring 1 cane, stick, or some support for walking
4	Requiring 2 sticks, crutches, or walker
5	Confined to bed or wheel chair

All SDAVFs except for one were initially detected by magnetic resonance imagining (MRI). In one patient with a cardiac pacemaker, the diagnosis was made by means of myelography. Diagnosis of SDAVF was verified in all cases using conventional spinal digital subtraction angiography (DSA).

In all patients, the choice of treatment modality was discussed interdisciplinarily with neurosurgeons and interventional neuroradiologists experienced in treatment of cerebral and spinal vascular pathologies. Microneurosurgical obliteration was performed if the radiculomedullary arteries (anterior or posterior spinal artery) were part of or in close proximity to the feeding artery/fistula point or if, according to the neuroradiologic expertise the point of arteriovenous fistula could not be reached by embolization material, e.g., due to strong vessel elongation of the feeding artery or if branches of more than one segmental artery were involved in feeding the fistula. If neuroradiological intervention was deemed to be feasible with a comparable risk profile to the microneurosurgical procedure, the patient was offered this possible alternative treatment method. All patients were treated according to the same endovascular or neurosurgical protocol. All patients received post-therapeutic spinal DSA to ascertain successful obliteration of the fistula.

Endovascular technique

All embolizations were performed under general anesthesia. An arterial approach was obtained and a guiding catheter placed in the segmental artery; under fluoroscopy, a microcatheter was introduced coaxially through the feeding pedicle and advanced into the distal aspect of a feeding artery close to the fistula in the ideal case in wedge-position so that a liquid embolic agent could be pushed up to the proximal venous side. In seven patients, a mixture of Glubran® (cyanoacrylate glue, GEM s.r.l., Italy) and iodized oil (Lipiodol®, Guerbet, Aulnay-sous-Bois, France) in case-dependently variable concentrations (ranging from 1:3 up to 1:5) for appropriate flow characteristics and in one patient Onyx® (Covidien, Mansfield, MA, USA) was injected. In the ideal case the feeding pedicle, including the terminal feeders up to the fistulous point, as well as the beginning of the early draining vein was embolized in a continuous injection. A final spinal angiography of the initially feeding segmental artery and of the adjacent and contralateral segmental arteries was performed. An illustrative case is demonstrated in Fig. 1.

Surgical technique

All surgical procedures were performed under permanent control of somatosensory evoked potentials (SSEP) and motor evoked potentials (MSEP).

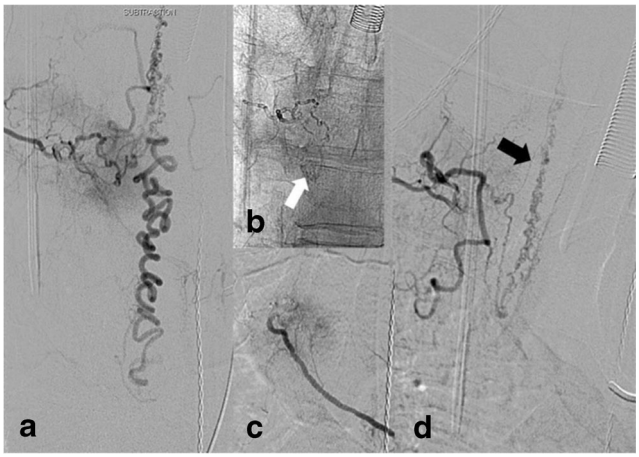

Fig. 1 A 71-year-old female with thoracic SDAVF. Superselective angiogram of the right Th5 segmental artery (**a**) and plain film of glue cast (**b**) following embolization with 0.2 cm^3 Glubran/Lipiodol (1:3). The right-sided Th5 segmental artery is occluded (**c**). Angiogram of the right-sided Th4 segmental artery showed residual filling of the SDAVF and simultaneous filling of the artery of Adamkiewicz (*black arrow*), no further embolization was performed

Targeted hemilaminectomy, laminoplasty, or laminectomy was performed according to spinal anatomy and the location of the fistula point and extended to the side of the spinal AV fistula. Then, the feeding radicular artery was identified first visually, followed by opening of the dura and isolation of the draining vein. A temporary aneurysm clip was placed on the fistulous point under electrophysiological monitoring to isolate the right feeder. Doppler ultrasonography [11] and indocyanine green (ICG) angiography [16] were also additional tools for identifying the feeder. Permanent occlusion of the fistula by means of coagulation and division was performed if potentials remained stable and the draining vein was no longer arterialized. The epidural feeding artery was also coagulated and disconnected if necessary. Intraoperative fluoroscopy was additionally performed since the year 2005 after acquisition of a PENTERO® microscope (Zeiss®, Oberkoden, Germany). The technique is illustrated in Fig. 2.

Investigation of quality of life

For investigation of patients' QoL at late follow-up, the short form (SF)-36 was used. This instrument is a widely used and well-validated generic questionnaire on health- QoL. It differentiates between a physical and a mental component of QoL: The Physical Component Summary (SF-36 PCS) and Mental Component Summary (SF-36 MCS). Here, higher scores indicate a better QoL. The items of the questionnaire can be further subdivided into eight subscales. For the evaluation of the summary scores, the reference values for the German population were used [7].

Statistical analysis

Statistical analyses were conducted using IBM SPSS Statistics 22 (Statistical Package of the Social Sciences, SPSS Inc., Armonk/USA). Descriptive statistics of interval-scaled data were expressed as mean±standard deviations (SD) unless otherwise mentioned. Data was tested for normal distribution by conducting a Shapiro-Wilk test, in addition to histograms and Q-Q-Plots for every parameter. Because data did not meet the assumption of normality Wilcoxon signed-rank test for paired variables were used.

Categorical data was analyzed by Pearson Chi-Square test or, if expected frequencies were below 5, Fisher's exact test. For bivariate correlation analyses Spearman's rho was applied. Partial correlation analyses were used for controlling for the effect of age and the number of comorbidities. A p value of ≤ 0.05 was considered as statistically significant.

Results

Clinical characteristic of the study group

Thirty-two patients with SDAVF (6 females=18.8 %; 26 males=81.3 %) with a mean age of 64±11.1 years (range 41–81 years) were included in this study.

Table 2 shows the neurological symptoms of the patients at the time of admission (multiple symptoms in one patient possible). Gait disturbances and sensory deficits were most frequent and observed in 81 and 94 %, respectively. The time from first symptoms to diagnosis of SDAVF as reported by the patients ranged from 1 month to 20 years (18.06± 43.1 months). At the time of treatment, patients had numerous comorbidities, most frequently hypertension, coronary heart disease and diabetes mellitus as well as knee and hip replacement surgery. Mean number of comorbidities was 2.2±1.6. Four patients reported a trauma to the spine such as car accident with polytrauma and vertebral body fracture, injections to the lumbar spine region, heavy lifting with subsequent onset of symptoms, osteoporotic fracture and surgery for lumbar disc or spinal canal stenosis (Table 3). Figure 3 gives an overview of the locations of the fistulas. All but one patient had one fistula point each. The predominant fistula location was at the thoracic (T) 6 level (n=8). According to the decision algorithm described above, 25 (79 %) patients underwent neurosurgical fistula obliteration, while 5 (16 %) were treated primarily interventionally by endovascular means. Two of these patients had to be operated upon after unsuccessful endovascular intervention. In another two patients, postoperative DSA showed persistent fistulas. One of them was re-operated whereas the other underwent successful neuroradiological embolization. By means of these therapies, complete obliteration of the fistula was achieved and documented by DSA in all patients.

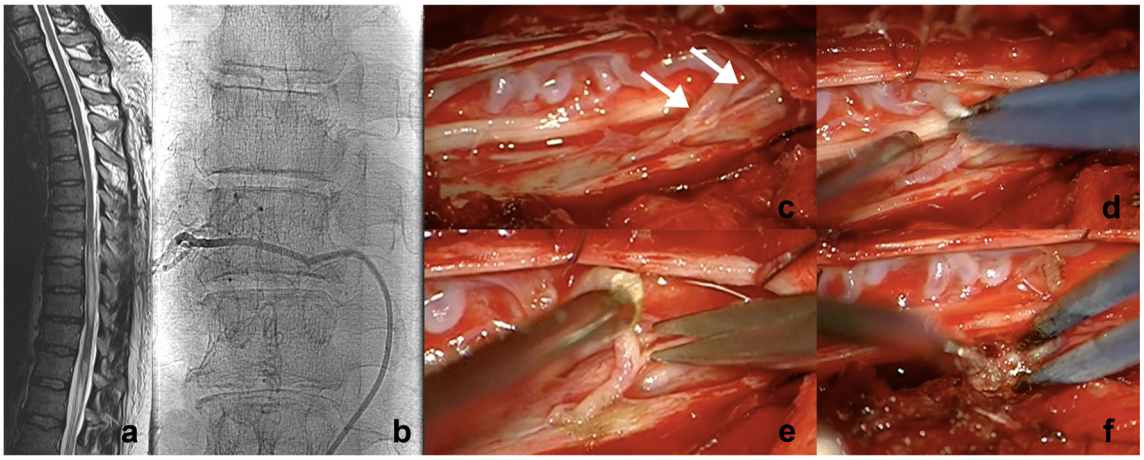

Fig. 2 A 50-year-old male who suffered of hypaesthesia of both legs and gait disturbance. **a** T2-weighted MRI showing spinal cord edema **b** superselective angiography demonstrating right-sided dural AV fistula at the level of Th8, **c** after hemilaminectomy the fistula was exposed showing two feeding arteries (*arrows*), **d** fistula was then coagulated intradurally, **e** transsection with micro-scissor, **f** coagulation and transection of the feeding arteries epidurally

Outcome

The interventions described above resulted in complete angiographically proven occlusion of the fistula in all patients. Three patients deteriorated neurologically after surgery. An epidural hematoma was diagnosed (Fig. 4) and evacuated surgically in one of them, leading to postoperative neurological improvement. In the other two patients (Table 4), the operative course was uneventful but MRI revealed persistent intramedullary edema. All other patients treated neurosurgically or interventionally improved or remained neurologically unchanged.

AL-scores as the primary outcome were available for all 32 patients at every follow-up performed. AL-score at 3-month follow-up (1.78±1.50) did not improve significantly compared to AL-Score preoperatively (2.00±1.41; p=0.129). A long-term neurological follow-up was also available in all patients with a mean follow-up latency of 34.81±49.41 months. At this follow-up, a significant improvement of AL-score to 1.69±1.51 compared to the preoperative AL-Score was observed (p=0.027) (Fig. 5).

A significant positive correlation between AL-Score before and 3 months after treatment follow-up (r_s=0.90; p<0.01), but not duration of symptoms and the AL-Score 3 months after treatment (r_s=0.05; p=0.769) was observed, with more than 81 % of the variance being explained by the AL-score before treatment. Patient age was also significantly correlated with AL-Score before (r_s=0.37; p<0.05) and 3 month after treatment (r_s=0.41; p<0.05). In addition, we correlated the number of comorbidities with the preoperative, postoperative and 3-month follow-up AL-score and there was a statistically significant correlation between those variables (p<0.05), which remained statistically different (r_s=0.497; p=0.006) for the last follow-up. When controlling for the effect of age (partial correlation), the correlation of patients AL-Score before and after surgery and at 3-months of follow-up was still significant (p<0.01). No correlation between AL-Score at 3-month

Table 2 Symptoms before treatment

Symptoms	Number of patients (%)
Sensory deficits	30 (94)
Gait disturbance	26 (81)
Paresis	20 (63)
Bladder and bowel dysfunction	20 (63)
Back pain	7 (22)
No neurological deficits	3 (9)

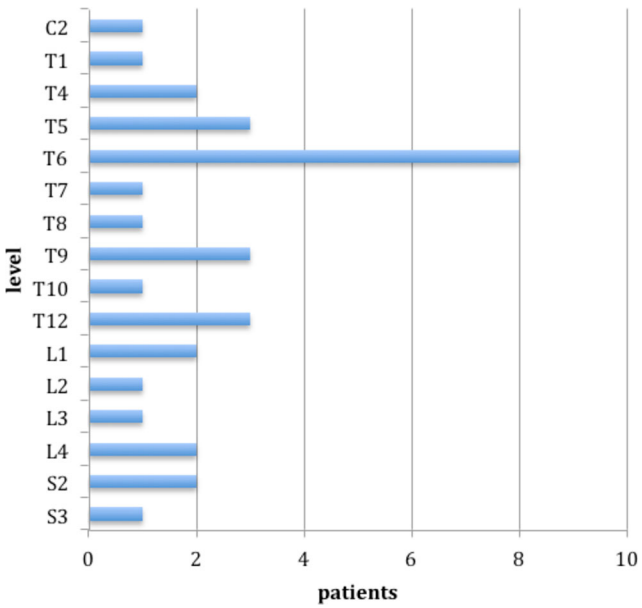

Fig. 3 Level of the dural AV fistula

Table 3 Comorbidities

Comorbidity	Number of patients (%)
Hypertension	10 (31)
Coronary heart disease	6 (19)
Prior surgery	6 (19)
Spine surgery	2 (6)
Diabetes mellitus	5 (16)
Spine trauma in history	4 (13)
Borreliosis	1 (3)
Neuronitis vestibularis	1 (3)

follow-up and localization of the SDAVF was observed (p=0.422). All other clinical parameters investigated had no impact on patient outcome as assessed by the AL-score.

Of the 32 patients, 12 patients agreed to fill-in the SF-36 QoL questionnaires at last follow-up. The results of the Qol-assessment are displayed in Table 5. In regard to the physical component score a seriously decreased QoL, which was 1 to 2 standard deviations below average, compared to a German standard population, was observed in three patients [8]. For the mental component score, a standard deviation of 2 below average was identified in one patient.

Significant negative correlations between AL-score at the last follow-up and SF-36 domains were observed for the mental component summary score of the SF-36 (p=0.023) and the subscales of the physical function scale (p=0.002), general health perception (p=0.024), social functioning (p=0.005), role limitations due to emotional problems (p=0.026) and general mental health (p=0.003). When analyzing the impact of comorbidities, the correlation between AL-score and the SF-36 component score of mental health and the subscales of general health perception and role limitations due to emotional problems were no longer significant (p>0.05, respectively).

Discussion

This retrospective study was performed to demonstrate the clinical course of SDAVF, identify variables influencing outcome, to assess the impact of functional impairment on QoL and to discuss the results in the light of the current literature.

Since the first anatomical description of SDAVF dates from the late nineteenth century Hebold and Gaupp [3] and the first presentation of a large patient series by Aminoff and Logue almost 100 years later, several studies on patients with SDAVF have been published, focusing mainly on the comparison of different treatment methods and the description of neurological outcome. Merland et al. published one of the first comparison study between surgical and interventional treatment of SDAVFs in 1985 [27]. Table 6 gives an overview of the recent comparative published studies in this field. As in the majority of these and other descriptive studies, our patient sample also exhibited the well-known clinical characteristics such as the lesion's prevalence in middle-aged males, predominance of thoracolumbar location, progressive course of symptoms, and nearly uniform occurrence of lower-extremity weakness and sensory disturbance, as well as bladder dysfunction [3, 9, 19, 24, 26, 36].

In our patient series, two patients with prior severe trauma to the spine (one osteoporotic fracture; one polytrauma with vertebral body fracture and later fistula at the same level) and two patients with prior spine surgery were identified. This anamnestic information entices to speculate on a possible traumatic pathomechanism in spinal fistula development, especially since vertebral body fractures, spinal stenosis or disc prolapse and spinal surgery have been implicated in case reports as to be associated with SDAVF occurrence [6, 21, 37, 48]. Yet, the early neurological symptoms of SDAVF are

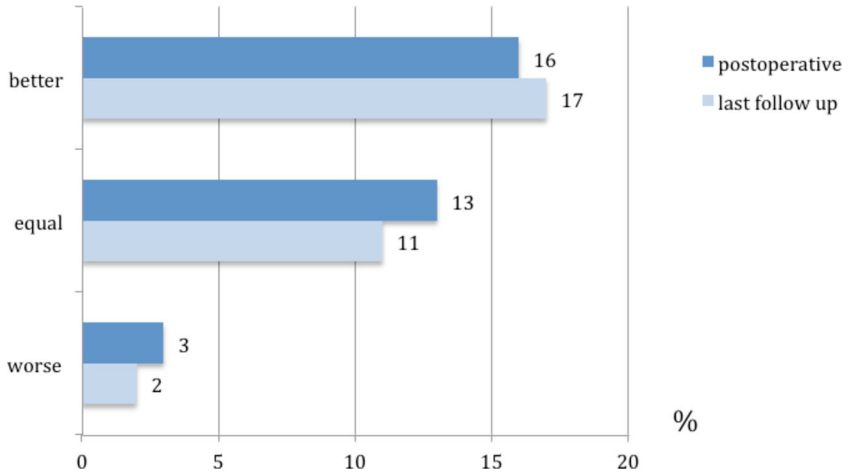

Fig. 4 Postoperative outcome in comparison to the preoperative neurological findings

Table 4 Postoperative deterioration

Patient	Age	Level and side of fistula	Treatment	Postoperative MRI	Angiography	Preoperative AS	AL Score last follow-up
Case 1	69	T 5 right	Hemilaminectomy and fistula occlusion	Increased medullary edema	Fistula completely occluded	4	5
Case 2	75	L 4 left	Hemilaminectomy and fistula occlusion	No pathology on MRI	Fistula completely occluded	5	5[a]

[a] Patient has developed additional motor deficits postoperatively. The function of the lower extremities was the same

unspecific and may be erroneously attributed to coexisting common abnormalities in older patients, such as spinal stenosis. In this context, Saladino et al. [36] reported, that 10 % of their patients underwent surgery other than occlusion of the fistula for symptoms that, in retrospect, were related to the SDAVF.

The authors of two cases of SDAVF in association with spondylolisthesis speculate on a pathomechanism in which local inflammation due to the spondylolisthesis could have led to subsequent development of an arteriovenous shunt [26, 31]. However, it seems equally possible that in those cases fistula development was the consequence of venous stasis with consecutive thrombosis. In analogy to the well-researched pathomechanisms of intracranial AV fistulas [6, 30, 31], we propose inflammation, infection, trauma, or thrombosis [25, 42, 45] to be possibly common but so far underreported causes of SDAVFs. Thorough clinical history in patients with SDAVF could reveal more anamnestic evidence for such pathophysiological correlations.

In accordance with the literature [9, 24, 36], the predominant fistula location in our series was in the middle and lower thoracic spine (25 patients, 78 %). Sacral locations of SDAVF constitute a rarity. Saladino et al. [36] reported that in only 6.4 % on sacral locations, we observed sacral location of fistula points in 9.3 % (3 patients). Higher thoracic fistula location has been described as a predictor for a poorer neurological outcome by Centano et al. [9], who postulated that the lower thoracic myelon has a better vascular collateral supply, making it less prone for fistula-related ischemia. Since significant relations between location of the SDAVF and clinical outcome could neither be observed in the large series by Saladino et al. [36] nor in our study, we cannot support this theory [2, 9, 10, 22, 35].

Since only the occlusion of the fistulous point will prevent progressive myelopathy caused by venous hypertension [4, 3], a causal therapy is required in all patients harboring SDAVF. Up to date, endovascular and surgical treatment have both been proven safe and effective [13, 19]. In the literature, many authors state a preference for surgical treatment since it is easy, safe, and effective to permanently exclude the fistula microneurosurgically [20, 24, 33, 36, 40, 41]. This is also

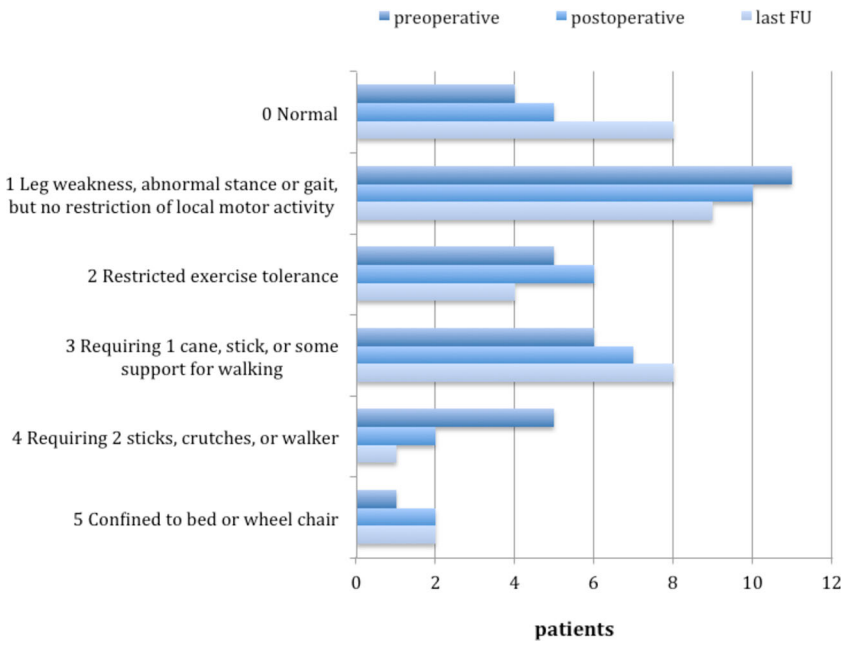

Fig. 5 Postoperative functional outcome according to Aminoff-Logue scale

Table 5 Results of the SF-36 questionnaires of 12 patients with SDAVF at last follow-up and reference values of the German standard population with an age of 61–70 years (mean±SD)

Variables	Study sample size	German standard population
Summary scores[a]		
Physical Component Summary (PCS)	33.14±15.08	44.81±10.33
Mental Component Summary (MCS)	53.27±10.27	53.18±7.91
Subdomains[b]		
Physical functioning (PF)	44.21±36.93	75.95±22.59
Role limitations due to physical health (RP)	37.50±43.3	72.54±35.23
Physical pain (PP)	55.17±40.87	71.20±27.00
General health perception (GH)	54.17±21.28	58.69±18.13
Vitality (VT)	47.92±20.83	61.11±18.45
Social functioning (SF)	72.92±31.91	87.07±18.43
Role limitations due to emotional problems (RE)	80.56±38.82	88.89±25.77
General mental health (MH)	73. 00±19.61	75.73±16.64

[a] Summary scores range from 0 to 50, a value below 40 is considered as a restricted quality of life, a value below 30 is considered as a severely restricted quality of life

[b] Subdomains range from 0 to 100

our experience, especially in cases with more than one fistulous point (see Fig. 3). In our series, surgery generally yielded good results with only two persisting fistulas postoperatively which were located at the lumbar and sacral level of the spine. In one of those patients, the fistulous point at the L1/2 level was located and divided uneventfully at second surgery. In the other, the fistulous point was located very deep at the S2/3 level. Because of the anatomical and vascular characteristics of this region, especially these deeply located sacral SDAVF represent a special challenge for surgical treatment because of the laborious surgical approach. This second patient was treated without complications by endovascular embolization. An endovascular approach could have general advantages in such cases which are difficult to access surgically.

Clinical outcome was good in general in our series, with 30/32 patients improved and only 2 (6.3 %) patients worsened neurologically after surgery without further improvement. Both patients had already deteriorated in the early postoperative period despite regular results of postoperative MRI and spinal DSA. Such unexplainable neurological deterioration has also been described in 11 (7.1 %) patients in the series of Saladino et al. [36], who postulated this to be caused by an increase in abdominal pressure due to intraoperative positioning. We do not assume this to be the cause for deterioration in our patients. Knowing that Hassler et al. [17, 18] reported that the balance between normal vascularization/drainage and ischemia/edema could be negatively affected by any increase in abdominal pressure, all of our patients had put in a prone position for surgery with a freely hanging belly, carefully avoiding any pressure being put on the abdomen. Another possible explanation for the early neurological deterioration is occurrence of partial thrombosis of the venous component causing acute onset ischemia. Indirect support for this theory stems from endovascular series in patients who always receive effective anticoagulation with heparin after embolization and in those where such early neurological deterioration was not observed [23].

In contrast to other authors, we did not observe an influence of duration of symptomatology before treatment with late outcome [9, 14, 17, 23, 32, 35, 36, 38, 39, 41, 44]. In our patient population, only age, preoperative AL-score and number of comorbidities had an impact on late neurological result, while level of fistula point, pretreatment duration of neurological deficits, or other clinical variables did not. Nevertheless, these results should not preclude timely diagnosis and treatment of SDAVFs since clinical experience shows that even patients with severe neurological deficits of short duration can improve substantially. Preoperative AL-score was also a major factor determining outcome in other studies [9, 12, 29, 41, 46], while a high or moderate influence of age on neurological outcome has only been described in two further studies [9, 32]. We postulate that age may have an impact on neurological result because of the higher comorbidities in elderly patients possibly exerting a negative influence on rehabilitation measures.

QoL of patients with SDAVF has so far not been investigated before. In our exploratory series, QoL as assessed by the SF-36 was reduced, as expected. In the 12 patients of whom questionnaires were available, we observed significant negative correlations between several physical QoL domains of the SF-36 but also the mental component summary score with AL-scores at last follow-up, which indicates that physical impairment by fistula-related symptomatology influences

Table 6 Overview of the current literature

Authors	Year	Number	Management	Outcome criteria	Conclusion
Gokhale et al. [14]	2013	27	Endovascular embolization vs. surgical ligation Mean age, ≥50 years	AL-Scale Complication rates Recurrence rates	Embolization is associated with higher incidence of recurrence Time of diagnosis is essential to maximize chances for recovery
Inagawa et al. [19]	2013	25	Clinical outcomes of multidisciplinary treatment (embolization and surgery) Mean age, 59.0 years	AL-Scale	Improved clinical functional outcome for half of the patients and stable outcome for most of the other half
Gemmente et al. [13]	2013	38	Clinical outcomes after embolization as primary treatment Mean age, 64.4 years	AL-Scale McCormick Classification Modified Rankin Scale	Endovascular treatment can result in good clinical outcomes Surgery treatment of choice when safe embolization not possible
Ofran et al. [32]	2013	8	Correlation between length of diagnostic process and rehabilitation outcomes Mean age, 61.3 years	AL-Scale LEMS British Medical Council Scale Functional Independence Measure Scale Spinal Cord Independence Measure Scale Walking Scale for Spinal Cord Injury	Strong correlation between final outcome and length of diagnostic process Moderate correlation between age and functional outcome Poor prognosis when intervention is delayed, despite prolonged rehabilitation
Dhandapani et al. [10]	2013	22	Determination of Clinico-radiological characteristics Outcomes after surgical ligation Mean age, 55.0 years	AL-Scale	Improvement was not significantly greater for younger patients, acute onset of symptoms and fistula below T9 Decreased improvement when pain was the first symptom
Kirsch et al. [23]	2013	78	Comparison of embolization and microsurgical treatment Mean age, 60.6 years	Length of diagnostic process Parestesia Paraparesis Gait and Micturition disability Follow-up MRI	No differences in clinical outcomes between treatment techniques
Cenzato et al. [9]	2012	65	Comparison of embolization and microsurgical treatment Mean age, 61 years	AL-Scale Sphincter disturbances Sensorial deficiency Presence of Pain	Neurological status before treatment, location of fistula and presenting symptoms are predictive factors for outcome
Wakao et al. [46]	2012	30	Evaluation of clinical factors that influence neurological outcome Mean age, 59.0 years	AL-Scale Age, sex, localization, initial symptom, treatment Follow-up MRI	Both treatments have equivalent efficacy Only gait function before treatment was correlated with motor deficit Early detection and intervention are key to preferable outcome
Ruiz-Juretschke et al. [35]	2011	19	Comparison of embolization and microsurgical treatment Mean age, 62.0 years	AL-Scale Feeding vessel Localization Pre- and postoperative MEPs/SSEPs	No significant association between clinical outcome and age, duration of symptoms, pretreatment functional status, level or type of fistula
Sherif et al. [39]	2008	26	Long-term outcomes of a multidisciplinary approach Mean age, 56.8 years	AL-Scale Modified Rankin Scale	Significant improvement of AL-Gait-Scores and Rankin-Scores
Andres et al. [5]	2008	21	Clinical outcome of patients treated with surgery, embolization or surgery after embolization Mean age, 64.7 years	Modified AL-Scale Modified Rankin Scale	Significant improvement of AL-Scores and a tendency towards an improvement of Rankin-Scores So significant improvement in the scores after surgical and endovascular treatment

psychological well-being negatively. However, some of the lost significance after taking the effect of comorbidities into account again shows that not only disease-specific impairment but also the general state of health and age need to be taken into consideration in counseling the individual SDAVF patient in terms of prognosis and rehabilitation.

Conclusion

Our series and the literature indicate that clinical outcome after treatment of SDAVF is good in general. Both neurosurgical and neurointerventional therapies appear to be safe and effective. However, since microneurosurgery provides direct access to the fistula point, in the interdisciplinary approach utilized in our setting, this was the treatment of choice in most of our cases and also in most other series. Deep-seated sacral fistulas may constitute an exemption from this approach. Neurological deterioration of some patients after adequate treatment is still a problem. Thrombosis of the draining vein is a possible pathophysiological explanation. Further studies should clarify whether postoperative heparinization could prevent progressive edema and postoperative neurological deterioration. In contrast to other studies, in this investigation, the length of the diagnostic process had no statistically significant impact on late outcome. However, age and presurgery AL-Score were relevant factors for the physical disability of patients with arteriovenous fistula after surgery. We assume that neurological recovery of patients is not only explained by fistula-related symptoms but also the higher comorbidity of older patients.

The patients' perspective was first investigated in this study, but further research on QoL and psychosocial impairment of SDAVF patients is needed to enable individualized counseling and rehabilitation strategies.

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Comments

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In this issue of NSR, Özkan et al. present their interdisciplinary neurosurgical/neuroradiological management strategy of spinal dural arteriovenous fistulas (SDAVFs) in 32 patients. The article is a retrospective clinical report. Although somewhat difficult to decipher as the table with patient characteristics is incomplete, from the text it seems that the treatments were endovascular in 5/32 (two of whom were later operated due to residual SDAVFs), microsurgical in 25/32 and another 2/32 patients of whom we only learn about due to their retreatments (endovascular and microsurgical, respectively). Follow-up was 100 % at 3 months. Outcome parameters were obliteration rates, modified Aminoff-Logue (AL) myelopathy scale and quality of life (QoL). The obliteration rates after primary therapy is not stated, but a complete fistula obliteration was eventually achieved and documented by angiography in all patients. The AL-score at the 3-month follow-up did not improve significantly ($p=0.13$). Three patients (9 %) deteriorated neurologically after surgery, caused by an epidural hematoma in one and persistent intramedullary edema in two patients. With respect to clinical outcome at 3 months, 30/32 patients improved and only two (6.3 %) patients worsened neurologically after surgery. Of the 32 patients treated, only 12 patients filled in the SF-36 QoL questionnaires, making firm conclusions impossible, although the authors use a German standard population as a reference. Not surprisingly, there is a negative correlation between the AL-scores and QoL as measured by the SF-36 questionnaire, but the statistics are not shown, only the p values. The authors conclude that clinical outcome after treatment of SDAVF is good and that microneurosurgery was the treatment of choice in most cases since it provides direct access to the fistula point. It could preferably have been backed up by their own data showing that retreatment was far more frequent after endovascular than microsurgical treatment in their hands.