

Simultaneous Parkinsonism and Dementia as Initial Presentation of Intracranial Dural Arteriovenous Fistulas: A Systematic Review

Pavel S. Pichardo-Rojas¹, Luis A. Marín-Castañeda², Fernando De Nigris Vasconcellos¹, Shadia I. Flores-López³, Adrian Coria-Medrano⁴, Perla de Teresa López-Zepeda⁵, Claudia D. Sánchez-Serrano⁶, Mario C. Torres-Chávez⁷, Jesús M. Escobar-López⁸, Luz C. Choque-Ayala⁹, Gorbachev Jowah¹, Leonardo Rangel-Castilla¹⁰

■ **BACKGROUND:** Intracranial dural arteriovenous fistulas (IDAVFs) are abnormal vascular connections between dural arteries and various venous structures within the brain. IDAVFs, rarely present with parkinsonism and dementia concurrently, making this a unique and underexplored clinical scenario. To the best of our knowledge, this is the first systematic review to comprehensively analyze cases of IDAVFs manifesting as both parkinsonism and dementia.

■ **METHODS:** We assessed databases from inception to September 18, 2023. We identified studies describing patients with IDAVFs initially presenting with dementia or parkinsonism. Inclusion criteria encompassed case reports and case series, while excluding review articles, guidelines, technical notes, comments, conference abstracts, and editorials.

■ **RESULTS:** The systematic search resulted in the initial screening of 383 studies, with 33 articles meeting the inclusion criteria. Among these, 29 were case reports, often describing 3 or fewer patients. From the remaining 4 case series, data pertinent to patients presenting both parkinsonism and dementia were selectively extracted, yielding a total study population of 43 patients. The anatomical distribution of IDAVFs within this cohort was diverse, with the transverse and sigmoid sinuses being the most common locations. Although most of these patients received

endovascular therapy, a few underwent microsurgical occlusion or combined surgical and endovascular treatment.

■ **CONCLUSIONS:** IDAVFs presenting with both parkinsonism and dementia represent a rare clinical entity. This systematic review provides valuable insights into the clinical characteristics, treatment options, and outcomes for such cases. However, additional research involving larger cohorts is essential to better comprehend the underlying mechanisms and establish standardized therapeutic guidelines.

INTRODUCTION

Intracranial dural arteriovenous fistulas (IDAVFs) are abnormal vascular shunts between dural arteries and either dural venous sinuses, meningeal veins, or cortical veins. They account for up to 10%–15% of all intracranial arteriovenous malformations.^{1,2} IDAVFs usually develop in adulthood and are commonly found within the transverse, sigmoid, and cavernous sinuses.^{1,3,4} Although most IDAVFs are idiopathic, a small percentage can be acquired, often correlated with prior craniotomies, trauma, venous hypertension, and dural sinus thrombosis.^{1,5,6} Clinical manifestations are highly heterogeneous; however, symptoms are closely associated with

Key words

- Dementia
- Intracranial dural arteriovenous fistulas (IDAVFs)
- Parkinsonism

Abbreviations and Acronyms

IDAVF: Intracranial dural arteriovenous fistula

From the ¹The Vivian L. Smith Department of Neurosurgery, The University of Texas Health Science Center at Houston McGovern Medical School, Houston, Texas, USA; ²La Salle University School of Medicine, Ciudad de México, México; ³Centro de Investigación en Ciencias de la Salud (CICSA), Facultad en Ciencias de la Salud, Universidad Anáhuac México Campus Norte, Estado de México, Huixquilucan de Degollado, México; ⁴Instituto de Neurobiología, Campus Universidad Nacional Autónoma de México-Juriquilla, Querétaro, México; ⁵Escuela de Medicina y Ciencias de la Salud, Tecnológico de Monterrey,

Guadalajara, Jalisco, México; ⁶Centro Universitario de Ciencias de la Salud, Guadalajara, Universidad de Guadalajara, Guadalajara, Jalisco, México; ⁷Facultad de Medicina, Universidad Autónoma de Baja California, Mexicali, Baja California, México; ⁸Escuela de Ciencias de la Salud, Universidad Del Valle de México, Ciudad de México, México; ⁹Facultad de Medicina, Universidad Católica Boliviana San Pablo, Santa Cruz de la Sierra, Bolivia; and ¹⁰Hospital Lomas International, San Luis Potosí, San Luis Potosí, México

To whom correspondence should be addressed: Pavel S. Pichardo-Rojas, M.D.
[E-mail: Pavel.S.PichardoRojas@uth.tmc.edu]

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the location of the lesion and the venous drainage pattern. Common symptoms include pulsatile tinnitus, headache, cognitive impairments, memory deficits, decreased visual acuity, cranial nerve abnormalities, cerebellar symptoms, ophthalmoplegia, parkinsonism, and dementia.^{1,7-13} Parkinsonism and dementia are notably infrequent clinical presentations associated with IDAVFs. Although both presentations remain poorly understood, current hypotheses propose a correlation with the frontal lobe and basal ganglia hypoperfusion attributed to impaired venous drainage.¹³⁻¹⁶ Given the limited studies available on this topic,^{16,17} primarily consisting of case reports and case series, to our knowledge, this study represents the first systematic review exploring concurrent parkinsonism and dementia as the initial presentation of IDAVF. Secondly, our study aims to describe published IDAVF cases manifesting with either dementia or parkinsonism.

METHODS

Search Strategy

This systematic review was conducted adhering to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines,¹⁸ with registration secured through PROSPERO CRD42023468361.

A systematic search was conducted across the MEDLINE (PubMed), Embase, and Cochrane Library databases from inception to September 18, 2023, without language restriction. The search strategy was designed and conducted by one author (P. S. P.-R.), using a controlled vocabulary supplemented with key words “arteriovenous fistula or dural arteriovenous fistula or central nervous system vascular malformations,” “dementia,” and “parkinsonian disorders or parkinsonism or Parkinson disease,” to search for studies describing the clinical course and outcomes of patients with IDAVFs initially manifesting as dementia or parkinsonism. The complete search strategy, including all terms and combinations, is provided in [Supplementary Appendix 1](#).

Eligibility

The inclusion criterion was restricted to published articles that reported patients with IDAVFs presenting initially with dementia and parkinsonism. These studies had to report well-defined clinical characteristics, diagnostic strategies, imaging characteristics, treatment, and therapeutic outcomes. Although patients manifesting with isolated dementia or parkinsonism were taken into consideration for a secondary narrative assessment, they did not align with our study's primary objective. Regarding study design, we only included case series and case report studies; review articles, guidelines, technical notes, comments, conference abstracts, and editorials were excluded.

Data Extraction and Screening

The initial screening of titles and abstracts was independently conducted by 2 authors (P. T. L.-Z. and L. A. M.-C.) using Microsoft Excel spreadsheets (Microsoft Inc., Redmond, Washington, USA). For those abstracts deemed eligible, full-text articles were retrieved and subsequently scrutinized by 2 authors (A. C.-M. and S. I. F.-L.), concluding in the final list of included articles. Based on the inclusion and exclusion criteria, 285 articles were

retained for full examination, of which 33 were chosen to be included in this review.

Baseline patient characteristics were extracted from each article. These included sex, age, location, clinical presentation, and Borden classification. Any patients whose initial presentation was characterized by symptoms other than dementia or parkinsonism were excluded from the study.

RESULTS

From our initial evaluation, a total of 383 studies were screened, of which 33 articles met our inclusion criteria. Among these, 29 were case reports^{13,15,19-45,46} including ≤ 3 patients. From the remaining 4 case series,^{39-41,47,48} we selectively extracted data for individual patients that aligned with our focus on IDAVFs presenting both parkinsonism and pseudodementia, because not all patients matched these characteristics. The publication dates from the different studies ranged from 1988 to 2022. The articles were reported from 11 countries including the United Kingdom, Japan, South Korea, China, France, India, Israel, Portugal, Canada, Italy, and Switzerland. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram is shown in [Figure 1](#). The baseline study characteristics can be found in [Table 1](#).

Our search encompassed a total study population of 43 patients with 48 IDAVFs, with ages ranging from 40 to 87 years. These 48 IDAVFs were distributed across various locations including 17 in the transverse sinus,^{13,20,21,24,27-29,31,35,36,39,41,47,50} 14 in the sigmoid sinus,^{15,20,21,24,29,31,33,39,50} 9 in the superior sagittal sinus,^{21,23,25,30,33,34,39,45,47} 4 in the straight sinus,^{13,19,47,48} and 10 in the confluence of the sinuses or torcula.^{20,21,25,28,34,38,40,45,47} An additional 9 were categorized under other venous sinuses,^{22,26,29,32,36,37,42,44,47} including the jugular foramen, great vein of Galen, tentorium cerebri, and tentorium cerebelli. For certain cases, the exact anatomic location remained unspecified. [Figure 2](#) provides a schematic representation of the IDAVF locations. Regarding the Borden classification, 9 IDAVFs were grade II^{23,30,32,38,40,47} and 3 were grade III.^{19,20,36} One case was classified as Cognard type IIa,⁴¹ and another case was type IIIa+b.¹³ The rest of the studies did not categorize them. Population characteristics can be found in [Tables 2](#) and [3](#).

All included patients had an initial presentation of parkinsonism and dementia or pseudodementia. Parkinsonism included bradykinesia, resting tremor, postural instability, and rigidity. Those with dementia or pseudodementia demonstrated memory impairment, language deficits, visuospatial dysfunction, and executive dysfunction. Additional alterations included focal motor deficits,^{23,30,33} altered mental status,^{15,30,32,38,48} seizures,³¹ cerebellar symptoms,²⁹ urinary incontinence,^{15,24,25,28,43,48} headaches,²⁵ hallucinations,²¹ ocular movement impairment,^{21,34} papilledema,³⁴ Horner syndrome, and scleral injection.⁵⁰

The imaging findings from imaging modalities for patients with IDAVFs revealed a broad spectrum of radiographic abnormalities^{13,15,19-45,47,48,50}; these are described in [Tables 2](#) and [3](#). Imaging characteristics were not detailed in 2 of the studies.^{31,49} Magnetic resonance imaging findings on T2-weighted sequences demonstrated diffuse hyperintensities across affected regions (e.g., thalamus, white matter, cerebral

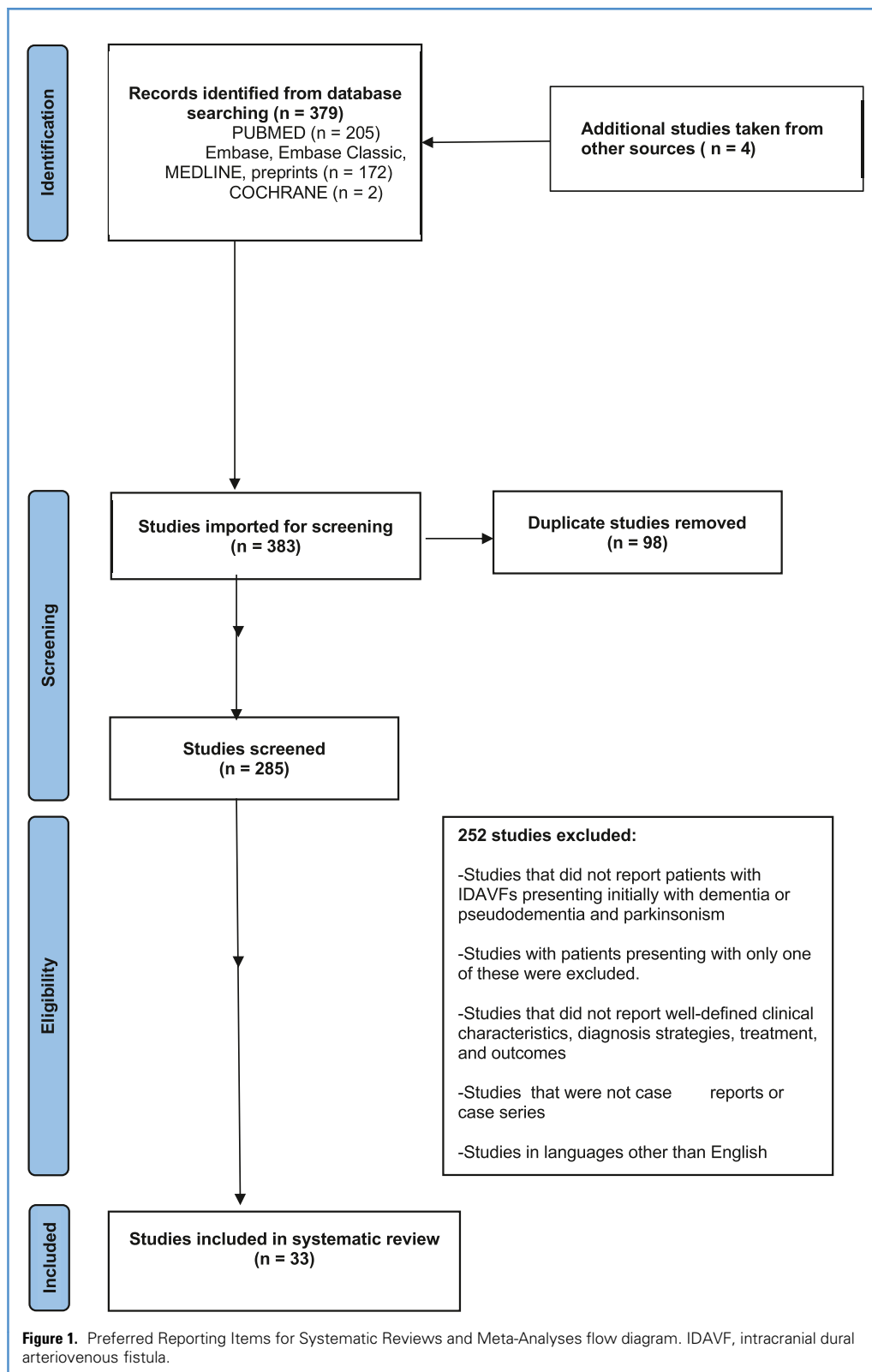


Table 1. Study Characteristics

Study	Country	Total Population (Analyzed)	Follow-Up Time	Patient Presentation (Clinical Manifestations)	Key Findings
Case reports					
Hirono et al., 1993 ³³	Japan	1	3 months	Progressively cognitive impairment, gait disturbance.	IDAVF in the superior sagittal sinus and right sigmoid sinus.
Touho et al., 1994 ³²	Japan	1	2 months	Gait disturbance, dementia, hyperkinesia, quadriparesis, Broca aphasia.	IDAVF in the left transverse and straight sinuses.
Yoshimura et al., 1995 ³¹	Japan	1	10 months	Status epilepticus, gait disturbance, tremor, cognitive impairment.	IDAVF in the posterior fossa.
Datta et al., 1998 ³⁰	China	1	1 month	Dementia, gait disturbance, tremor.	Multiple IDAVFs in the superior sagittal sinus.
Tominaga et al., 2003 ²⁹	Japan	2	6 months	Case 1: confusion, vomiting, cerebellar dysfunction. Case 2: dementia and parkinsonism.	IDAVF in the transverse-sigmoid sinus.
Belo et al., 2004 ²⁷	France	1	2 months	Dementia, urinary incontinence, and parkinsonism.	IDAVF in the right lateral sinus.
Magot et al., 2004 ²⁸	France	2	4 months/24 months	Case 1: gait disturbance, dementia, incontinence. Case 2: dementia, parkinsonism, tinnitus.	IDAVF in the centrum semiovale and left transverse sinus.
Ishihara et al., 2009 ²⁶	Japan	2 (1)	NE	Progressive dementia, gait disturbances	IDAVF that was fed by the accessory middle meningeal artery and ascending pharyngeal artery.
Nogueira et al., 2009 ⁴¹	USA	1	4 months	Postural instability, rigidity, bradykinesia, dementia.	IDAVF in the transverse sinus.
Netravathi et al., 2011 ²⁵	India	2	NE	Cognitive impairment, urinary incontinence, parkinsonism.	IDAVF in the torcular Herophili and superior sagittal sinus.
Shahar et al., 2012 ³⁷	Israel	1	6 months	Progressing freezing of gait, dementia, nystagmus.	IDAVF in the tentorium cerebri.
Geraldes et al., 2012 ⁴⁰	Portugal	1	3 months	Bradykinesia, rigidity, dysmetria, myoclonus, ataxic gait, dementia.	IDAVF in the torcular Herophili.
Hattori et al., 2013 ³⁹	Japan	1	3 years	Disorientation, gait disturbance, mutism, urinary incontinence.	IDAVF in the transverse-sigmoid sinus and 3 years later in the superior sagittal sinus.
Luo et al., 2014 ²⁴	China	2	17 months/24 months	Bradykinesia, cognitive dysfunction, urinary incontinence.	IDAVF in the transverse and sigmoid sinus.
Ma et al., 2015 ²²	China	1	12 months	Rigidity, memory loss, behavioral abnormalities.	IDAVF in the left temporal region.
Fujii et al., 2014 ²³	Japan	1	7 days	Parkinsonism and cognitive dysfunction.	IDAVF in the superior sagittal sinus.
Gopinath et al., 2017 ³⁴	India	1	6 months	Dementia and parkinsonism.	IDAVF in the superior sagittal sinus and torcular Herophili
Nakano et al., 2017 ²⁰	Japan	1	7 months	Memory disturbance, bradykinesia, gait disturbance.	IDAVF in the torcular Herophili.
Lai et al., 2017 ²¹	Canada	2	5 months/3 months	Case 1: headache, parkinsonism, gait disturbance, dementia. Case 2: pulsatile tinnitus, cognitive impairment, parkinsonism.	IDAVF in the superior sagittal sinus, transverse sinuses, torcular Herophili, and right sigmoid sinus.
Cascio Rizzo et al., 2021 ³⁸	Italy	1	NE	Parkinsonism, disorientation, memory impairment	IDAVF in the torcular Herophili.

Continues

Table 1. Continued

Study	Country	Total Population (Analyzed)	Follow-Up Time	Patient Presentation (Clinical Manifestations)	Key Findings
Velz et al., 2020 ¹⁹	Switzerland	1	3 months	Progressive cognitive impairment, bradykinesia, gait impairment.	IDAVF in the straight sinus
Prosperini et al., 2022 ³⁵	Italy	1	NE	Dementia, bradykinesia, rigidity, gait disturbance.	IDAVF in the transverse sinus.
Tominaga et al., 2022 ³⁶	Japan	1	NE	Parkinsonism and dementia.	IDAVF in the tentorium cerebelli and transverse sinus.
Case series					
Matsuda et al., 1999 ¹⁵	Japan	3	NE	Case 1: gait impairment, bradykinesia, forgetfulness, rigidity Case 2: blurred vision, generalized convulsion, confusion, rigidity, bradykinesia Case 3: bradykinesia, disorientation, difficulty of walking, urinary incontinence	IDAVF in the sigmoid sinus.
Dehdashti et al., 2010 ⁴⁷	Canada	246 (4)	3–6 months in most cases	Case 1: gait instability, tremor, cognitive decline. Case 2: personality change, episodes of confusion, gait instability. Case 3: gait instability, personality change, worsening memory. Case 4: personality change, memory loss, tremor.	IDAVF in the transverse sinus, superior sagittal sinus, straight sinus, torcular Herophili, and jugular foramen.
Colorado et al., 2018 ⁴⁸	USA	4 (3)	Case 1: 3 months Case 3: 34 months Case 4: 6 months	Case 1: parkinsonism and bradykinesia with impaired balance. Case 3: memory impairment, disorientation, parkinsonism, hypersomnolence Case 4: memory impairment, disorientation, generalized seizure.	All IDAVFs were located in the straight sinus.
Lazar et al., 2022 ⁴⁹	USA	104 (1)	24 months	Rapidly progressive dementia, parkinsonism, gait instability, akinetic mutism.	IDAVF was found ruling out CJD.
Fearon et al., 2022 ⁵⁰	Canada	7 (1)	NE	Cognitive decline and personality change, Horner syndrome, parkinsonism.	Extensive IDAVF in the left sigmoid and transverse sinus.

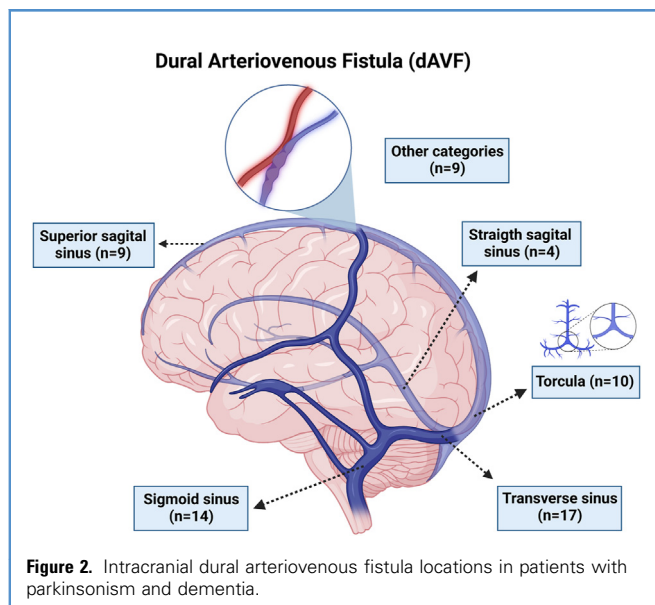
IDAVF, intradural arteriovenous fistula; CJD, Creutzfeldt-Jakob disease; NS, not specified.

hemispheres). Flow voids, indicative of blood flow disruption, were frequently observed. These commonly occurred in temporal and occipital regions. T1-weighted images demonstrated areas of enhancement or hyperintensity. These magnetic resonance imaging findings are represented in **Figure 3**. Noncontrast computed tomography scans generally displayed hypodense regions in the subcortical white matter and other areas (e.g., thalamus). Other findings included cerebral edema, dilation of deep cerebral veins, and evidence of thrombosis or hemorrhage in the affected regions.

Of the 43 patients, microsurgical IDAVF occlusion was performed in 3 cases^{19,42,47}; 2 of them experienced clinical improvement, whereas the third remained stable after surgical intervention. Of these patients, 36 were treated with endovascular therapy. Specifically, 35 patients underwent IDAVF embolization^{13,15,20-23,25-34,36-40,43-45,47,48,50} and 1 was treated with pressure cooker technique.³⁵ Among those treated with

embolization, 28 experienced clinical improvement posttherapy, 6 did not show clinical improvement,^{15,25,31,38,48} and clinical outcomes were not reported for 2 patients.⁴⁷ Additionally, 1 patient underwent a combination of endovascular and surgical therapy and demonstrated posttherapeutic clinical improvement.⁴¹ Poor outcomes were not confined to any specific type or location of IDAVF because they presented heterogeneously.

Studies that did not meet our primary criteria and presented with isolated parkinsonism or dementia were secondarily assessed. We identified a total population of 70 patients from our main search that presented with dementia or parkinsonism as an initial presentation of IDAVF, which are displayed in **Supplementary Table 1**.^{14,42,51-57} In our search, 5 studies with 5 patients were identified with isolated parkinsonism. These patients exhibited bradykinesia, rigidity, gait disturbances, hypomimia, and hypophonia. They were associated with IDAVFs of the



transverse sinus, straight sinus, sigmoid sinus, and torcular Herophili. Three of them experienced complete recovery after treatment.^{14,51–53,58–98} Common IDAVF locations included the superior sagittal sinus, transverse sinus, and sigmoid sinus. After treatment, 28 of these patients experienced complete recovery.

DISCUSSION

IDAVFs represent 10% of all cerebrovascular malformations,¹ accounting for a significant proportion of intracranial arteriovenous malformations. Although their clinical manifestations can be heterogeneous, it is uncommon for them to present as parkinsonism or dementia, and even rarer as both.¹⁶ To our knowledge, this systematic review represents the first review analyzing this unique presentation of parkinsonism and dementia, aiming to deepen our understanding of its characteristics, treatment options, and clinical outcomes.

In our review, 40 patients with IDAVFs presented with both parkinsonism and dementia. As noted, these symptoms were frequently found with other clinical manifestations including motor deficits,^{23,30,33} altered mental status,^{15,30,32,38,48} seizures,³¹ cerebellar symptoms,²⁹ urinary incontinence,^{15,24,25,28,48} headaches,²⁵ hallucinations,²¹ ocular movement impairment,^{21,34} papilledema,³⁴ Horner syndrome, and scleral injection.⁵⁰ Similar to other IDAVFs, the coexistence of parkinsonism and dementia often presents alongside other symptoms, rather than as an isolated syndrome.^{1,99,100}

Diagnostic imaging studies, including computed tomography and magnetic resonance angiography, were used for initial identification of the IDAVFs, with the use of digital subtraction angiography for confirmation.¹⁰⁰ Similar to what has been reported in the literature regarding IDAVFs, the most frequent anatomic locations were the transverse and sigmoid sinuses,^{1,101}

regardless of this unique clinical presentation. Interestingly, although the tentorial location is typically associated with a more aggressive course,⁵ all tentorial IDAVFs in our study demonstrated favorable outcomes after treatment.^{29,32,36,37} In accordance with the Borden classification system,¹⁰² higher-grade IDAVFs, specifically types II and III, along with Cognard classification⁷ types II–V, have an aggressive progression with an increased risk of hemorrhage and intracranial hypertension. Of the 14 IDAVFs classified in these groups from our selected population, 11 patients experienced favorable clinical outcomes without any clinical deterioration.^{13,19,20,23,30,32,36,38,40,41} Hemorrhage was observed in 5 patients; only 2 of these were Borden type II IDAVFs, whereas the remaining 3 were unclassified.^{21,25,36,38,40}

Although asymptomatic IDAVFs are usually treated conservatively,¹⁰⁰ symptomatic cases representing high-grade IDAVFs are candidates for intervention. In summary, 77% of the treated patients experienced positive clinical outcomes, with most of them receiving endovascular therapy.¹⁰³ Of the 40 patients, surgery was performed in 3 cases,^{19,42,47} 33 were treated with endovascular therapy,^{13,15,20–23,25–40,47,48,50} and a combination of endovascular and surgical therapy was performed in 1 case.⁴¹

Although parkinsonism and dementia are rare presentations of IDAVFs, their timely identification is crucial given the potential reversibility after intervention. Many cases were initially diagnosed and managed as primary dementia or Parkinson disease, which might have delayed appropriate treatment and possibly impacted clinical outcomes. Recognizing these symptoms as potential indicators of IDAVFs can aid early diagnosis and prompt treatment, potentially modifying the natural history of this and improving patient outcomes. This study provides valuable insights into the underreported association between IDAVFs and both parkinsonism and dementia. Further research involving larger patient cohorts could offer a more comprehensive understanding of these correlations. This systematic review assists in addressing this knowledge gap by summarizing the available evidence.

Limitations

Although we think this study represents a valuable contribution to the literature, it comes with certain limitations. The observational nature of the systematic review inherently introduces potential bias considering the differences in follow-up, clinical workup, and interventions, which may come with confounders. Furthermore, the limited number of cases reporting the simultaneous presentation of parkinsonism and dementia restricts generalizability to the broader population. Additionally, some cases might not be published due to lack of novel findings or unfavorable outcomes, leading to a publication bias. Additionally, it is important to account for the potential effect of the learning curve effects and advancements in neurosurgical care over time.

CONCLUSIONS

IDAVF presenting with both parkinsonism and dementia is a rare presentation. Our comprehensive review was able to elicit information about the characteristics, clinical outcomes, and treatment modalities for these cases. Although our findings provide valuable

Table 2. Case Report Characteristics

Study	Gender/ Age (Years)	Parkinsonism Symptoms	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF	Arterial Feeders	Venous Outflow Patterns	CT Findings	MRI Finding	Borden Classification	ICH	Treatment	Outcome
Hirono et al., 1993 ³³	Male/76	Gait disturbance	Memory impairment and disorientation	Incontinence and hemiparesis	SSS and SiS	ECA and OA	Right cerebral veins	NE	Multiple T1 and T2 signal voids in right frontoparietal region and lateral ventricle	NE	No	Onyx TAE	CR
Touho et al., 1994 ³²	Male/58	Gait disturbance and involuntary movement	Broca aphasia and memory impairment	Headache and quadriplegia	StS and TS	Left VA	Inferior vermian vein, StS, Cv, SPS, SiS, and IJV	Low-density area in thalamus; deep veins appeared as high-density	NE	Type II	No	TAE	CR
Yoshimura et al., 1995 ³¹	Male/56	Gait disturbance and tremor	Memory impairment	Status epilepticus	Right TS and SiS	Right OA, APA, MMA, and VA	Sphenoparietal sinuses	NE	NE	NE	No	Onyx TAE	Died months later
Datta et al., 1998 ³⁰	Male/69	Unsteadiness of gait	Memory impairment and disorientation	NE	Sagittal sinus	ECA	Cv	Contrast CT showed prominent vascular markings over wide areas of the brain	Prominent vascularity and venous congestion	Type II	No	TAE and surgery	CR
Pierot et al., 1998 ⁴³	Male/68	Unsteadiness of gait	Impaired mental function	Urinary incontinence	SSS	ECA, VA, and posterior cerebral arteries	SSS and Cv	NE	Bilateral thalamic lesions in the supratentorial white matter and abnormal vessels in both hemispheres	NE	No	TAE	IR and died months later

MMSE, Mini-Mental State Examination; IDAVF, intracranial dural arteriovenous fistula; CT, computed tomography; MRI, magnetic resonance imaging; ICH, intracerebral hemorrhage; SSS, superior sagittal sinus; SiS, sigmoid sinus; ECA, external carotid artery; OA, occipital artery; NE, not specified; TAE, transarterial embolization; CR, complete recovery; StS, straight sinus; TS, transverse sinus; VA, vertebral artery; Cv, cortical veins; SPS, superior petrosal sinus; IJV, internal jugular vein; APA, ascending pharyngeal artery; MMA, middle meningeal artery; IR, incomplete recovery; NI, no improvement; CS, cavernous sinus; SAH, subarachnoid hemorrhage; TSS, transverse-sigmoid sinus; TVE, transvenous embolization; PMA, posterior meningeal artery; ICA, internal carotid artery; MR, magnetic resonance; LS, lateral sinus; DWI, diffusion-weighted imaging; NBCA, n-butyl cyanoacrylate; PCA, posterior cerebral artery; TH, torcular Herophili; VG, vein of Galen; DAVF, dural arteriovenous fistula; TCB, tentorium cerebelli; VR, vein of Rosenthal; FLAIR, fluid-attenuated inversion recovery; GP, globus pallidus; 3D, 3-dimensional; TOF, time-of-flight; MRA, magnetic resonance angiography; mb, meningeal branches; ICV, internal cerebral veins.

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Table 2. Continued

Study	Gender/ Age (Years)	Parkinsonism Symptoms	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF	Arterial Feeders	Venous Outflow Patterns	CT Findings	MRI Finding	Borden Classification	ICH	Treatment	Outcome
Matsuda et al., 1999 ¹⁵	Male/55	Gait disturbance, bradykinesia, and rigidity	Memory impairment	Headache	Right SiS	OA and MMA	NE	Nonenhanced CT showed hypodensity of subcortical white matter	T2-weighted scan showed bilateral high signal and deep and subcortical white matter	NE	No	TAE	CR
	Male/78	Gait disturbance and bradykinesia	Memory impairment and confusion	Generalized convulsion and urinary incontinence	Right SiS	OA and MMA	StS, SSS, and Cv	Contrast-enhanced CT showed enlarged vessels in the deep cerebral white matter	Gadolinium T1 showed 2 enlarged vessels in the deep cerebral white matter	NE	No	TAE	IR
	Female/ 69	Gait disturbance and bradykinesia	Progressive disorientation	Tinnitus, headache, and urinary incontinence	Left SiS	OA and MMA and VA	Left TS, SSS, and Cv	Nonenhanced CT showed diffuse low density in the subcortical white matter and enhanced CT showed multiple vermiform enlarged vessels in white matter	T2-weighted scan showed diffuse high signal intensity in the bilateral cerebral white matter	NE	No	TAE	NI
Tominaga et al., 2003 ²⁹	Male/71	Tremor	Confusion and cerebellar dysfunction	Nausea and vomiting	TSS	Left MMA, APA, and branches of the OA	Bilateral basal vein, CS, and Sylvian vein	Showed an SAH	NE	NE	Yes	TVE and surgery	CR
	Male/73	Tremor and bradykinesia	Cognitive impairment	NE	TSS	Branches of the left ECA and the left PMA	StS, right basal vein, vein of Labbé, and left occipital Cv	NE	T2-weighted MR images showed hyperintense lesions bilaterally in the thalamus	NE	No	TVE and surgery	CR
Belo et al., 2004 ²⁷	Male/70	Bradykinesia, tremor, and hypomimia	Disorientation, mood lability, and memory impairment	Incontinence and fatigue	Right TS	ECA	NE	Cerebral edema	NE	NE	No	Embolization	CR
Lee et al., 2004 ¹³	Female/ 60	Tremor, gait impairment and hypomimia	Impaired cognitive functions for recent memory and calculation (MMSE: 15)	NE	Left TSS	OA and MMA	Deep venous system and SSS	NE	T2-weighted scan showed dilated deep cerebral veins with slightly increased white matter signal intensity	Cognard type Illa + b	No	TAE	CR

Magot et al., 2004 ²⁸	Female/60	Gait disturbance	Apraxmatism and bradypsychia (MMSE: 19)	Urinary incontinence and dysesthesia in lower limbs	Centrum semiovale	VA, both ICAs, and right OA	SSS and right LS	Diffuse cerebral edema	T2-weighted scan showed dilated vascular structures in the right occipital region and DWI showed restricted diffusion of the white matter	NE	No	TAE and surgery	CR
	Female/58	Bradykinesia and tremor	Disorientation, memory impairment, and aphasia (MMSE: 3)	Pulsatile tinnitus	Left TS	ICA, ECA, and VA	Left TS	Dilation of Cv	Evidence of thrombosis of the TS	NE	No	TAE	CR
Ishihara et al., 2009 ²⁶	Female/75	Gait disturbance	Progressive disorientation	Vertigo	NE	Right accessory meningeal and APA	NE	NE	T2-weighted scan showed hyperintense signals in the right front temporal lobe T1-weighted scan demonstrated cortical enhancement	NE	No	TAE with NBCA	CR
Nogueira et al., 2009 ⁴¹	Male/79	Gait imbalance, postural instability, hypomimia, and tremor	Cognitive impairment	Tinnitus and vertigo	Left TS	OA, MMA, and branches of PCA and ICA	SSS and deep venous system	NE	T2-weighted scan showed numerous bilateral serpiginous flow voids in the posterior fossa and in the temporal and occipital lobes	Cognard type IIa + b	No	TAE with NBCA, coils, and surgery	CR
Netravathi et al., 2011 ²⁵	Male/54	Hypomimia, tremor, bradykinesia, and rigidity	Memory disturbance and confusion (MMSE: 27)	Headache and incontinence	TH	OA and meningeal arteries	StS, VG, cavernous sinus, and superior ophthalmic vein	Left thalamic hemorrhage	T2-weighted scan showed bilateral symmetrical thalamic and right basal ganglia white matter hyperintensities	NE	Yes	Onyx TAE	IR
	Male/40	Gait disturbance, tremor, hypomimia, and rigidity	Rapidly progressive memory impairment (MMSE: 21)	Urinary incontinence	SSS	ICA and MMA	Cv	Multiple hyperdense enhancing lesions in the gray and white matter with draining vessels suggestive of multiple DAVF	NE	NE	No	TVE and TAE	IR

MMSE, Mini-Mental State Examination; IDAVF, intracranial dural arteriovenous fistula; CT, computed tomography; MRI, magnetic resonance imaging; ICH, intracerebral hemorrhage; SSS, superior sagittal sinus; SiS, sigmoid sinus; ECA, external carotid artery; OA, occipital artery; NE, not specified; TAE, transarterial embolization; CR, complete recovery; StS, straight sinus; TS, transverse sinus; VA, vertebral artery; Cv, cortical veins; SPS, superior petrosal sinus; IJV, internal jugular vein; APA, ascending pharyngeal artery; MMA, middle meningeal artery; IR, incomplete recovery; NI, no improvement; CS, cavernous sinus; SAH, subarachnoid hemorrhage; TSS, transverse-sigmoid sinus; TVE, transvenous embolization; PMA, posterior meningeal artery; ICA, internal carotid artery; MR, magnetic resonance; LS, lateral sinus; DWI, diffusion-weighted imaging; NBCA, n-butyl cyanoacrylate; PCA, posterior cerebral artery; TH, torcular Herophili; VG, vein of Galen; DAVF, dural arteriovenous fistula; TCB, tentorium cerebelli; VR, vein of Rosenthal; FLAIR, fluid-attenuated inversion recovery; GP, globus pallidus; 3D, 3-dimensional; TOF, time-of-flight; MRA, magnetic resonance angiography; mb, meningeal branches; ICV, internal cerebral veins.

Continues

Table 2. Continued

Study	Gender/ Age (Years)	Parkinsonism Symptoms	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF	Arterial Feeders	Venous Outflow Patterns	CT Findings	MRI Finding	Borden Classification	ICH	Treatment	Outcome
Shahar et al., 2012 ³⁷	Male/59	Progressive freezing of gait, hypomimia, and rigidity	Memory deterioration and bradypsychia	Ptosis of the right eye, limitation in right and up-gaze	TCB	Right MMA and right occipital meningial artery	VG, VR, and internal cerebral veins	Noncontrast CT revealed hyperdense lesion with surrounding edema in right occipital lobe and hypodensity of lenticular nuclei bilaterally	FLAIR sequences showed a high signal in the GP bilaterally; no signs of proton restriction were demonstrated on diffusion coefficient sequences	NE	No	Onyx TAE	CR
Geraldes et al., 2012 ⁴⁰	Male/64	Gait disturbance, rigidity, and bradykinesia	Loss of speech, fluctuating attention, disorientation, anomia, and memory impairment (MMSE: 12)	Right hemiplegia	TH	Posterior OA and MMA	StS and deep venous system	Left capsulolenticular hematoma	Engorged cerebellar veins and basal ganglia hypersignal in T2-weighted scan without white matter involvement	Type II	Yes	TVE	IR
Hattori et al., 2013 ³⁹	Female/52	Gait disturbance, hypomimia, and hypophonia	Disorientation and mental slowness	Fatigue and urinary incontinence	TSS and 3 years later in the SSS	MMA, OA, and tentorial arteries	StS and Cv	Contrast-enhanced scan revealed multiple vermiform and enlarged Cv	Diffusion-weighted and T2-weighted scans revealed diffuse high intensity lesions in the deep white matter and basal ganglia	NE	No	Coil TVE and TAE	IR
Luo et al., 2014 ²⁴	Male/54	Bradykinesia, hypomimia, and gait disturbance	Memory impairment (MMSE: 14)	NE	Right TSS	Tentorial artery	StS and right TS	Nonenhanced CT scan showed curvilinear calcification in the corticomedullary junction at the bottom of the cerebral sulcus bilaterally	T2-weighted scan revealed flow void clusters at the inner part of the left temporal lobe; 3D TOF MRA showed flow-related enhancement of a DAVF	NE	No	No treatment	Did not receive treatment and lost follow-up
	Male/75	Gait disturbance, tremor, and bradykinesia	Cognitive impairment (MMSE: 8)	NE	Left TSS	NE	Left temporal Cv and StS	NE	T2-weighted scan showed a significantly dilated superficial vein on the left temporal cortex	NE	No	No treatment	Died before treatment because of seizures

Ma et al., 2015 ²²	Male/62	Rigidity and bradykinesia	Memory loss and behavioral abnormalities	NE	Left temporal region	Bilateral MMA and mb of the VA	SSS	NE	T2-weighted scan showed a flow void shadow of enlarged meningeal vessels in the left temporal lobe and a vermiform flow void shadow of vessels in the left temporal lobe	NE	No	TAE	CR
Fujii et al., 2014 ²³	Male/69	Tremor and festinating gait	Memory impairment, attention disturbance, and deficits in executive function (MMSE: 26)	NE	SSS	STA and OA	Cv	NE	T2-weighted scan revealed dilation of the medullary vein in the bilateral frontal and parietal lobes	Type II	No	TVE	CR
Gopinath et al., 2017 ³⁴	Female/45	Rigidity and bradykinesia	Apathy, impaired attention, and memory (MMSE: 18)	Bilateral papilledema and reduced abduction of both eyes	TH and SSS	ICA, ECA, MMA	NE	NE	Diffuse deep white matter and periventricular T2 and FLAIR hyperintensities bilaterally	NE	No	TAE	CR
Nakano et al., 2017 ²⁰	Male/63	Gait disturbance and bradykinesia	Memory impairment and disorientation	Pulsatile tinnitus, headache, and diplopia	TSS and TH	NE	StS and VG	NE	Low T1 signals in the bilateral basal ganglia with marked hyperintensity on a series of T2-weighted, FLAIR, and diffusion-weighted scans	Type III	No	TVE	IR

MMSE, Mini-Mental State Examination; IDAVF, intracranial dural arteriovenous fistula; CT, computed tomography; MRI, magnetic resonance imaging; ICH, intracerebral hemorrhage; SSS, superior sagittal sinus; StS, sigmoid sinus; ECA, external carotid artery; OA, occipital artery; NE, not specified; TAE, transarterial embolization; CR, complete recovery; StS, straight sinus; TS, transverse sinus; VA, vertebral artery; Cv, cortical veins; SPS, superior petrosal sinus; IJV, internal jugular vein; APA, ascending pharyngeal artery; MMA, middle meningeal artery; IR, incomplete recovery; NI, no improvement; CS, cavernous sinus; SAH, subarachnoid hemorrhage; TSS, transverse-sigmoid sinus; TVE, transvenous embolization; PMA, posterior meningeal artery; ICA, internal carotid artery; MR, magnetic resonance; LS, lateral sinus; DWI, diffusion-weighted imaging; NBCA, n-butyl cyanoacrylate; PCA, posterior cerebral artery; TH, torcular Herophili; VG, vein of Galen; DAVF, dural arteriovenous fistula; TCB, tentorium cerebelli; VR, vein of Rosenthal; FLAIR, fluid-attenuated inversion recovery; GP, globus pallidus; 3D, 3-dimensional; TOF, time-of-flight; MRA, magnetic resonance angiography; mb, meningeal branches; ICV, internal cerebral veins.

Continues

Table 2. Continued

Study	Gender/ Age (Years)	Parkinsonism Symptoms	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF	Arterial Feeders	Venous Outflow Patterns	CT Findings	MRI Finding	Borden Classification	ICH	Treatment	Outcome
Lai et al., 2017 ²¹	Male/62	Bradykinesia, symmetrical cogwheeling rigidity, fine tremor of the hands and a narrow-based shuffling gait	Rapid decline with disorientation, visual hallucinations, and poor short-term memory	Hallucinations and headache	SSS, TSS, and torcula	Bilateral OA, MMA, and tentorial arterial branches	StS, VG, pterygoid plexus, and SSS	Right anterior temporal intraparenchymal hematoma with intraventricular extension and abnormal dilated veins	FLAIR showed diffuse hyperintensity in the cerebral hemispheric white matter	NE	Yes	Onyx and coli TVE	CR
	Female/ 65	Tremors, hypomimia, and a shuffling gait with postural instability, bradykinesia, and rigidity	Subacute functional decline and cognitive slowing	Pulsatile tinnitus, headache, visual and auditory hallucinations, and myoclonus	Right TSS	NE	Deep venous system	NE	FLAIR showed diffuse hyperintensity in the cerebral and cerebellar white matter	NE	No	Coil embolization	CR
Wiblin et al., 2019 ⁴⁴	Female/ 78	Bradykinesia, rigidity, tremor, short-stepping and stooped gait, hypomimia, and mild hypophonia	Emotional lability, apathy, memory impairment, and cognitive changes	Double incontinence	Right basal ganglia (putamen) and posterior cerebellum	OA	StS, ICV, and basal VR	Hyperdensity area over the left parieto-occipital cortex	T2-weighted scan showed flow voids in the posterior cerebrum with high signal in right putamen	NE	No	TAE	IR
Chen et al., 2020 ⁴⁶	Male/68	Gait with mild bilateral truncal swaying and short strides when walking	Progressive memory impairment	NE	VG	ICA	NE	NE	FLAIR T2 showed a bilateral asymmetrical thalamic hyperintensity and T1-weighted showed patchy enhancement associated with venous congestion	NE	No	Surgery	IR
Hall et al., 2020 ⁴⁵	Male/79	Gait impairment, rigidity, and hypophonia	Confusion and memory impairment	Upgaze limitation	TH	OA and MMA	StS	NE	T2-weighted demonstrated bilateral thalamic edema; FLAIR image showed hyperintensity in the thalamus, midbrain, and tectal plate	Type II	No	Onyx TAE	IR

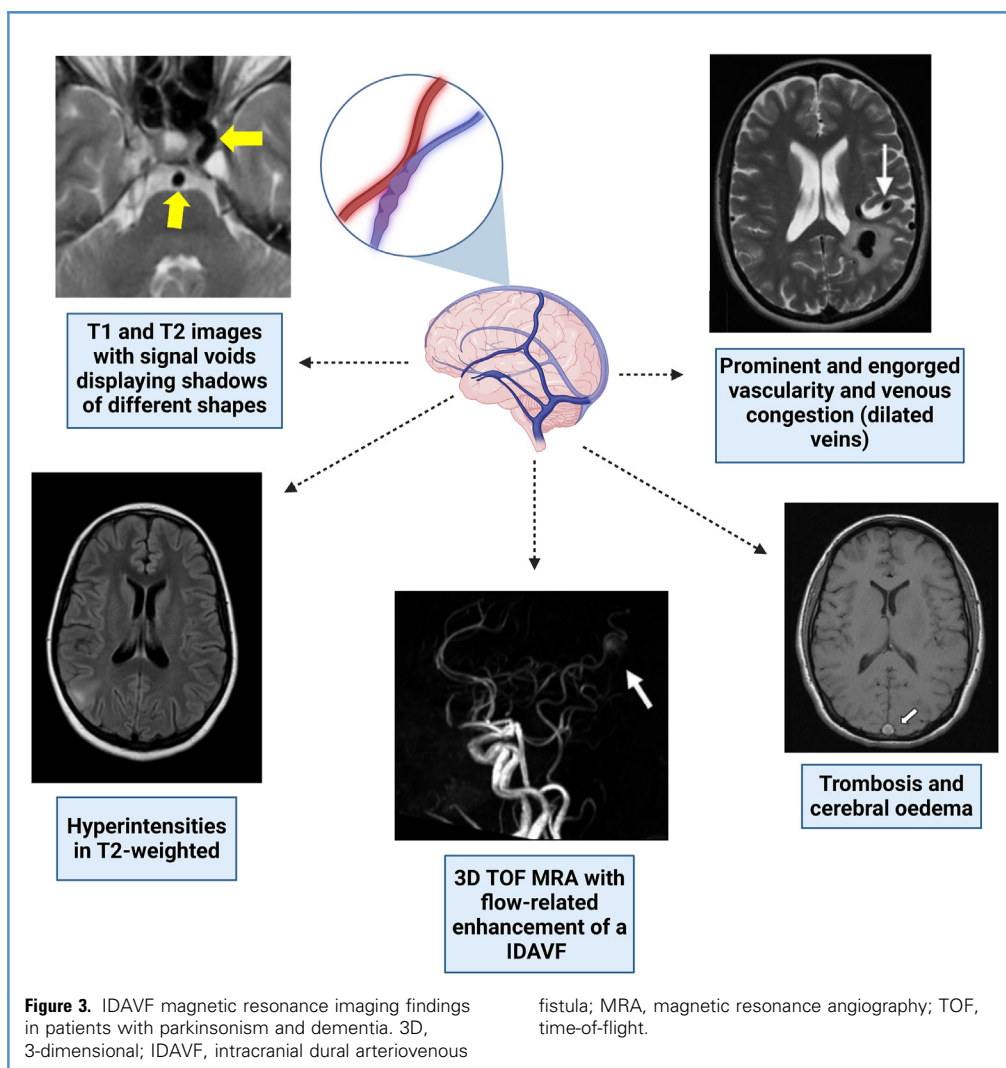
Cascio Rizzo et al., 2021 ³⁸	Male/61	Hypomimia and mild parkinsonism (mild rigidity of the left arm, reduced bilateral arm swing during gait, and global mild bradykinesia)	Excessive daytime sleepiness, partial disorientation in time and space, and short- and long-term memory impairment, and behavioral changes (MMSE: 15/30)	NE	TH	Right OA and VA	VG, VR, and cerebral veins	NE	FLAIR and T2-weighted scan showed bilateral, symmetrical thalamic hyperintensities T1-weighted scan showed hypointensities in the same regions with a subtle and patchy gadolinium enhancement	Type II	Yes	TAE	NI
Velz et al., 2020 ¹⁹	Male/57	Bradykinesia, gait impairment hypophonia, and hypomimia	Disorientation, altered mental status, and impaired executive function	NE	StS	Tentorial dural arteries	StS into the median tentorial sinus, supraculminar vein, superior vermian vein, and system of the VG	NE	Partial thrombosis of the StS with diffuse edema of both thalami, the internal capsule, the hippocampi, the pallidum, the base of the mesencephalon, and dilated deep cerebral veins	Type III	No	Surgery	CR
Prosperini et al., 2022 ³⁵	Male/84	Resting and kinetic tremor, bradykinesia, and gait disturbances	Attention and verbal fluency impairment, disorientation, and mental state alteration (MMSE: 15)	NE	Left TS	OA	Supratentorial venous drainage	NE	T1-weighted scan showed subtentorial hyperintense oval area with alterations in venous drainage FLAIR scan showed bilateral and symmetrical hyperintensity in the white matter of both cerebral hemispheres	NE	No	Onyx TAE	CR
Tominaga et al., 2022 ³⁶	Female/87	Rigidity, bradykinesia, tremor, and gait disturbance	Disturbance of consciousness and memory	Depression	TCB	Left OA and MMA	SPS and left petrosal vein	Diffuse low-density areas in the brainstem and left cerebellar peduncle	FLAIR scan showed hyperintensity areas in the brainstem, the left cerebellar peduncle, and a spotty area in the left basal ganglia	Type III	No	icvOnyx TAE	CR

MMSE, Mini-Mental State Examination; IDAVF, intracranial dural arteriovenous fistula; CT, computed tomography; MRI, magnetic resonance imaging; ICH, intracerebral hemorrhage; SSS, superior sagittal sinus; StS, sigmoid sinus; ECA, external carotid artery; OA, occipital artery; NE, not specified; TAE, transarterial embolization; CR, complete recovery; StS, straight sinus; TS, transverse sinus; VA, vertebral artery; Cv, cortical veins; SPS, superior petrosal sinus; IJV, internal jugular vein; APA, ascending pharyngeal artery; MMA, middle meningeal artery; IR, incomplete recovery; NI, no improvement; CS, cavernous sinus; SAH, subarachnoid hemorrhage; TSS, transverse-sigmoid sinus; TVE, transvenous embolization; PMA, posterior meningeal artery; ICA, internal carotid artery; MR, magnetic resonance; LS, lateral sinus; DWI, diffusion-weighted imaging; NBCA, n-butyl cyanoacrylate; PCA, posterior cerebral artery; TH, torcular Herophili; VG, vein of Galen; DAVF, dural arteriovenous fistula; TCB, tentorium cerebelli; VR, vein of Rosenthal; FLAIR, fluid-attenuated inversion recovery; GP, globus pallidus; 3D, 3-dimensional; TOF, time-of-flight; MRA, magnetic resonance angiography; mb, meningeal branches; ICV, internal cerebral veins.

Table 3. Case Series Characteristics

Study	Type of Study	Period	Number of Patients (Included Patients)	Average Age	Gender/ Age (Years)	Location of IDAVF	Parkinsonism Symptoms	Dementia Symptoms (MMSE)	CT Findings	MRI Findings	Borden Classification	Treatment	Outcome
Lazar et al., 2022 ⁴⁹	Case-control study	2014–2021	104 (1)	64.6 (range, 44.6–76.4)	Male/70	NE	Gait instability that progressed to akinetic mutism	Rapidly progressive dementia and psychosis	NE	NE	NE	NE	Alive, NE extent of recovery
Fearon et al., 2022 ⁵⁰	Case series	NE	7 (1)	NE	Male/64	Left SiS and TS; IDAVF, supplied by branches of VA, ECA, and tentorial branches of ICA	Bradykinesia, postural instability, and hypomimia	Progressive cognitive decline and personality change	NE	Contrast-enhanced T1-weighted scan showing enhancement of engorged vessels T2-weighted scan showing small flow voids anterior to the brainstem and in the right temporal lobe	NE	Embolization and ligation of the IDAVF	CR
Dehdashti et al., 2010 ⁴⁷	Case series	1984–2008	8 (4)	62 (range, 48–86)	Female/64	StS and torcula	Gait instability and tremor	Cognitive decline and psychotic features (MMSE: 10)	NE	MRI without gadolinium revealed engorged cortical veins. T2-weighted scan did not show hyperintensities	Type II	TAE	IR
					Female/62	Jugular foramen and SSS	Gait instability	Cognitive decline, personality change, and episodes of confusion (MMSE: 16)	NE		Type II	TAE	IR
					Female/52	TS	Gait instability	Cognitive decline, personality change, and memory impairment (MMSE: 12)	NE		Type II	Surgical management	IR
					Male/72	SSS	Generalized weakness and tremor	Cognitive decline, personality change, and memory loss (MMSE: 12)	NE	Type II	TAE	IR	
Colorado et al., 2018 ⁴⁸	Case series	2012–2015	4 (2)	51.6	Female/62	StS	Gait instability, tremor, severe lead pipe rigidity, and bradykinesia with impaired balance	Subacute cognitive decline	Head CT showed a new thalamic hemorrhage	T2-weighted scan demonstrated bithalamic and right dorsal midbrain hyperintensity	NE	Onyx embolization	IR
					Male/51	VG and StS	Rigidity, bradykinesia, and gait disturbance	Subacute cognitive decline, memory impairment, and disorientation	NE	T2-weighted scan demonstrated bithalamic, right dorsal midbrain, and pons hyperintensity	NE	Onyx and NBCA embolization	NE

IDAVF, intracranial dural arteriovenous fistula; MMSE, Mini-Mental State Examination; CT, computed tomography; MRI, magnetic resonance imaging; NE, not specified; SiS, sigmoid sinus; TS, transverse sinus; VA, vertebral artery; ECA, external carotid artery; ICA, internal carotid artery; CR, complete recovery; StS, straight sinus; TAE, transarterial embolization; IR, incomplete recovery; SSS, superior sagittal sinus; VG, vein of Galen; NBCA, n-butyl cyanoacrylate.



insights, more extensive studies are warranted to better understand the underlying mechanisms and to establish standardized therapeutic guidelines. Understanding these nuances is vital for optimizing patient care and improving prognosis.

CRedit AUTHORSHIP CONTRIBUTION STATEMENT

Pavel S. Pichardo-Rojas: Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Luis A. Marín-Castañeda:** Writing – review &

editing, Writing – original draft, Methodology, Investigation. **Fernando De Nigris Vasconcellos:** Writing – original draft. **Shadia I. Flores-López:** Methodology, Investigation. **Adrian Coria-Medrano:** Writing – original draft, Data curation. **Perla de Teresa López-Zepeda:** Methodology. **Claudia D. Sánchez-Serrano:** Data curation. **Mario C. Torres-Chávez:** Writing – original draft. **Jesús M. Escobar-López:** Data curation. **Luz C. Choque-Ayala:** Data curation. **Gorbachev Jowah:** Data curation. **Leonardo Rangel-Castilla:** Writing – review & editing, Writing – original draft.

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SUPPLEMENTARY DATA

Supplementary Table 1. Additional Studies Presenting with Isolated Parkinsonism or Dementia

Parkinsonism							
Study	Gender/ Age (Years)	Parkinsonism Symptoms (MDS-UPDRS)	Additional Clinical Findings	Location of IDAVF (Borden Classification)	Arterial Feeders	Venous Outflow Patterns	Outcome
Kawasaki et al., 2022 ¹⁴	Male/67	Bradykinesia, rigidity, short-stepping and freezing gait, hypomimia and hypophonia (MDS-UPDRS: 48)	NE	TS and SiS	OA and APA	StS and VG	IR (MDS-UPDRS: 19)
Chang et al., 2019 ⁵¹	Male/57	Hypomimia, left forearm showed bradykinesia and rigidity	Tinnitus and lethargy	TS	NE	StS, right TS, and Cv	CR
Pu et al., 2017 ⁵²	Male/51	Bradykinesia, rigidity, hypokinesia, hypomimia, and hypophonia	NE	StS and posterior fossa (Cognard type IIa + b)	PMA, MHT, and left ICA	VG, VR, and ICV	CR
Kawasaki et al., 2022 ¹⁴	Male/67	Bradykinesia, rigidity, hypomimia, hypophonia, and postural instability	NE	TSS	Right OA	StS and VG	IR
Kim et al., 2015 ⁵³	Male/59	Gait disturbance and rigidity	Vertical nystagmus, hemiparesis, and diplopia	TH	MMA and OA	Cv and VR	CR
Dementia							
Study	Gender/ Age (Years)	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF (Borden Classification)	Arterial Feeders	Venous Outflow Patterns	Outcome
Ferrazzoli et al., 2023 ⁵⁴	Male/64	Acute confusion, progressive dementia, and behavioral change	Motor perseverance, verbal reiteration, and disorientation	SPS (Cognard type III)	Petrous branch MMA, inferolateral mb, and MHT	Basal VR, right superior and inferior PS, and right CS	Death
Khan et al., 2022 ⁵⁵	Male/45	Attention impairment and memory deficit (MoCa: 3)	NE	StS	NE	NE	NE
Dargazanli et al., 2022 ⁵⁶	Male/39	Cognitive impairment with apathy, aphasia, and attention	NE	Falcotentorial	Falx cerebelli arteries	Superior vermian vein and VG	IR: persistence of aphasia
Liu et al., 2022 ⁴²	Male/52	Memory impairment, aphasia, and slow response (MMSE: 13)	NE	TCB (Borden II)	MMA	Basilar vein	CR
Méndez-Gallardo et al., 2022 ⁵⁷	Male/43	Inappropriate behavior, inattention, amnesia, aphasia, and disorientation	Headache and hemiparesis	NE	MMA	VG	CR
Zhang et al., 2021 ⁵⁹	Male/53	Memory decline, abnormal behavior, and personality changes (MMSE: 20)	NE	TCB (Cognard type IIa+b)	MMA	VG	IR

IDAVF, intracranial dural arteriovenous fistula; NE, not specified; TS, transverse sinus; SiS, sigmoid sinus; OA, occipital artery; APA, ascending pharyngeal artery; StS, straight sinus; VG, vein of Galen; TSS, transverse-sigmoid sinus; IR, incomplete recovery; Cv, cortical veins; CR, complete recovery; PMA, posterior meningeal artery; MHT, meningohypophyseal trunk; ICA, internal carotid artery; VR, vein of Rosenthal; ICV, internal cerebral veins; TH, torcular Herophili; MMA, middle meningeal artery; MMSE, Mini-Mental State Examination; SPS, superior petrosal sinus; mb, meningeal branches; PS, petrous or petrosal sinus; TCB, tentorium cerebelli; ECA, external carotid artery; VA, vertebral artery; SSS, superior sagittal sinus; LS, lateral sinus; CSF, spontaneous cerebrospinal fluid; ACF, anterior cranial fossa; AMI, acute myocardial infarction; NI, no improvement; STA, superficial temporal artery; MDS-UPDRS, Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale; MoCa, montreal cognitive assessment; CS, Cavernous Sinus.

Continues

Supplementary Table 1. Continued

Dementia							
Study	Gender/ Age (Years)	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF (Borden Classification)	Arterial Feeders	Venous Outflow Patterns	Outcome
Chee et al., 2020 ⁶⁰	Female/38	Progressive amnesia, language difficulties, and confusion (MMSE: 14)	Visual deterioration and headache	TS (Borden III)	ECA and OA	Cv	Died due to cardiac arrest
Iamprechakul et al., 2020 ⁶¹	Male/52	Apathy, disorientation, and memory impairment	NE	Multiple IDAVF in StS and SSS (Cognard type II a+b)	OA	StS and VG	CR
Brito et al., 2019 ⁶²	Male/79	Rapidly progressive dementia	Weakness	SSS and TS	ECA	StS	CR
	Male/77	Rapidly progressive dementia	NE	SSS	MMA and OA	Superficial middle cerebral vein	CR
	Male/75	Memory impairment and disorientation	NE	SSS	NE	Cv	CR
	Male/51	Cognitive deficit, memory impairment, and disorientation	Incontinence	Tentorial incisura	OA	Posterior communicating vein and VR	CR
	Male/61	Dementia and behavioral disturbance	NE	SSS and TSS	ECA and VA	NE	IR
	Male/71	Memory impairment and disorientation	NE	TS	MMA, OA, and VA	NE	CR
Kumonda et al., 2018 ⁶³	Male/69	Memory impairment, apathy, and disorientation	NE	Tentorial artery	NE	NE	CR
Tetsuo et al., 2018 ⁶⁴	Female/76	Disturbance of consciousness and memory impairment	NE	TSS	NE	StS and SSS	NE
Matsuzaki et al., 2017 ⁶⁵	Female/71	Cognitive impairment, aphasia, and memory disturbance	Tinnitus	TSS (Cognard type IIb)	NE	SSS	CR
Enofe et al., 2017 ⁶⁶	Female/82	Memory deficit and visuospatial abnormalities (MMSE: 21)	Generalized unprovoked seizures	NE	ECA and VA	TH, SSS, and TSS	IR
Hwang et al., 2017 ⁶⁷	Male/43	Inattention and episodic memory loss (MMSE: 27)	NE	LS and TSS	OA and MMA	NE	IR
Holekamp et al., 2016 ⁶⁸	Male/53	Memory impairment, attention deficit, associative prosopagnosia, and emotional lability (MMSE: 24)	NE	VG and StS (Borden-Shucart 2S)	MMA and ICA	StS and vermian vein	CR
	Male/59	Long-term memory deficits, verbal fluency impairment, and associative confabulation	NE	Tentorial artery (Borden-Shucart 3S)	OA and MMA	Vermian vein	IR
	Male/60	Worsening confusion and memory deficits	NE	TH (Borden-Shucart 3S)	OA	Vermian vein	CR
	Male/71	Memory impairment, attention deficit, and confusion	Weakness and numbness	TH (Borden-Shucart 3S)	OA and MMA	Vermian vein	IR
Watanabe et al., 2016 ⁶⁹	Male/59	Progressive dementia	NE	SSS	OA and STA	Cv	CR
Higashida et al., 2015 ⁷⁰	Male/64	Cognitive impairment and disorientation	Pulsatile tinnitus, CSF otorrhoea, and generalized seizure	TSS	ECA	NE	IR

Continues

Supplementary Table 1. Continued

Dementia							
Study	Gender/ Age (Years)	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF (Borden Classification)	Arterial Feeders	Venous Outflow Patterns	Outcome
Takada et al., 2015 ⁷¹	Male/64	Progressive dementia (MMSE: 13)	NE	TH (Borden type II)	MMA	Cv	IR (MMSE: 23)
Imazeki et al., 2015 ⁷²	Male/72	Rapid progressive memory disturbance (MMSE: 6)	Generalized seizure	SSS	STA and MMA	NE	CR (MMSE: 23)
Randall et al., 2015 ⁷³	Female/ 67	Cognitive decline and visual hallucinations	Anxiety and depression	Tentorium (Cognard type III)	OA and MMA	Cv and SSS	IR
Huded et al., 2014 ⁷⁴	Male/35	Behavioral abnormality and anterograde memory impairment (MMSE: 15)	Partial seizure and sensory impairment	VG	MMA, OA, and posterior cerebral arteries	StS	CR (MMSE 30)
Pasi et al., 2014 ⁷⁵	Male/71	Memory disturbance, confusion, and disorientation (MMSE: 18)	NE	TS and SSS (Cognard type IIa + b/Cognard type IIa)	MMA and OA	NE	IR (MMSE: 28)
Yoshihara et al., 2014 ⁷⁶	Female/ 73	Disorientation and memory disturbance (MMSE: 1)	Tinnitus, headache, nausea, and anorexia	TSS	OA, MMA, and APA	SiS	IR (MMSE: 24)
Abe et al., 2014 ⁷⁷	Male/67	Rapidly progressive dementia	Headache	SSS	MMA and STA	Cv	CR (MMSE: 30)
Morparia et al., 2012 ⁷⁸	Male/71	Memory impairment, inattention, and hypersomnolence	NE	Tentorium	OA, MMA, and ECA	Deep venous system and VR	IR
Henderson et al., 2012 ⁷⁹	Female/ 53	Dysarthria, memory disturbance, and derangements in taste sensation	NE	Temporal and sphenoid arteries	Ophthalmic artery	Sphenoparietal sinus and Cv	IR
	Male/72	Altered mental status	Visual disturbances and dizziness	SSS	STA and MMA	NE	CR
Mendonça et al., 2012 ⁸⁰	Female/ 70	Amnesia, language deficit, and incoherent speech (MMSE: 15)	Flaccid tetraparesis	SSS, TH, and TS (Borden type II)	MMA and OA	Cv and deep venous system	IR (MMSE: 17)
Nakahara et al., 2011 ⁸¹	Female/ 76	Memory impairment and disorientation (MMSE: 16)	Urinary incontinence	TSS	ICA and ECA	NE	CR
Sugrue et al., 2009 ⁸²	Male/51	Memory loss and disorientation	NE	SSS	MMA, ICA, and VA	StS, VG, and ICV	IR
Lv et al., 2008 ⁸³	Male/65	Chronic dementia	Generalized seizure	ACF	Ophthalmic arteries	SSS	CR
Gonçalves et al., 2008 ⁸⁴	Male/43	Apathy and memory deficit	NE	Tentorium (Borden II/Cognard type IIa+IIb)	ECA, ICA, and OA	Cv, ICV, VG, and StS	CR
Pekçevik et al., 2008 ⁸⁵	Female/ 72	Cognitive dysfunction	Headaches and hemiparesis	SSS	ECA and OA	Cv, SSS, CS, and deep venous system	IR
Racine et al., 2008 ⁸⁶	Male/51	Confusion, slurred speech, and memory impairment (MMSE: 11)	Anxiety, depression, and headache	Posterior fossa	NE	NE	IR (MMSE: 27)

IDAVF, intracranial dural arteriovenous fistula; NE, not specified; TS, transverse sinus; SiS, sigmoid sinus; OA, occipital artery; APA, ascending pharyngeal artery; StS, straight sinus; VG, vein of Galen; TSS, transverse-sigmoid sinus; IR, incomplete recovery; Cv, cortical veins; CR, complete recovery; PMA, posterior meningeal artery; MHT, meningohypophyseal trunk; ICA, internal carotid artery; VR, vein of Rosenthal; ICV, internal cerebral veins; TH, torcular Herophili; MMA, middle meningeal artery; MMSE, Mini-Mental State Examination; SPS, superior petrosal sinus; mb, meningeal branches; PS, petrous or petrosal sinus; TCB, tentorium cerebelli; ECA, external carotid artery; VA, vertebral artery; SSS, superior sagittal sinus; LS, lateral sinus; CSF, spontaneous cerebrospinal fluid; ACF, anterior cranial fossa; AMI, acute myocardial infarction; NI, no improvement; STA, superficial temporal artery; MDS-UPDRS, Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale; MoCa, montreal cognitive assessment; CS, Cavernous Sinus.

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Supplementary Table 1. Continued

Dementia							
Study	Gender/ Age (Years)	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF (Borden Classification)	Arterial Feeders	Venous Outflow Patterns	Outcome
Waragai et al., 2006 ⁸⁷	Male/58	Disorientation, memory, and judgment impairment (MMSA: 12)	NE	SiS and SSS	OA and ECA	Sagittal sinus and StS	IR (MMSE: 21)
	Male/48	Memory impairment, disorientation, and mental slowness	NE	TSS	OA	SSS and StS	CR
Chan et al., 2006 ⁸⁸	Male/77	Memory impairment and disorientation (MSSE: 0)	Incontinence	TSS	OA and MMA	Vein of Labbe	IR (MMSE: 5)
Festa et al., 2004 ⁸⁹	Female/80	Wernicke aphasia, short-term memory loss, apraxia, and confusion (MSSE: 22)	Generalized seizure	SiS	OA and MMA	Cv	IR (MMSE: 27)
Abrahams et al., 2002 ⁹⁰	Male/77	Rapidly progressive dementia	NE	ACF	Ethmoidal branches of the ophthalmic arteries bilaterally	SSS and pial veins of the anterior frontal lobe	Died due to AMI
	Male/64	Loss of consciousness	NE	ACF	Ethmoidal branches of the ophthalmic arteries bilaterally	SSS and pial veins of the anterior frontal lobe	IR
Yamakami et al., 2001 ⁹¹	Male/55	Dementia	Urinary incontinence, drowsiness	TSS and torcula junction	NE	StS and temporo-parieto-occipital area	CR
	Female/63	Progressive dementia and rapid deterioration in conscious state	Coma and seizures	Left transverse-sigmoid junction	Left OA	StS	IR
Greenough et al., 1999 ⁹²	Male/62	Confusion	Nausea, diaphoresis, mute, inability to form new memories, docile, and aboulia	Posterior fossa	NE	Vein of Galen and ICV	IR
Hurst et al., 1998 ⁹³	Male/54	Progressive confusion, disorientation, generalized dementia, and widespread cerebral dysfunction	Headache, aphasia, and facial palsy	Left TSS	Left ECA (OA, APA, and MMA), left ICA (MHT), and VA (mb)	SSS, StS, and Cv	IR
	Male/64	Confusion, memory loss, and cognitive deterioration	Headache and progressive left hemiparesis	Right TSS	Right ECA (OA and APA)	SSS and StS	IR
	Male/70	Progressive mental status deterioration and memory loss	Headache, unresponsiveness, and bedridden	Right TSS	Basilar ECA (OA and APA), ICA and VA	Retrograde into right TSS, SSS and StS	Death
	Male/65	Progressive confusion, memory loss, and multifocal or generalized cerebral dysfunction	Headache, bruit, unresponsiveness, bedridden, and anomia	Right TSS	Right ECA (OA and APA), ICA and VA	SSS and StS	IR
	Male/77	Confusion and memory loss	Headache	Anterior fossa	ECA and ICA (ophthalmic)	Cv and SSS	CR
Nakai et al., 1997 ⁹⁴	Female/70	Aphasia and memory impairment	Pulsatile tinnitus and seizure	TSS	NE	Cv	CR

Continues

Supplementary Table 1. Continued

Dementia							
Study	Gender/ Age (Years)	Dementia Symptoms (MMSE)	Additional Clinical Findings	Location of IDAVF (Borden Classification)	Arterial Feeders	Venous Outflow Patterns	Outcome
Olteanu-Nerbe et al., 1997 ⁹⁵	Female/ 49	Dementia	Pulsatile tinnitus and bruit	TS (Cognard type IIa)	ECA and ICA	TS and SSS	IR
	Male/68	Dementia	Pulsatile tinnitus and bruit	TS (Cognard type III)	ECA	TS and Cv	NI
	Male/17	Dementia	Pulsatile tinnitus and bruit	TS (Cognard type IIa)	ECA, ICA, and VA	TS, SSS, and occipital sinus	CR
Ito et al., 1995 ⁹⁶	Man/49	Memory disturbance, decreased mental activity, and thalamic dementia	Ataxic gait	StS	OA and VA	SiS, SSS, and VR	CR
Zeidman et al., 1995 ⁹⁷	Male/55	Global aphasia, dysarthria, and disorientation	Headache and seizures	APA and jugular bulb	NE	TSS, SSS, and StS	NI
	Male/56	Memory loss and transient disorientation	Emotional lability, pulsatile tinnitus, and headache	ICA, ECA, OA, and STA	ECA	TSS and sagittal sinus	CR
Ishii et al., 1987 ⁹⁸	Female/ 75	Progressive dementia	Seizures and right hemiparesis	TS and SiS	OA and MMA	SSS, CV, Sylvian veins, and CS	Death
	Female/ 62	Progressive dementia	Tinnitus, headache, and vomiting	TS and TH	OA, MMA, VA, and ICA	SSS, StS, Cv, and basal vein	CR

IDAVF, intracranial dural arteriovenous fistula; NE, not specified; TS, transverse sinus; SiS, sigmoid sinus; OA, occipital artery; APA, ascending pharyngeal artery; StS, straight sinus; VG, vein of Galen; TSS, transverse-sigmoid sinus; IR, incomplete recovery; Cv, cortical veins; CR, complete recovery; PMA, posterior meningeal artery; MHT, meningohypophyseal trunk; ICA, internal carotid artery; VR, vein of Rosenthal; ICV, internal cerebral veins; TH, torcular Herophili; MMA, middle meningeal artery; MMSE, Mini-Mental State Examination; SPS, superior petrosal sinus; mb, meningeal branches; PS, petrous or petrosal sinus; TCB, tentorium cerebelli; ECA, external carotid artery; VA, vertebral artery; SSS, superior sagittal sinus; LS, lateral sinus; CSF, spontaneous cerebrospinal fluid; ACF, anterior cranial fossa; AMI, acute myocardial infarction; NI, no improvement; STA, superficial temporal artery; MDS-UPDRS, Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale; MoCa, montreal cognitive assessment; CS, Cavernous Sinus.

SUPPLEMENTARY APPENDIX 1. SEARCH STRATEGY

PubMed

((("arteriovenous fistula"[MeSH Terms] OR ("arteriovenous"[All Fields] AND "fistula"[All Fields]) OR "arteriovenous fistula"[All Fields]) AND "dural"[All Fields]) OR ("dural arteriovenous fistula"[All Fields] OR "DAVF"[All Fields] OR ("central nervous system vascular malformations"[MeSH Terms] OR ("central"[All Fields] AND "nervous"[All Fields] AND "system"[All Fields] AND "vascular"[All Fields] AND "malformations"[All Fields]) OR "central nervous system vascular malformations"[All Fields] OR ("dural"[All Fields] AND "arteriovenous"[All Fields] AND "fistula"[All Fields]) OR "dural arteriovenous fistula"[All Fields]))) AND ("dementia"[MeSH Terms] OR "dementia"[All Fields] OR

"dementias"[All Fields] OR "dementia s"[All Fields] OR ("parkinson disease"[MeSH Terms] OR ("parkinson"[All Fields] AND "disease"[All Fields]) OR "parkinson disease"[All Fields] OR "parkinsons"[All Fields] OR "parkinson"[All Fields] OR "parkinson s"[All Fields] OR "parkinsonian disorders"[MeSH Terms] OR ("parkinsonian"[All Fields] AND "disorders"[All Fields]) OR "parkinsonian disorders"[All Fields] OR "parkinsonism"[All Fields] OR "parkinsonisms"[All Fields] OR "parkinsons s"[All Fields])).

Embase, Embase Classic, MEDLINE, Preprints

('dural arteriovenous fistula'/exp OR 'dural arteriovenous fistula' OR davf OR dural) AND arteriovenous AND ('fistula'/exp OR fistula) AND (parkinson OR dementia).