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.\(^9\)\(^{11}\) 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.\(^{12}\)^\(^{10}\)^\(^{22}\) 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, clinicoradiological, radiological, pathophysiological, surgical management, endovascular management, endovascular and/or surgical management, endovascular and/or ra-
diasurgical 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-thirds 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 AVMs 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 | Kliisch J et al., 2003   | Transvenous treatment of carotid cavernous and dural arteriovenous fistulas: 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., 1989 | 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   |
| Rank | Authors                  | Title                                                                 | Journal Name                      | CC   | CY  |
|------|--------------------------|----------------------------------------------------------------------|-----------------------------------|------|-----|
| 41st | Kim MS et al., 2002      | Clinical characteristics of dural arteriovenous fistula              | Journal of Clinical Neurosciences  | 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 fistula | 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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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 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.,1995 in Radiology to which it received 977 citations and 39 citations per year.
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, have investigated the clinical features of DAVF and subsequently correlated them with the angiographic features. The authors have classified DAVFs into five types according to their venous drainage. This can allow risk prediction to allow for appropriate decision-making strategies for treatment.

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. They have concluded that DAVFs and AVMs are different disease entities in terms of etiology, pathophysiology, symptomatology, radiological findings, and treatment response. 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.

**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. 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.

Uranishi et al., (ranked 35th) published an article in 1999 with 118 CC. The researchers investigated the role of angiographic growth factors in the development of DAVF. They have proposed that angiographic growth factors, produced as a result of sinus thrombosis, might contribute to the pathogenesis of DAVFs.

**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. The authors have investigated the long-term follow-up in a cohort of 236 patients. They showed that annual risk of intracranial hemorrhage and neurological deficits in patients with cerebral DAVFs was 8.1% and 6.9%, respectively.

**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. The authors presented their experience with complex DAVF in sixteen patients. Their results confirmed that surgical access to the draining veins, coupled with endovascular therapy, is effective in the management of cranial DAVFs.

**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. They prospectively studied 30 patients with cerebral DAVFs. Their study revolutionized the treatment strategies for DAVFs, as they were the first to apply and recommend Onyx as a treatment of choice.

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

**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). The researchers performed a narrative review article discussing spinal DAVF. They postulated that spinal dural fistulas could present with features mimicking polyradiculopathy or anterior horn cell disorders. As a result, healthcare providers should keep a high index of suspicion in any middle-age patient presenting with an ascending sensory and/or motor dysfunction. This allows for the prompt diagnosis of spinal DAVFs early in the course of the disease.

**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. They evaluated the efficacy of contrast-enhanced angiography in the detection of spinal DAVF. They concluded that the level of the fistula could be predicted using a contrast-enhanced MRA in addition to avoidance of radiation exposure and the radiation dose that are associated with angiography.

**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. The main aim of their study was to investigate the role of endovascular, surgical, and combined modalities in the treatment of spinal DAVF. 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. Their meta-analysis suggests that the cure rate after surgery can reach up to 98%. In the authors’ perspective, that is based on their experience, surgery should be offered as a first-line therapy for spinal DAVFs.

**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 55\textsuperscript{th}) published an article entitled with 94 CC and 4.48 CY.\textsuperscript{19} They assessed the effectiveness of embolization using polyvinyl alcohol (PVA) particles in 14 patients with spinal DAVFs.\textsuperscript{19} However, in their cohort, embolization with PVA deemed to be ineffective for treating spinal DAVFs.\textsuperscript{19} Consequently, they recommend N-butyl cyanoacrylate (NBCA) embolization as the treatment of choice for DAVFs.\textsuperscript{19,23} Niimi and his colleagues (Rank 17\textsuperscript{th}) published an article with 155 CC and 5.7 CY.\textsuperscript{20} The authors investigated the feasibility of the application of embolization in the treatment of spinal DAVF.\textsuperscript{20} Of note, they recommend frequent, periodic follow-up for patients with spinal DAVFs, as subsequent deterioration can occur following embolization.\textsuperscript{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 47\textsuperscript{th}) evaluating the efficacy of MRA in the identification of arteriovenous fistula.\textsuperscript{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.\textsuperscript{18} Partington et al. in their article (1992; CC=70; CY=2.5, ranked 96\textsuperscript{th}) 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).\textsuperscript{21} They have supported the theory of venous hypertension as a pathophysiological mechanism in the development of DAVFs, irrespective of the location.\textsuperscript{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 DAVF, 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 DAVF. This bibliometric analysis identifies the publication trends and provides a comprehensive overview of the most influential articles addressing DAVF.

**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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