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Original Article

Spontaneous closure of non-cavernous sinus dural arteriovenous fistulas: A case series and systematic review of the literature

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ABSTRACT

Background and purpose. – To report 9 new cases of non-cavernous sinus dural arteriovenous fistulas (NCS-DAVFs) that closed spontaneously and systematically review reports of other cases in the literature.
Material and methods. – We performed a retrospective analysis of 9 cases from 2 institutions of NCS-DAVFs that closed spontaneously. Using PubMed and Scopus in accordance with the PRISMA guidelines, we systematically reviewed English language articles about NCS-DAVFs showing spontaneous closure.
Results. – Review of the cases from 2 institutions identified 9 cases of NCS-DAVFs showing spontaneous closure in follow-up magnetic resonance angiography (MRA), and the systematic review of the literature yielded an additional 38 cases, which had been diagnosed by repeated arteriography. Collectively, the patients included 23 men and 24 women with a mean age of 54 years. The shunts were located in the transverse-sigmoid sinus in 24 cases (51%), anterior condylar confluence in 11, and other locations in 12. Based on the venous drainage pattern on arteriography, 27 cases (57%) were classified as low-risk NCS-DAVF (without cortical venous reflux) and 17 were classified as high-risk NCS-DAVF (with cortical venous reflux). Shunt closure was observed within 3 months in 17 cases (36%). Extrinsic predisposing factors for shunt closure were detected in 14 cases (30%). These included angiography in 7 cases, sinus recanalization in 4, development of sinus occlusion in 2, and sinus compression by a newly developed hematoma in 1.
Conclusion. – Spontaneous closures of NCS-DAVFs can occur for both high- and low-risk types. One-third of these closures occur within 3 months.

Introduction

Cranial dural arteriovenous fistulas (DAVFs) are an abnormal arteriovenous communication within the dura and account for 5–15% of all cranial vascular malformations.[1] The presence of cortical venous reflux on arteriography (Borden types II and III, Cognard types IIb-V) indicated high-risk DAVFs, the annual incidence of intracranial hemorrhage and nonhemorrhagic neurological deficit associated with DAVFs ranges from 8% to 15%. Therefore, aggressive curative treatment is recommended for such lesions.[2–4] In contrast, DAVFs without venous reflux (Borden type I, Cognard types I and IIa) have a low event risk of which annual incidence is <1.5%, and the presenting symptoms are usually stable or improve during follow-up.[5–8] There are a few reports of spontaneous closure of DAVFs, except for cavernous sinus DAVFs (CS-DAVFs), which have characteristics distinct from other cranial DAVFs.[8,9] In the present study, we report a case series of 9 patients who experienced spontaneous closure of non-cavernous sinus DAVFs (NCS-DAVFs), which were

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diagnosed by follow-up magnetic resonance angiography (MRA). We reviewed the literature on spontaneous closure of NCS-DAVFs and have combined all cases, including the 9 presented here, to illustrate the clinical features of this relatively unrecognized phenomenon.

Material and methods

Patient recruitment and inclusion criteria

The present study was approved by our institutional review board, which waived the requirement for informed consent because of the retrospective nature of the study. Among 125 consecutive patients in 2 university hospitals who were registered as having cranial DAVFs between January 2009 and December 2018, 57 cases involved CS-DAVF. Of the remaining 68 patients with NCS-DAVFs, 47 patients received endovascular embolization, 3 patients were lost to follow-up, and 18 patients were observed with three-dimensional (3D) time-of-flight (TOF) MRA without undergoing any treatment including embolization, surgery, nor manual arterial compression maneuvers (Fig. 1). The initial diagnosis for all 18 observed patients had been made following the MRA criteria proposed by Noguchi, that is, the presence of multiple high-intensity curvilinear or nodular structures adjacent to the sinus wall on 3D TOF MRA source images.[10] Of these 18 patients, 12 underwent conventional arteriography: 10 patients had fistulas classified as Borden type I (5 were Cognard type I, and 5 were Cognard type IIa) and 2 were Borden type III (Cognard type III). The reasons for observational follow-up in 11 patients were intolerable symptoms and 1 patient refused treatment because of their advanced age. For the remaining 6 patients, the reasons for observational follow-up were refusal of both diagnostic angiography and treatment in 4 patients, precedence of treatment for coexisting carcinoma in 1, and a past history of anaphylactic shock to ionic contrast medium in 1.

After the initial diagnosis, the first follow-up 3D TOF MRA examination was performed within 6 months, and further follow-up 3D TOF MRA examinations were performed every 6–13 months thereafter. The mean and median durations of follow-up for these patients were 40 and 34 months, respectively, range 12–109 months. The median number of follow-up 3D TOF MRA examinations was 3.5 (range, 2–9). The closure of a DAVF was defined as complete resolution of the previously mentioned features on 3D TOF MRA, because 3D TOF MRA has reported to provide equal sensitivity of detecting cranial DAVF compared with conventional arteriography.[10,11] In the follow-up cohort, complete obliteration was observed in 9 patients (50%), partial remission in 2 (11%), no change in 6 (33%), and aggravation in 1 (6%).

Systematic review

We conducted a systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Guidelines.[12] The PubMed and Scopus databases were searched for studies published from January 1, 1990 to December 31, 2019. Keyword search terms were as follows: ("dural arteriovenous fistula" OR "dural arteriovenous malformation") AND ("spontaneous closure") OR ("spontaneous obliteration") OR ("spontaneous regression") OR ("natural obliteration") OR ("natural regression"). Studies were limited to those published in English and involving humans. Two reviewers (NK and MF) independently screened the titles and abstracts of the retrieved reports, then assessed the full text for eligibility (Fig. 2). The reference lists of all reports were checked manually for potential inclusion of further articles. Articles reporting patients younger than 18 years, that were limited to CS-DAVF, or that included patients described in other articles were excluded. Disparities between the 2 reviewers were resolved through discussion until a consensus was reached, with the involvement of a third reviewer (HT).

Data extraction

In the observational study of 18 institutional patients, baseline clinical features including sex, age, presenting symptoms, shunt sites, and the Borden and Cognard classifications on arteriography were extracted.[13,14] We compared features between the patients showing shunt closures and patients with persistent shunt. A Student *t* test was used to compare their mean ages, and a Fisher exact test was used for other clinical features. Differences with $P < 0.05$ were considered significant. According to the institutional and literature reported patients with showing shunt closures, we also collected features related to shunt closures including duration from initial diagnosis to shunt closure, symptomatic changes at the time of closure, and possible predisposing factors for shunt closure.

Results

Retrospective case series and illustrative cases

The clinical features of the 18 patients are summarized in Table 1. Illustrative cases showing spontaneous closures are presented in Figs. 3 and 4. There were no significant differences in baseline clinical features between patients showing shunt closure and patients with persistent shunt. In both groups, sex distribution showed female dominance, mean and median age were their 7th decade, the most common presenting symptom was pulsatile tinnitus, the most frequent site was the transverse-sigmoid sinus, and angiography usually showed no cortical venous reflux (Borden type I, Cognard types I and IIa), indicating low-risk DAVF.

For the features related to shunt closures, the duration from the initial MRA diagnosis to shunt closure ranged from 25 to 3240 days, and the median number of follow-up MRA examinations until shunt closure was 2 (range, 1–9). Shunt closures occurred within 3 months in 2 patients, between 3 months and 1 year in 2 patients, and after 1 year in 5 patients. At the time of shunt closure, the presenting symptoms resolved in 4 patients, improved in 4, and were unchanged in 1. In 5 patients, confirmation of shunt closure by MRA followed improvements in presenting symptoms with a time-lag ranging from 6 to 72 months. In 2 patients, the symptoms regressed immediately after arteriography, and subsequent MRA confirmed shunt closure within 5 weeks. We concluded that arteriography was a predisposing factor for shunt closure in these 2 patients. Except for arteriography, no other potential predisposing factors for shunt closure were detected.

Illustrative cases

Case 1

An 87-year-old-woman was admitted to our institution for headache and impaired consciousness. The initial MRI showed a small patchy hematoma with white matter edema in the left occipital lobe. 3D TOF MRA showed visualization of the left sigmoid sinus with dilated arteries in the sinus wall and left skull base (Fig. 3A and B).

Based on the diagnosis of NCS-DAVF causing intracranial hemorrhage, arteriography was performed. In addition to arterial flow to the left sigmoid sinus, we observed early visualization of the isolated transverse sinus with retrograde cortical venous reflux, which indicated Borden type III (Cognard type III) classification (Fig. 3C and D). Thrombosis of the transverse-sigmoid sinus junction was also observed.

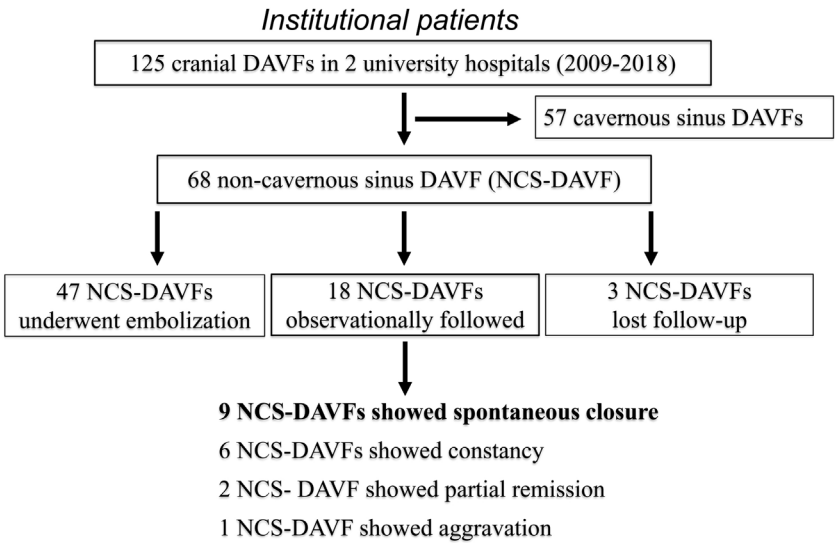

Fig. 1. Overview of patient selection process in two institutions.

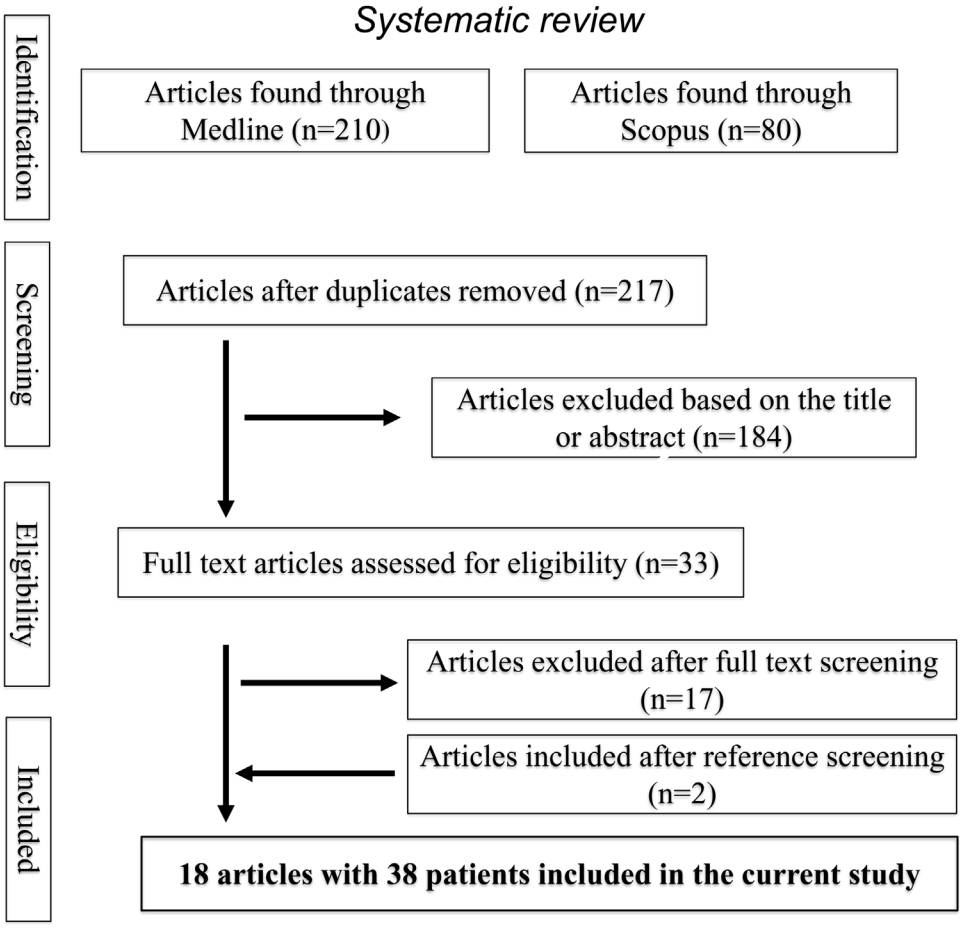

Fig. 2. PRISMA flowchart for the search strategy in for the systematic review.

The patient's state of consciousness recovered within a few days, and endovascular treatment was proposed because of the risk of rebleeding. However, the patient and her family refused the curative treatment because of her age, and the patient was followed up with regular neurological and 3D TOF MRA examinations. Her headache gradually resolved and 3D TOF MRA, 4 years after the initial examination revealed complete resolution of the DAVF (Fig. 3E and F). T2-weighted and fluid-attenuated inversion-recover (FLAIR) images obtained simultaneously with 3D TOF MRA showed hyperintensity of the sigmoid-transverse sinus junction, suggesting persistence of the sinus thrombosis. Further follow-up 3D TOF MRA examination 1 year later showed no recurrence.

Table 1
Summary of data for institutional 18 patients.

		Spontaneous closure (*N* = 9)	Persistent shunt (*N* = 9)	*P* Value
Sex	Men	4 (44%)	2 (22%)	0.62
Age	Mean, median, range	66, 64, (51–87)	65, 64, (53–78)	0.73
Presenting symptom	Pulsatile tinnitus	7 (78%)	7 (78%)	1.00
	Headache	2 (22%)	0	0.47
	Impaired consciousness	1 (11%)	0	1.00
	Hypoglossal nerve palsy	0	1 (11%)	1.00
	None (incidental)	0	2 (22%)	0.47
Site	Transverse-sigmoid sinus	6 (67%)	5 (56%)	1.00
	Anterior condylar confluence	3 (33%)	2 (22%)	1.00
	Anterior cranial fossa	0	2 (22%)	0.47
Borden classification	Type 1	5 (56%)	4 (44%)	1.00
	Type 2	0	0	1.00
	Type 3	1 (11%)	1 (11%)	1.00
	Not available	3 (33%)	4 (44%)	–
Cognard classification	Type 1	3 (33%)	2 (22%)	1.00
	Type 2a	2 (22%)	2 (22%)	1.00
	Type 3	1 (11%)	1 (11%)	1.00
	Not available	3 (33%)	4 (44%)	–
Duration from AVF	Within 3 months	2 (22%)		
	3 months–1 year	2 (22%)		
	Over 1 year	5 (56%)		
Symptomatic change	Resolved	4 (44%)		
	Improved	4 (44%)		
	Stable	1 (11%)		
Predisposing factor	Arteriograhy	2 (22%)		

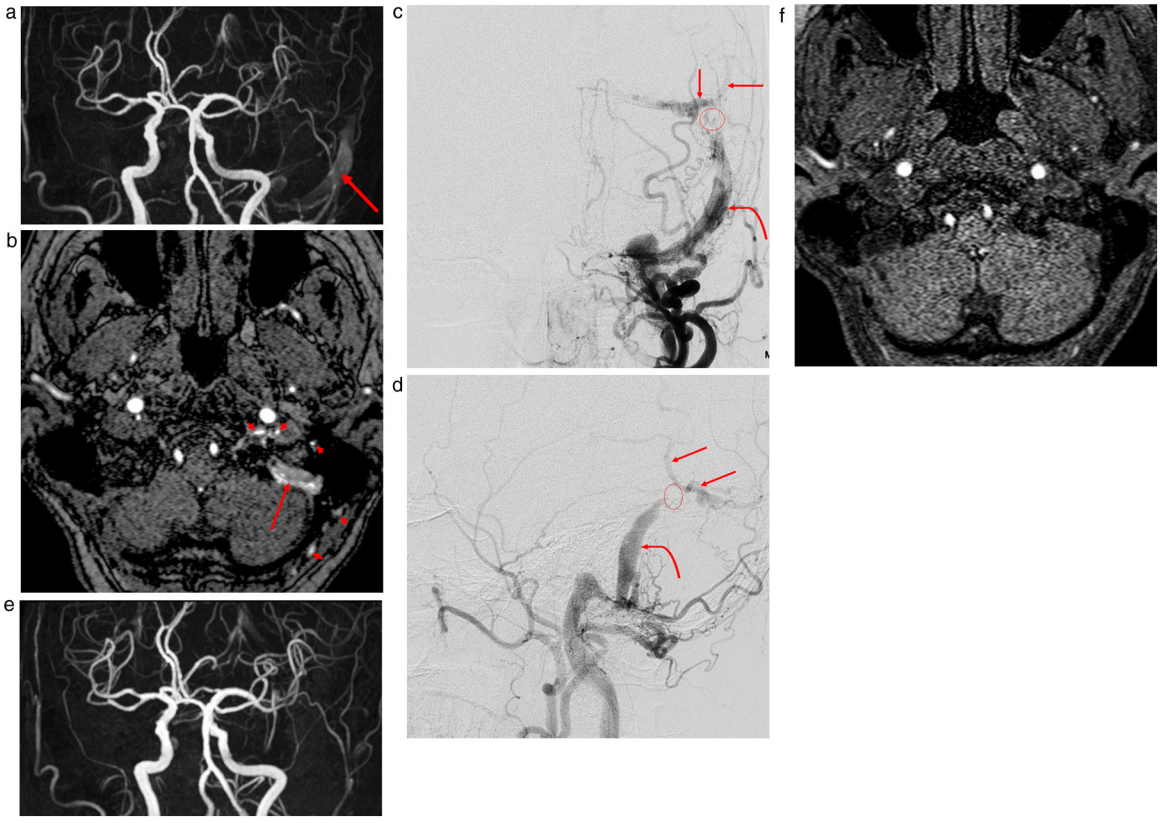

Fig. 3. An 87-year-old woman with DAVF of the left sigmoid sinus. Maximum intensity projection (MIP) (A) and source images (B) from 3D TOF MRA show a hyperintense left sigmoid sinus (arrow) and dilated branches of the left ascending pharyngeal artery and the left occipital artery (arrowheads). Anterior–posterior (AP) and lateral views (C and D) from a left external angiogram show early visualization of the left sigmoid sinus (curved arrow) and cortical venous reflux via isolated transverse sinus (arrows). Defect in the transverse-sigmoid sinus junction is also observed (circle). Three-dimensional TOF MRA (E and F) performed 4 years after the initial presentation shows complete resolution of hyperintensity in the left sigmoid sinus and dilated arteries.

Case 2

A 67-year-old woman was referred to our institution for pulsatile tinnitus. The initial 3D TOF MRA examination showed arterialized flow signal in the left anterior condylar confluence and hypoglossal canal (Fig. 4A and B), resulting in a diagnosis of DAVF. Subsequent arteriography showed shunt to the anterior condylar confluence with an antegrade venous drainage, indicating Borden type I (Cognard type I) classification (Fig. 4C and D). Immediately after the arteriography, the patient reported a decrease in tinnitus. A follow-up 3D TOF MRA examination was performed 5 weeks later

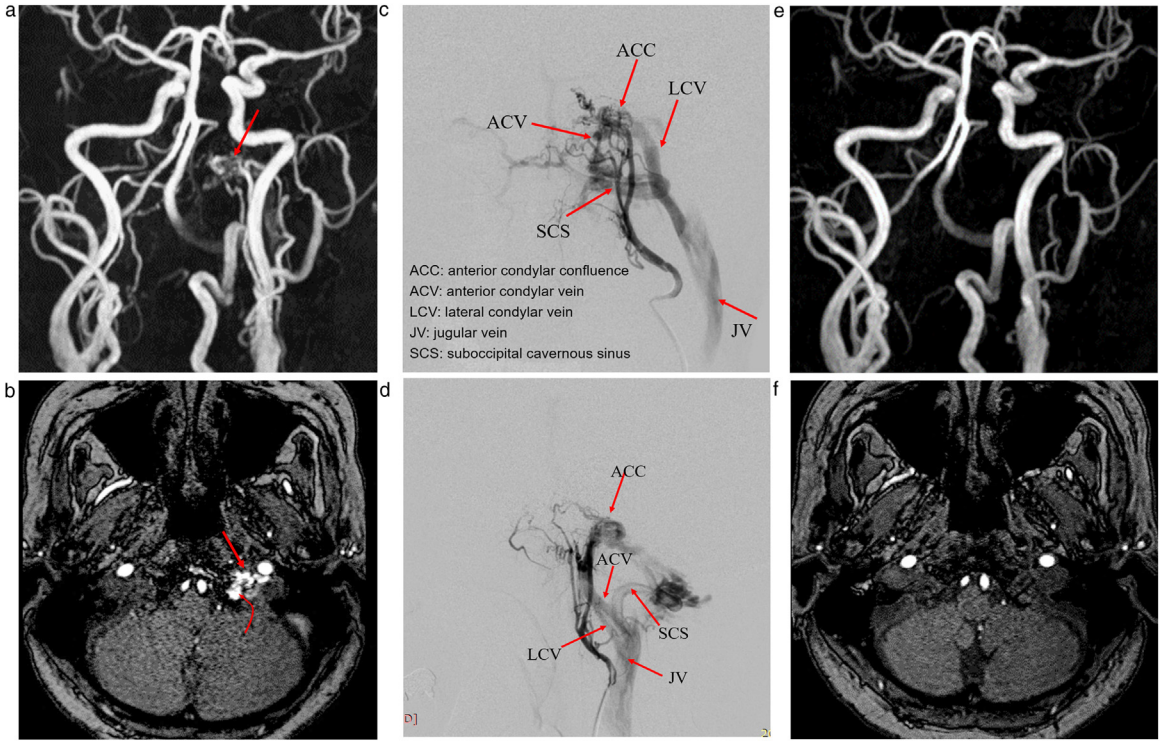

Fig. 4. A 67-year-old woman with DAVF of the left ACC. The initial 3D TOF MRA, MIP and source images (A and B) show aggregation of multiple hyperintense spots in the left ACC (arrow) and the hypoglossal canal (curved arrow), leading to a diagnosis of DAVF. AP and lateral views (C and D) of selective injection into the left ascending pharyngeal artery show a fistula to the ACC, which drains into the anterior condylar vein (ACV) connecting to the suboccipital cavernous sinus (SCS). Another drainer is the lateral condylar vein (LCV), which directly connects to the internal jugular vein as a normal variant. 3D TOF MRA (E and F) performed 5 weeks after the initial presentation shows complete resolution of the hyperintensity observed in the venous structure.

and showed complete remission of the shunted flow (Fig. 4E and F). Further follow-up 3D TOF MRA examination 1 year later showed no recurrence.

Systematic review and combined data

Our initial literature search yielded 217 articles, from which we retrieved 18 eligible articles that included 38 patients.[8,15–31] When combined with our 9 patients, we reviewed a total of 47 cases, which are summarized in Table 2. The patients included 23 men and 24 women, with a mean age of 54 years (median, 53 years, range 24–87 years). Multiple presenting symptoms were often seen in these patients. The most frequent symptom was pulsatile tinnitus in 29 patients (62%), followed by headache in 15 patients (32%). Unusual manifestations included impaired consciousness in 2 patients (3%), paralysis of the hypoglossal nerve in 2 patients (3%), convulsion in 2 patients (3%), dysesthesia in 1 patient (2%), and aphasia in 1 patient (2%). The shunts were located in the transverse-sigmoid sinus in 24 patients (51%), anterior condylar confluence in 11 patients (23%), superior sagittal sinus in 4 patients (9%), anterior cranial fossa in 2 patients (3%), and at other locations or not described in 6 patients (13%).

The venous drainage patterns on arteriography were Borden type I in 27 patients (57%), Borden type II in 6 (13%), Borden type III in 11 (23%), and not available in 3 (6%). Among the patients with Borden type 2 or 3 NCS-DAVF, which were recognized as high-risk DAVFs, the reasons for observational follow-up were symptom regression immediately after the diagnostic angiography or while awaiting curative treatment in 4 patients (24%), shunt closure at the time of endovascular treatment in 3 patients (18%), technical treatment failure in 1 patient (6%), treatment refusal in 2 patients (12%), and unknown reasons in 7 patients (41%).

The duration from the initial diagnosis to shunt closure ranged from 3 days to 15 years. Shunt closures occurred within 3 months in 17 patients (36%), between 3 months and 1 year in 8 patients (17%), and after 1 year in 11 patients (23%). The time of closure was not described in 11 patients (23%). Symptomatic changes were resolved in 21 patients (45%), improved in 12 patients (26%), and unknown or unchanged in 14 patients (30%). In 5 patients, transient episode of headache or impaired consciousness preceded the improvement or resolution of the symptoms. Possible predisposing factors for shunt closure were identified in 14 patients (30%); those included arteriography in 7 patients (15%), recanalization of the occluded sinus in 4 patients (9%), development of sinus occlusion in 2 patients (4%), compression of the shunt by a hematoma in 1 patient (2%). We defined arteriography as a predisposing factor when symptomatic changes occurred during arteriography or within a few days after arteriography, followed by confirmation of shunt closures by repeated arteriography.[18,25,28,29]

Discussion

In our 9 patients with NCS-DAVFs who were followed up without any treatment, the rate of spontaneous shunt closure was 50%, which is higher than the 0–44% reported in the literature.[5–8,15] This difference may be explained as follows. In the previous reports, follow-up arteriography was only performed in selected patients, mainly those who had relevant symptomatic changes. By contrast, the noninvasive character of 3D TOF MRA enabled us to perform multiple imaging evaluations of all follow-up patients. In fact, 5 of our 9 patients showed a time lag between the awareness of symptomatic changes and confirmation of shunt closure. In such cases, it may be difficult to confirm shunt closure with a single follow-up arteriography study. Another possible explanation is that the methodology used to confirm shunt closure may affect the inci-

Table 2
Summary of data for combined 47 patients.

Combined patients ($N = 47$)		
Sex	Men	23 (49%)
Age	Mean, median, range (years)	54, 53, 24–87
Presenting symptom	Pulsatile tinnitus	29 (62%)
	Headache	15 (32%)
	Others	8 (17%)
Site	Transverse-sigmoid sinus	24 (51%)
	Anterior condylar confluence	11 (23%)
	Superior sagittal sinus	4 (9%)
	Anterior cranial fossa	2 (3%)
	Others or Undescribed	6 (13%)
Borden classification	Type 1	27 (57%)
	Type 2	6 (13%)
	Type 3	11 (23%)
	Not available	3 (6%)
Duration from AVF diagnosis to shunt closure	Within 3 months	17 (36%)
	3 months–1 year	8 (17%)
	Over 1 year	11 (23%)
	Undescribed	11 (23%)
Symptomatic change at the time of shunt closure	Resolved	21 (45%)
	Improved	12 (26%)
	Unknown or stable	14 (30%)
Predisposing factor for shunt closure	Arteriography	7 (15%)
	Recanalization of occluded sinus	4 (9%)
	Development of sinus thrombosis	2 (4%)
	Compression of the shunt by a hematoma	1 (2%)

dence. By comparison with arteriography, which is the criterion standard for the diagnosis of DAVF, the sensitivity of 3D TOF MRA for the detection of cranial DAVF in the initial diagnosis is reported to be 100%.[10,11] However, the sensitivity for detection of residual shunt in the follow-up examinations after treatment is reported to be 88%,[32] indicating that small and low-flow DAVFs could be missed on 3D TOF MRA. Therefore, we cannot exclude the possibility that our institutional series included cases with residual small and low-flow shunts that could be detected only by arteriography.

Our analysis of combined data from our institutional patients and systematic review of the literature revealed several clinical features of spontaneous closure of NCS-DAVFs. First, Borden type II or III, which was recognized as high-risk NCS-DAVFs, accounted for 36% of cases, which contrasts with the classical belief that spontaneous closure occurs mainly for Borden type I, which was recognized as low-risk NCS-DAVFs.[16–18] These data may be affected by bias because the unexpected spontaneous closure of high-risk NCS-DAVFs promotes publication of such cases. Although our combined data cannot be used to advocate the conservative management of high-risk NCS-DAVFs, it may provide reference information for planning the treatment strategy for high-risk NCS-DAVFs in specific patients, such as those in a poor clinical state or those requiring difficult treatment procedures.

Second, the shunt closures occurred at various times after the initial diagnosis, which suggests that diverse mechanisms may contribute to spontaneous closure of NCS-DAVFs. We note that in 36% of patients, shunt closure occurred within 3 months. This result seemed to reflect that arteriography was most frequent predisposing factor for shunt closure. In addition, even if arteriography is not a predisposing factor, the hemodynamics of NCS-DAVFs may be liable to change in the early stages. Therefore, 3 months of observation followed by curative treatment is proposed as a treatment option for patients with low-risk NCS-DAVFs.

Third, arteriography was most frequent predisposing factor for shunt closure accounting for 15% of cases. According to the mechanism, temporary blood flow stagnation by selective catheterization to feeding artery and endothelial damage caused by the contrast medium using arteriography were explained.[18,25,28,29] In the latter mechanism, thrombogenesis can occur in 3 months after arteriography. Therefore, arteriography may account for a potentially larger proportion of predisposing factors.

Fourth, predisposing factors shunt closures were not identified in about 70% of cases, despite several proposed extrinsic factors including arteriography, recanalization of the occluded sinus, thrombosis of the involved sinus, and a mass effect caused by a hematoma.[16,18,19,24–31] Therefore, we speculate that the mechanism most frequently responsible for shunt closure is the intrinsic mechanism proposed by Luciani et al.,[17] in which the direct arterial shunt flow into the venous system causes focal expansion of the dura, which compresses the shunt point.

Our study has some limitations. First, closure of NCS-DAVFs in our institutional patients was identified using 3D TOF MRA and not the criterion-standard conventional arteriography. Although nonvisible shunt on 3D TOF MRA cannot completely exclude the residual presence of a small or low-flow shunt,[32] its high sensitivity for detection of NCS-DAVF may allow a diagnosis of shunt closure without confirmatory arteriography, which has potential risks of complications and relatively higher cost. Thus, to evaluate hemodynamic information that cannot be provided by 3D TOF MRA, further examination using contrast-enhanced imaging such as time-resolved contrast-enhanced MRA or time-resolved CT angiography may be recommended.[32–34] Second, our review comprises predominantly case reports, and there may be an inherent publication bias within the included data. However, it is difficult to collect prospective data about the natural history of cranial DAVFs, including the high-risk type, because of their low incidence and high annual event risk of 7–13%.[1–4] So, our pooled analysis of our case series and published data can be considered meaningful.

Conclusion

In our review of 68 cases with NCS-DAVFs in patients attending our institutions, 18 (26%) were followed without any treatment, and 9 (13%) revealed shunt closures on follow-up MRA examinations. In the combined analysis of cases with NCS-DAVFs showing spontaneous closures from our institutions and systematic literature review, the high risk NCS-DAVFs accounted for 36%. Shunt closure occurred within 3 months in 36% of patients, and potential

predisposing factors for shunt closure could be detected in only 30% of patients.

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Ethics approval

Our study was approved by the institutional review board, which waived the requirement for informed consent given the retrospective nature of the study.

Consent to participate

This study is retrospective observational study.

Consent for publication

All authors consent to publication of this manuscript in Journal of Neuroradiology.

Authors' contribution

Nobuo Kashiwagi: conceptualization, writing.

Koichi Miyazaki, Hiroto Takahashi, Masahiro Fujiwara: data curation, data analysis.

Kiyoshi Tsuji, Atsuko Arisawa, Hajime Nakamura, Haruhiko Kishima: data curation.

Kazunari Ishii: review and editing.

Noriyuki Tomiyama: supervision.

Disclosure of interest

All authors declare that they have no conflict of interest.

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