



Original Article

The Top-100 most cited articles on dural arteriovenous fistula: A bibliometric analysis

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Objective: Dural arteriovenous fistula (DAVF) is a rare pathological vascular lesion with variable clinical manifestations. Since 1968, several articles have been published to address spinal and cranial DAVFs. The aim of this study is to identify, analyse, and review the pertinent literature of the top-100 most cited articles on DAVFs published to date.

Methods: A title-specific, keyword-based search with no time restriction was performed in June 2020. The Scopus database was used to identify the top-100 most cited articles on DAVFs. The term “dural arteriovenous fistula” was used as a search keyword. The search results were arranged in descending order based on the total citation count. The top-100 articles were categorized into ten categories.

Results: Between 1968 and 2020, a total of 2298 articles were published on DAVFs. The top-100 most cited articles were published between 1983 and 2012. The total number of citations for the top-100 articles was 12393 (123 citations/article). Most articles (34%) were investigating the clinical aspect of DAVFs. The country contributing to the most impactful and highest volume of publications (46%) was the United States. The Mayo Clinic was the most active institute in contribution. Most articles (29%) were published by the *Journal of Neurosurgery*.

Conclusions: In the top-100 most cited articles on DAVF, most studies were published in neurosurgery/neuroradiology-dedicated journals. This bibliometric analysis identifies the publication trends and provides a comprehensive overview of the most influential articles addressing DAVFs.

Keywords Dural arteriovenous fistula, Bibliometric, Citation analysis

INTRODUCTION

In 1881, Rizzoli reported the first cranial dural arteriovenous fistula (DAVF), defined as an abnormal shunting between the meningeal arteries and dural venous sinuses, meningeal vein, or subarachnoid veins.⁹⁾⁽¹¹⁾

Etiopathological historical overviews have postulated the origin of this abnormality as congenital or acquired in adults with the association of cerebrovascular diseases in some patients. Afterwards, the pathophysiological understanding of the entity was highlighting the role of cortical venous drainage and its implication on DAVF natural history.⁹⁾ Epidemiologically, the reported rate of cranial DAVFs in Japan was 0.29/100,000 per year whereas a study in Minnesota reported an incidence of 0.15/100,000 per year.⁷⁾ A DAVF represents 10-15% of all detected intracranial arteriovenous malformations (AVMs).⁷⁾ The incidence of the intracranial location of DAVF is reported in the literature as the following: transverse sinus (50%), cavernous sinus (16%), tentorium cerebelli (12%), and superior sagittal sinus (8%).¹⁵⁾ The most frequently used classification for cranial DAVF are the Cognard and the Borden Classification.⁵⁾⁽⁷⁾ Cranial DAVF can be managed by different modalities which includes; conservative management, endovascular management, surgical management, and radiation therapy.

On the other hand, spinal DAVFs account for approximately two-thirds of all pathological spinal vascular lesions with an annual incidence of 5-10 cases per million.¹⁴⁾ In 1926, Foix and Alajouanine described for the first time the diagnostic features of spinal DAVFs.⁸⁾ The diagnosis of spinal DAVFs is affected by many disguising clinical conditions that underrepresented this condition epidemiologically. Pathophysiologically, thrombosis of the extradural spinal vein and trauma are implicated in the development of spinal DAVFs.¹⁴⁾ The most predominant location of spinal DAVFs is in the lower thoracic and upper part of the lumbar spine according to many reports.¹⁷⁾ The classification of spinal DAVFs has undergone many historical changes to enhance the understanding of this pathology. Throughout history, eight classification systems were proposed starting with Di

Chiro G in 1967 and contemporarily concluding with K. Takai's classification in 2017 which reflects the historical controversy in setting a standard classification system for spinal DAVFs.²⁵⁾

In the literature, many articles were published on DAVFs from all over the world. To introduce the topic in a unique, comprehensive fashion and provide an evidence-based practice, a bibliometric analysis is warranted. In neurosurgery, bibliometric analyses have been published in many topics as this trend became more popular in recent years.¹⁾⁽²⁾⁽⁴⁾⁽²²⁾ A bibliometric analysis sets the basis for assessing the most influential articles and publication patterns on a certain area of interest. They have been conducted to obtain key information on the research timeline, most reputable journals, institutions, and prominent contributing authors in a specific field.

MATERIALS AND METHODS

In the execution of this bibliometric-based review article, the Scopus database was used to perform a title-specific, keyword-based search with no time restriction in June 2020. The "dural arteriovenous fistula" was used as a search keyword. The outcome of the search was arranged in descending order based on the article's citations count and the most-cited 100 articles were selected for analysis. Article-based pertinent parameters were collected which included the following: title, citation count, citation per year, contributing authors, speciality of top contributing authors, contributing institutes, country of origin, journal of publications, Journal's Source Normalized Impact Per Paper (SNIP), Journal's SCImago Journal Rank (SJR), and the Journals Impact Factor (IF). Exhaustive in-depth analysis of the top 100 most-cited articles to identify the studied categories was performed. The top 100 most-cited articles are categorized into ten categories which includes the following: clinical, clinico-radiological, radiological, pathophysiological, surgical management, endovascular management, endovascular and/or surgical management, endovascular and/or ra-

diosurgical management, endovascular vs. conservative management, and radiosurgical management. Furthermore, anatomical based categorization of the articles' population was performed, which identified the three following categories: spinal, cerebral, and spinal/cerebral specific studies.

RESULTS

The keyword-based search showed that 2298 articles were published between 1968 and 2020 on DAVFs. The top 100 most-cited articles collected a total of 12393 citations

with an average of 123 citations per paper (Table 1). The rate of self-citations of all authors accounted for 4.86% and the rate of citations by books accounted for 9.2% from the overall accumulative citations. The top 100 articles were published between 1983 and 2012 (Fig. 1). In 2002, 10% of the most-cited articles were published. The most trending study category since 1983 was investigating the clinical aspect of DAVF (Fig. 2). Anatomical based categorization showed that cerebral DAVFs populated two-third of the most-cited articles from 1983 onwards. The United States, Canada, and France were the top three most contributing countries to the most impactful publications on DAVF (Fig. 3).

Table 1. Summary of the top-100 most cited articles on dural arteriovenous fistula in the literature

Rank	Authors	Title	Journal Name	CC	CY
1st	Cognard C et al., 1995	Cerebral dural arteriovenous fistulas: Clinical and angiographic correlation with a revised classification of venous drainage	Radiology	977	39.08
2nd	Rosenblum B et al., 1987	Spinal arteriovenous malformations: A comparison of dural arteriovenous fistulas and intradural AVM's in 81 patients	Journal of Neurosurgery	400	12.12
3rd	Van Dijk JM et al., 2002	Clinical course of cranial dural arteriovenous fistulas with long-term persistent cortical venous reflux	Stroke	359	19.94
4th	Davies MA et al., 1996	The validity of classification for the clinical presentation of intracranial dural arteriovenous fistulas	Journal of Neurosurgery	226	9.41
5th	Roy and Raymond, 1997	The role of transvenous embolization in the treatment of intracranial dural arteriovenous fistulas	Neurosurgery	216	9.39
6th	Brown RD Jr et al., 1994	Intracranial dural arteriovenous fistulae: Angiographic predictors of intracranial hemorrhage and clinical outcome in nonsurgical patients	Journal of Neurosurgery	214	8.23
7th	Cognard C et al., 2008	Endovascular treatment of intracranial dural arteriovenous fistulas with cortical venous drainage: New management using onyx	American Journal of Neuroradiology	211	17.58
8th	Duffau H et al., 1999	Early rebleeding from intracranial dural arteriovenous fistulas: Report of 20 cases and review of the literature	Journal of Neurosurgery	210	10
9th	Krings and Geibprasert, 2009	Spinal dural arteriovenous fistulas	American Journal of Neuroradiology	191	17.36
10th	Van Dijk JMC et al., 2002	Multidisciplinary management of spinal dural arteriovenous fistulas: Clinical presentation and long-term follow-up in 49 patients	Stroke	184	10.2
11th	Klisch J et al., 2003	Transvenous treatment of carotid cavernous and dural arteriovenous fistulae: Results for 31 patients and review of the literature	Neurosurgery	179	10.52
12th	Gilbertson JR et al., 1995	Spinal dural arteriovenous fistulas: MR and myelographic findings	American Journal of Neuroradiology	175	7
13th	Hurst RW et al., 1995	Spinal dural arteriovenous fistula: The pathology of venous hypertensive myelopathy	Neurology	175	7
14th	Steinmetz MP et al., 2004	Outcome after the treatment of spinal dural arteriovenous fistulae: A contemporary single-institution series and meta-analysis	Neurosurgery	171	10.68
15th	Satomi J et al., 2002	Benign cranial dural arteriovenous fistulas: Outcome of conservative management based on the natural history of the lesion	Journal of Neurosurgery	166	9.22
16th	Hurst RW et al., 1998	Dementia resulting from dural arteriovenous fistulas: The pathologic findings of venous hypertensive encephalopathy	American Journal of Neuroradiology	158	7.18

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Rank	Authors	Title	Journal Name	CC	CY
17th	Niimi Y et al., 1997	Embolization of spinal dural arteriovenous fistulae: Results and follow-up	Neurosurgery	155	6.7
18th	Jellema K et al., 2006	Spinal dural arteriovenous fistulas: A congestive myelopathy that initially mimics a peripheral nerve disorder	Brain	154	11
19th	Hassler W et al., 1989	Hemodynamics of spinal dural arteriovenous fistulas. An intraoperative study	Journal of Neurosurgery	146	4.7
20th	Gandhi D et al., 2012	Intracranial dural arteriovenous fistulas: Classification, imaging findings, and treatment	American Journal of Neuroradiology	143	17.87
21st	Lalwani AK et al., 1993	Grading venous restrictive disease in patients with dural arteriovenous fistulas of the transverse/sigmoid sinus	Journal of Neurosurgery	143	5.29
22nd	Criscuolo GR et al., 1989	Reversible acute and subacute myelopathy in patients with dural arteriovenous fistulas. Foix-Alajouanine syndrome reconsidered	Journal of Neurosurgery	142	4.58
23rd	Cognard C et al., 1998	Dural arteriovenous fistulas as a cause of intracranial hypertension due to impairment of cranial venous outflow	Journal of Neurology Neurosurgery and Psychiatry	139	6.31
24th	Thompson BG et al., 1994	Treatment of cranial dural arteriovenous fistulae by interruption of leptomeningeal venous drainage	Journal of Neurosurgery	138	5.3
25th	Nogueira RG et al., 2008	Preliminary experience with onyx embolization for the treatment of intracranial dural arteriovenous fistulas	American Journal of Neuroradiology	137	11.41
26th	Oldfield EH et al., 1983	Successful treatment of a group of spinal cord arteriovenous malformations by interruption of dural fistula	Journal of Neurosurgery	136	3.67
27th	Kiyosue H et al., 2004	Treatment of intracranial dural arteriovenous fistulas: Current strategies based on location and hemodynamics, and alternative techniques of transcatheter embolization	Radiographics	134	8.37
28th	Nelson PK et al., 2003	Use of a wedged microcatheter for curative transarterial embolization of complex intracranial dural arteriovenous fistulas: Indications, endovascular technique, and outcome in 21 patients	Journal of Neurosurgery	130	7.64
29th	Kwon BJ et al., 2005	MR imaging findings of intracranial dural arteriovenous fistulas: Relations with venous drainage patterns	American Journal of Neuroradiology	127	8.46
30th	Jellema K et al., 2003	Spinal dural arteriovenous fistulas: Clinical features in 80 patients	Journal of Neurology, Neurosurgery and Psychiatry	125	7.35
31st	Willinsky RA et al., 1999	Tortuous, engorged pial veins in intracranial dural arteriovenous fistulas: Correlations with presentation, location, and MR findings in 122 patients	American Journal of Neuroradiology	125	5.95
32nd	Atkinson JLD et al., 2001	Clinical and radiographic features of dural arteriovenous fistula, a treatable cause of myelopathy	Mayo Clinic Proceedings	122	6.42
33rd	Barnwell SL et al., 1989	Complex dural arteriovenous fistulas. Results of combined endovascular and neurosurgical treatment in 16 patients	Journal of Neurosurgery	121	3.9
34th	Davies MA et al., 1997	The natural history and management of intracranial dural arteriovenous fistulae. Part 2: Aggressive lesions	Interventional Neuroradiology	120	5.21
35th	Uranishi R et al., 1999	Expression of angiogenic growth factors in dural arteriovenous fistula	Journal of Neurosurgery	118	5.61
36th	Urtasun F et al., 1996	Cerebral dural arteriovenous fistulas: Percutaneous transvenous embolization	Radiology	118	4.91
37th	Hamada Y et al., 1997	Histopathological aspects of dural arteriovenous fistulas in the transverse-sigmoid sinus region in nine patients	Neurosurgery	113	4.91
38th	Bowen BC et al., 1995	Spinal dural arteriovenous fistulas: Evaluation with MR angiography	American Journal of Neuroradiology	113	4.52
39th	Afshar JKB et al., 1995	Surgical interruption of intradural draining vein as curative treatment of spinal dural arteriovenous fistulas	Journal of Neurosurgery	113	4.25
40th	Narvid J et al., 2008	Spinal dural arteriovenous fistulae: Clinical features and long-term results	Neurosurgery	111	9.25

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Rank	Authors	Title	Journal Name	CC	CY
41st	Kim MS et al., 2002	Clinical characteristics of dural arteriovenous fistula	Journal of Clinical Neuroscience	111	6.61
42nd	Saraf-Lavi E et al., 2002	Detection of spinal dural arteriovenous fistulae with MR imaging and contrast-enhanced MR angiography: Sensitivity, specificity, and prediction of vertebral level	American Journal of Neuroradiology	107	5.94
43rd	Farb RI et al., 2002	Spinal dural arteriovenous fistula localization with a technique of first-pass gadolinium-enhanced MR angiography: Initial experience	Radiology	107	5.94
44th	Graeb and Dolman 1986	Radiological and pathological aspects of dural arteriovenous fistulas. Case report	Journal of Neurosurgery	107	3.14
45th	Link MJ et al., 1996	The role of radiosurgery and particulate embolization in the treatment of dural arteriovenous fistulas	Journal of Neurosurgery	106	4.41
46th	Collice M et al., 2000	Surgical treatment of intracranial dural arteriovenous fistulae: Role of venous drainage	Neurosurgery	103	5.15
47th	Mull M et al., 2007	Value and limitations of contrast-enhanced MR angiography in spinal arteriovenous malformations and dural arteriovenous fistulas	American Journal of Neuroradiology	101	7.76
48th	Guo WY et al., 1998	Radiosurgery as a treatment alternative for dural arteriovenous fistulas of the cavernous sinus	American Journal of Neuroradiology	99	4.5
49th	Collice M et al., 1996	Surgical interruption of leptomeningeal drainage as treatment for intracranial dural arteriovenous fistulas without dural sinus drainage	Journal of Neurosurgery	98	4.08
50th	Kim DJ et al., 2006	Results of transvenous embolization of cavernous dural arteriovenous fistula: A single-center experience with emphasis on complications and management	American Journal of Neuroradiology	97	6.92
51st	Chung SJ et al., 2002	Intracranial dural arteriovenous fistulas: Analysis of 60 patients	Cerebrovascular Diseases	97	5.38
52nd	Houdart E et al., 2002	Transcranial approach for venous embolization of dural arteriovenous fistulas	Journal of Neurosurgery	96	5.05
53rd	Luciani A et al., 2001	Spontaneous closure of dural arteriovenous fistulas: Report of three cases and review of the literature	American Journal of Neuroradiology	95	5
54th	Pollock BE et al., 1999	Stereotactic radiosurgery and particulate embolization for cavernous sinus dural arteriovenous fistulae	Neurosurgery	94	3.35
55th	Nichols DA et al., 1992	Embolization of spinal dural arteriovenous fistula with polyvinyl alcohol particles: Experience in 14 patients	American Journal of Neuroradiology	94	4.475
56th	Friedman JA et al., 2001	Results of combined stereotactic radiosurgery and transarterial embolization for dural arteriovenous fistulas of the transverse and sigmoid sinuses	Journal of Neurosurgery	93	4.22
57th	Endo S et al., 1998	Direct packing of the isolated sinus in patients with dural arteriovenous fistulas of the transverse-sigmoid sinus	Journal of Neurosurgery	93	4.22
58th	Zipfel GJ et al., 2009	Cranial dural arteriovenous fistulas: Modification of angiographic classification scales based on new natural history data	Neurosurgical Focus	90	8.18
59th	Oishi H et al., 1999	Complications associated with transvenous embolisation of cavernous dural arteriovenous fistula	Acta Neurochirurgica	90	4.28
60th	Strom RG et al., 2009	Cranial dural arteriovenous fistulae: Asymptomatic cortical venous drainage portends less aggressive clinical course	Neurosurgery	89	8.09
61st	Davies MA et al., 1997	The natural history and management of intracranial dural arteriovenous fistulae. Part 1: Benign lesions	Interventional Neuroradiology	89	3.86
62nd	Barnwell SL et al., 1991	A variant of arteriovenous fistulas within the wall of dural sinuses. Results of combined surgical and endovascular therapy	Journal of Neurosurgery	89	3.06
63rd	Wrobel CJ et al., 1988	Myelopathy due to intracranial dural arteriovenous fistulas draining intrathecally into spinal medullary veins. Report of three cases	Journal of Neurosurgery	89	2.78
64th	Kakarla UK et al., 2007	Surgical treatment of high-risk intracranial dural arteriovenous fistulae: Clinical outcomes and avoidance of complications	Neurosurgery	86	6.61
65th	Meckel S et al., 2007	MR angiography of dural arteriovenous fistulas: Diagnosis and follow-up after treatment using a time-resolved 3D contrast-enhanced technique	American Journal of Neuroradiology	85	6.53

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Rank	Authors	Title	Journal Name	CC	CY
66th	Song JK et al., 2001	Surgical and endovascular treatment of spinal dural arteriovenous fistulas: Long-term disability assessment and prognostic factors	Journal of Neurosurgery	85	4.47
67th	De Marco JK et al., 1990	Dural arteriovenous fistulas: Evaluation with MR imaging	Radiology	84	2.8
68th	Westphal and Koch 1999	Management of spinal dural arteriovenous fistulae using an interdisciplinary neuroradiological/neurosurgical approach: Experience with 47 cases	Neurosurgery	83	3.95
69th	Cognard C et al., 1997	Long-term changes in intracranial dural arteriovenous fistulae leading to worsening in the type of venous drainage	Neuroradiology	83	3.6
70th	Chen JC et al., 1992	Suspected dural arteriovenous fistula: Results with screening MR angiography in seven patients	Radiology	83	2.96
71st	Saladino A et al., 2010	Surgical treatment of spinal dural arteriovenous fistulae: A consecutive series of 154 patients	Neurosurgery	82	8.2
72nd	Natarajan SK et al., 2010	Multimodality treatment of intracranial dural arteriovenous fistulas in the onyx era: A single center experience	World Neurosurgery	82	8.2
73rd	Eskandar EN et al., 2002	Spinal dural arteriovenous fistulas: Experience with endovascular and surgical therapy	Journal of Neurosurgery	81	4.5
74th	Gross and Du, 2012	The natural history of cerebral dural arteriovenous fistulae	Neurosurgery	80	10
75th	Tsai LK et al., 2004	Intracranial dural arteriovenous fistulas with or without cerebral sinus thrombosis: Analysis of 69 patients	Journal of Neurology, Neurosurgery and Psychiatry	80	5
76th	Lawton MT et al., 1999	Ethmoidal dural arteriovenous fistulae: An assessment of surgical and endovascular management	Neurosurgery	80	3.8
77th	Terwey B et al., 1989	Gadolinium-DTPA enhanced MR imaging of spinal dural arteriovenous fistulas	Journal of Computer Assisted Tomography	80	2.58
78th	Brunereau L et al., 1996	Intracranial dural arteriovenous fistulas with spinal venous drainage: Relation between clinical presentation and angiographic findings	American Journal of Neuroradiology	79	3.29
79th	Koch C, 2006	Spinal dural arteriovenous fistula	Current Opinion in Neurology	76	5.42
80th	Agid R et al., 2009	Management strategies for anterior cranial fossa (ethmoidal) dural arteriovenous fistulas with an emphasis on endovascular treatment: Clinical article	Journal of Neurosurgery	75	6.81
81st	Lawton MT et al., 2008	Tentorial dural arteriovenous fistulae: Operative strategies and microsurgical results for six types	Neurosurgery	75	6.25
82nd	Van Rooij WJ et al., 2007	Dural arteriovenous fistulas with cortical venous drainage: Incidence, clinical presentation, and treatment	American Journal of Neuroradiology	75	5.76
83rd	Jahan R et al., 1998	Transvenous embolization of a dural arteriovenous fistula of the cavernous sinus through the contralateral pterygoid plexus	Neuroradiology	75	3.4
84th	Huffmann BC et al., 1995	Spinal dural arteriovenous fistulas: a plea for neurosurgical treatment	Acta Neurochirurgica	75	3
85th	Halbach VV et al., 1990	Dural arteriovenous fistulas supplied by ethmoidal arteries	Neurosurgery	75	2.5
86th	Behrens and Thron 1999	Long-term follow-up and outcome in patients treated for spinal dural arteriovenous fistula	Journal of Neurology	74	3.52
87th	Willems PWA et al., 2011	Detection and classification of cranial dural arteriovenous fistulas using 4D-CT angiography: Initial experience	American Journal of Neuroradiology	73	8.11
88th	Goto K et al., 1999	Combining endovascular and neurosurgical treatments of high-risk dural arteriovenous fistulas in the lateral sinus and the confluence of the sinuses	Journal of Neurosurgery	73	3.47
89th	Gobin YP et al., 1992	Endovascular treatment of intracranial dural arteriovenous fistulas with spinal perimedullary venous drainage	Journal of Neurosurgery	73	2.6
90th	Pan DHC et al., 2002	Stereotactic radiosurgery for the treatment of dural arteriovenous fistulas involving the transverse-sigmoid sinus	Journal of Neurosurgery	72	4
91st	Song JK et al., 2001	N-butyl 2-cyanoacrylate embolization of spinal dural arteriovenous fistulae	American Journal of Neuroradiology	72	3.78

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Rank	Authors	Title	Journal Name	CC	CY
92nd	Barnwell SL et al., 1991	Multiple dural arteriovenous fistulas of the cranium and spine	American Journal of Neuroradiology	72	2.48
93rd	Luetmer PH et al., 2005	Preangiographic evaluation of spinal dural arteriovenous fistulas with elliptic centric contrast-enhanced MR angiography and effect on radiation dose and volume of iodinated contrast material	American Journal of Neuroradiology	71	4.73
94th	Noguchi K et al., 2004	Intracranial Dural Arteriovenous Fistulas: Evaluation with Combined 3D Time-of-Flight MR Angiography and MR Digital Subtraction Angiography	American Journal of Roentgenology	71	4.43
95th	Aviv RI et al., 2004	Cervical dural arteriovenous fistulae manifesting as subarachnoid hemorrhage: Report of two cases and literature review	American Journal of Neuroradiology	70	4.735
96th	Partington MD et al., 1992	Cranial and sacral dural arteriovenous fistulas as a cause of myelopathy	Journal of Neurosurgery	70	2.5
97th	Farb RI et al., 2009	Cranial dural arteriovenous fistula: Diagnosis and classification with time-resolved MR angiography at 3T	American Journal of Neuroradiology	69	6.27
98th	Lee TT et al., 1998	Diagnostic and surgical management of spinal dural arteriovenous fistulas	Neurosurgery	69	3.13
99th	Rezende MTS et al., 2006	Dural arteriovenous fistula of the lesser sphenoid wing region treated with Onyx: Technical note	Neuroradiology	68	4.85
100th	Suh DC et al., 2005	New concept in cavernous sinus dural arteriovenous fistula: Correlation with presenting symptom and venous drainage patterns	Stroke	68	4.53

CC, citation count; CY, citation per year

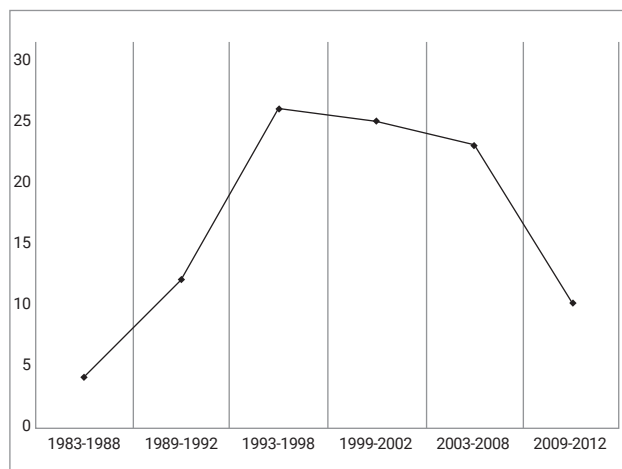


Fig. 1. Publication trends for the top-100 most cited articles between 1983-2012.

The Mayo Clinic and the University of Toronto were the most active institutes in contributing to the most-cited articles (Fig. 4). The majority of articles were published by three journals: The *Journal of Neurosurgery* “29 articles”, the *American Journal of Neuroradiology* “24 articles”, and *Neurosurgery* “17 articles” (Fig. 5). Neuroradiologists were the most active in studying DAVF and neurosurgeon ranked as second most contributing speciality. Halbach VV, a neuroradiologist, was the most contributing author to the list by producing

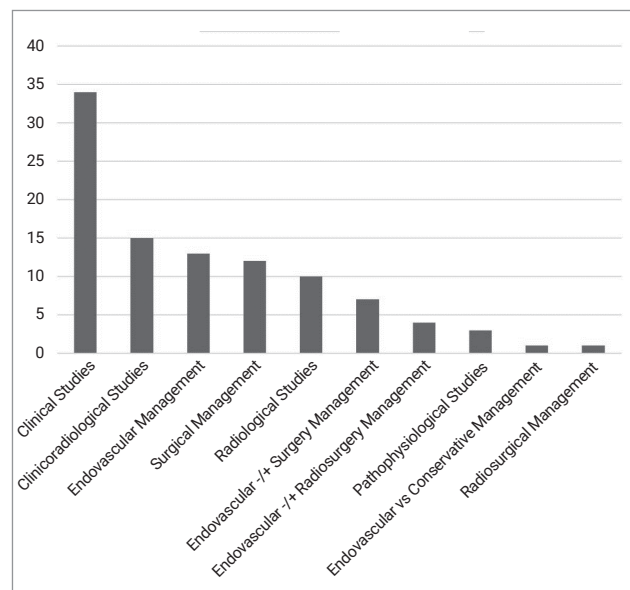


Fig. 2. Categorical distribution of the main topics addressing dural arteriovenous fistula in the top-100 cited articles.

10 publications with an H-index number of four as compared to other top authors (Fig. 6). The top number one most-cited article is titled “Cerebral dural arteriovenous fistulas: Clinical and angiographic correlation with a revised classification of venous drainage” published by Cognard et al.,⁵⁾ 1995 in *Radiology* to which it received 977 citations and 39 citations per year.

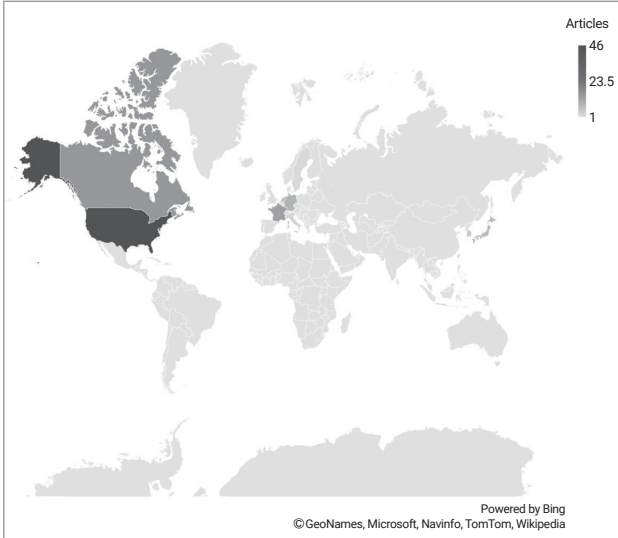


Fig. 3. Geographical distribution of the country of origin contributing to the top-100 cited articles.

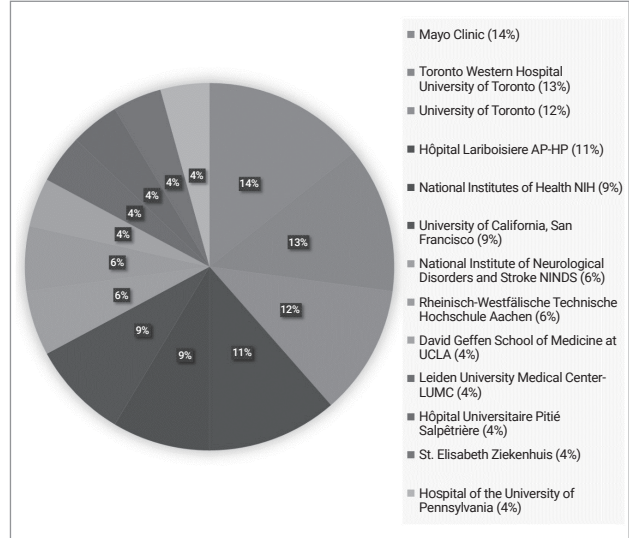


Fig. 4. Percentages of the top contributing institutions in which the work has been conducted.

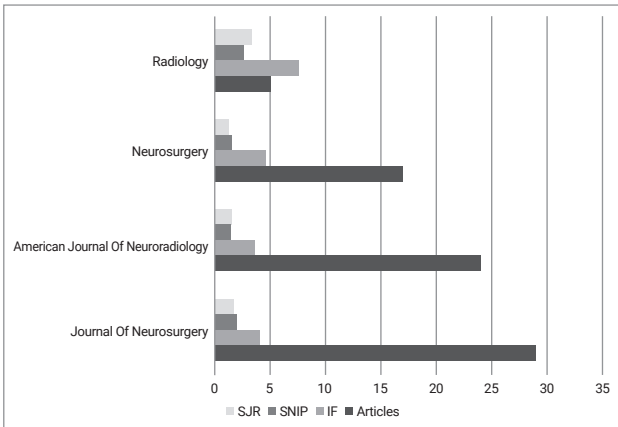


Fig. 5. The top journals publishing articles on dural arteriovenous fistula in terms of Journal's Source Normalized Impact Per Paper (SNIP), Journal's SCImago Journal Rank (SJR), and Journal Impact Factor (IF).

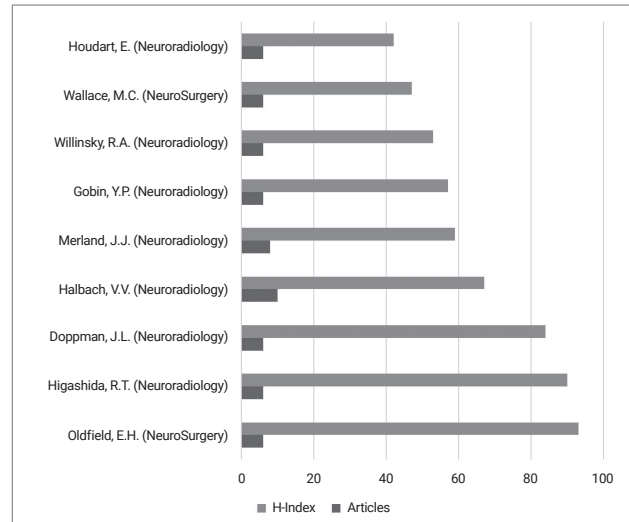


Fig. 6. The most reputable authors and their corresponding specialty/H-index/publications in the field of dural arteriovenous fistula.

DISCUSSION

Publications on DAVFs went through a distinct revolution, as a result of the improvement in both the radiological techniques as well as the technology used in endovascular evaluation and treatment. In the 1980s, publications addressing DAVFs were initially targeting the surgical aspects and clinical features in the context of surgical interruption of the dura, myelopathy, venous hypertension, and hemodynamics. Late in the 1980s, the

research interest was shifted towards the radiological description and endovascular management, in combination with the neurosurgical management. In the 1990s, the vast majority of published articles on DAVFs were assessing the clinicoradiological features. During this period, the diagnostics of DAVFs on MR/angiography and particulate embolization techniques populated most of the publications. In our top-100 cited articles, almost half of the articles were published between 2000-2012. These articles were trending after the advent of some

classification systems on DAVFs.

It is noteworthy to mention that the highest cited article was published by Cognard et al., with an accumulative citation count (CC) of 977 and citation per year (CY) 39, respectively. Cognard and his colleagues, in the article published in *Radiology* 1995,⁵⁾ have investigated the clinical features of DAVF and subsequently correlated them with the angiographic features.⁵⁾ The authors have classified DAVFs into five types according to their venous drainage.⁵⁾ This can allow risk prediction to allow for appropriate decision-making strategies for treatment.⁵⁾

The second highest cited article in the top 100 list was published by Rosenblum et al., entitled with 400 CC and 12.12 CY. The authors conducted a comparative analysis between spinal DAVF and AVMs.²³⁾ They have concluded that DAVFs and AVMs are different disease entities in terms of etiology, pathophysiology, symptomatology, radiological findings, and treatment response.²³⁾ In aforementioned article they concluded that DAVFs are responsive to treatment, as opposed to AVMs, in which the neurological risk after complete excision is high.²³⁾

Cerebral

In the present bibliometric analysis, approximately two-thirds of the articles addressed cerebral arteriovenous fistulas in terms of the clinical features, radiological description, and treatment modalities. Peak publications in the cerebral category were between 1995–2012. Some published articles investigated cerebral DAVFs in terms of their intracranial location, that is, tentorial, sphenoid wing, transverse, sigmoid, cavernous, ethmoidal, and confluence of sinuses.

Pathophysiology

In the pathophysiology category, the molecular pathogenesis and histopathological features of cerebral DAVFs were studied in two publications (Rank 35th and 37th) with an average yearly citation of 4.9 and 5.61. Hamada et al. (ranked 37th) investigated the histopathological features of nine patients with cerebral DAVFs.¹⁰⁾ They concluded that abnormal connection between the dural arteries and veins is essential to the pathophysiological

process. However, sinus thrombosis is not a key element to the development of cerebral arteriovenous fistulas.¹⁰⁾ Uranishi et al., (ranked 35th) published an article in 1999 with 118 CC.²⁶⁾ The researchers investigated the role of angiographic growth factors in the development of DAVF.²⁶⁾ They have proposed that angiographic growth factors, produced as a result of sinus thrombosis, might contribute to the pathogenesis of DAVFs.²⁶⁾

Clinical

In this bibliometric analysis, 21% of articles investigated the clinical features of cerebral arteriovenous fistulas (Peak=1986–2012). The publications trend in the clinical category focused on classification, natural history, and subsequently on the clinical features. Van Dijk et al. (Ranked 3rd) published an article in 2002 with 359 CC and 19.9 CY.²⁷⁾ The authors have investigated the long-term follow-up in a cohort of 236 patients.²⁷⁾ They showed that annual risk of intracranial hemorrhage and neurological deficits in patients with cerebral DAVFs was 8.1% and 6.9%, respectively.²⁷⁾

Radiological

The publication peak for the articles investigating the radiological description of cerebral DAVF was from 2004–2011. Most articles were published in neuroradiology-dedicated journals, that is, the *American Journal of Neuroradiology* and the *American Journal of Roentgenology*.

Surgical management

The surgical/endovascular management category DAVF peaked in publications between 1989–1999. The article with the highest citations in this category was published by Barnwell et al. (ranked 33rd) with an average of 121 CC and 3.9 CY.³⁾ The authors presented their experience with complex DAVF in sixteen patients.³⁾ Their results confirmed that surgical access to the draining veins, coupled with endovascular therapy, is effective in the management of cranial DAVFs.³⁾

Endovascular management

In the top-100 list, articles investigating the endovascu-

lar management had a publication peak between 1992-2008. Cognard et al. published an article (ranked 7th) in 2008, which received 211 CC and 17.85 CY.⁶⁾ They prospectively studied 30 patients with cerebral DAVFs.⁶⁾ Their study revolutionized the treatment strategies for DAVFs, as they were the first to apply and recommend Onyx as a treatment of choice.⁶⁾

Spinal

One-third of the articles were addressing spinal DAVFs. These articles peaked in the 21st century (2000-2012). In the 1980s, authors were initially targeting the surgical aspect of DAVFs vs. AVMs. Shortly thereafter, the clinicoradiological description was the area of interest to authors publishing articles on spinal DAVFs. In the 1990s, articles were heterogeneously discussing the endovascular, surgical, pathophysiological, radiological, and clinicoradiological aspects of spinal DAVFs.

Pathophysiology

The pathophysiology category emphasized on the histological features of spinal DAVE. Hurst et al. in their article, published in 1995 in *Neurology*, addressed the pathophysiology of spinal DAVE.¹²⁾ In the present bibliometric analysis, their article received 175 CC and 7 CY (ranked 13th).¹²⁾ This article was the first to report and document the histopathological features of the spinal cord in a patient with spinal DAVE.¹²⁾ Their histopathological examination supported the theory of increased venous congestion as a cause of neurological manifestations.¹²⁾

Clinical

The clinical category of spinal DAVFs started with articles addressing the clinical features and then shifted towards the long-term outcome. Those articles peaked in publication between 1987-2009. The most cited article in this category with 400 CC and 12.12 CY (ranked 2nd) was published by Rosenblum et al., 1987, in the *Journal of Neurosurgery*. Jellema et al., 2006, published an article with 154 CC and 11 CY (ranked 18th overall).¹³⁾ The researchers performed a narrative review article discussing

spinal DAVE.¹³⁾ They postulated that spinal dural fistulas could present with features mimicking polyradiculopathy or anterior horn cell disorders.¹³⁾ As a result, health-care providers should keep a high index of suspicion in any middle-age patient presenting with an ascending sensory and/or motor dysfunction.¹³⁾ This allows for the prompt diagnosis of spinal DAVFs early in the course of the disease.¹³⁾

Radiological

Publications targeting the neuroradiological description of spinal DAVF peaked in the years 1989-2005. All articles were published in neuroradiology-dedicated journals and were predominantly addressing magnetic resonance angiography (MRA). Luetmer et al. (ranked 93rd) published an article in 2005 with 71 CC and 4.43 CY.¹⁶⁾ The authors evaluated the efficacy of contrast-enhanced angiography in the detection of spinal DAVE.¹⁶⁾ They concluded that the level of the fistula could be predicted using a contrast-enhanced MRA in addition to avoiding radiation exposure and the radiation dose that are associated with angiography.¹⁶⁾

Surgical management

The surgical management and/or the endovascular aspect publications peaked between 1999-2012. Steinmetz and his colleagues (ranked 14th) performed a meta-analysis with 171 CC and 10.7 CY.²⁴⁾ The main aim of their study was to investigate the role of endovascular, surgical, and combined modalities in the treatment of spinal DAVE.²⁴⁾ They demonstrated that the surgical management was superior to embolization for the initial obliteration of spinal DAVF as the vast majority of patients improve or remain stable after treatment.²⁴⁾ Their meta-analysis suggests that the cure rate after surgery can reach up to 98%.²⁴⁾ In the authors' perspective, that is based on their experience, surgery should be offered as a first-line therapy for spinal DAVFs.²⁴⁾

Endovascular management

Out of the top-100 cited articles on spinal DAVFs, studies were mainly addressing the endovascular man-

agement alone, in the form of embolization. Nichols et al. (Rank 55th) published an article entitled with 94 CC and 4.48 CY.¹⁹⁾ They assessed the effectiveness of embolization using polyvinyl alcohol (PVA) particles in 14 patients with spinal DAVFs.¹⁹⁾ However, in their cohort, embolization with PVA deemed to be ineffective for treating spinal DAVFs.¹⁹⁾ Consequently, they recommend N-butyl cyanoacrylate (NBCA) embolization as the treatment of choice for DAVFs.¹⁹⁾²³⁾ Niimi and his colleagues (Rank 17th) published an article with 155 CC and 5.7 CY.²⁰⁾ The authors investigated the feasibility of the application of embolization in the treatment of spinal DAVE.²⁰⁾ Of note, they recommend frequent, periodic follow-up for patients with spinal DAVFs, as subsequent deterioration can occur following embolization.²⁰⁾

Spinal/Cerebral

A few articles had heterogeneous data of spinal and cerebral DAVFs. Mull et al. published an article (2007; CC=101; CY=7.76, ranked 47th) evaluating the efficacy of MRA in the identification of arteriovenous fistula.¹⁸⁾ They concluded that contrast-enhanced MRA could accurately locate arterial feeders of spinal DAVFs, as opposed to only visualizing the dominant arterial feeder in spinal AVMs.¹⁸⁾ Partington et al. in their article (1992; CC=70; CY=2.5, ranked 96th) investigated a series of 7 patients with spinal DAVFs where the nidus was located some distance away from the spinal cord (i.e., remote fistula).²¹⁾ They have supported the theory of venous hypertension as a pathophysiological mechanism in the development of DAVFs, irrespective of the location.²¹⁾

Limitations

Finally, there are few limitations that need to be acknowledged when interpreting the results of the current bibliometric analysis. Older articles published in the literature are likely to receive more citations over time than recently published ones. Second, self-citations in some articles might inflate the actual number of the total CC. However, numerous efforts were taken to overcome the obstacles in the study. The CY was calculated for all articles to compensate for the studies published in

recent years. Additionally, the rate of self-citation was minimal (<5%), and therefore, the CC closely reflects its true value. Disease-specific limitations exist due to the controversial definition of DAVF and its reporting embedded within articles discussing AVM. This might have led to missing some article in the present bibliometric title-based search.

CONCLUSIONS

In the top-100 most cited articles on DAVE, most studies were published in neurosurgery/neuroradiology-dedicated journals. The clinical aspect, in the form of clinical features and natural history, was the most investigated category on sural arteriovenous fistula. The top-2 most recognized articles were published in the *Journal of Radiology* and *Journal of Neurosurgery*, respectively. Neuroradiologists, followed by neurosurgeons, were the most contributing authors in the field of DAVE. This bibliometric analysis identifies the publication trends and provides a comprehensive overview of the most influential articles addressing DAVE.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

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