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Review article

Top 50 most cited articles on primary tumors of the spine

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ABSTRACT

Citation analysis was performed in order to identify the top 50 most cited articles pertaining to the field of primary spinal tumors. This collection of articles highlights important trends in the neurosurgical literature.

We searched the Thomson Reuters Web of Knowledge in order to identify articles pertaining to primary tumors of the spine. Impertinent articles were removed. The top 50 most cited articles were identified. Thereafter, article characteristics were determined including article type, article topic, level of evidence, and citation rate.

The selected articles were published between 1951 and 2008. The most productive year was 1997 with 6 publications. The top 50 articles were published in twenty-two different journals, most commonly in *Neurosurgery* (12), *Journal of Neurosurgery* (8), and *Spine* (6). The most frequently cited article was by Tomita et al. written in 1997 which described total en bloc spondylectomy as a novel surgical technique in management of primary tumors of the vertebral column.

We identified the 50 most-cited articles in the field of primary spinal tumors. This collection of articles serves as a reference for recognizing impactful studies in the field.

1. Introduction

Citation analysis allows the identification of studies that have influenced a given field. Although this methodology has been applied to spinal oncology in general [1], no previous study has specifically investigated the field of primary tumors of the spine. Given that primary and metastatic tumors of the spine are distinct pathologies with different management schemes, we aimed to perform a citation analysis of the primary tumors of the spine only. In this study, we identify and discuss the most cited articles published in the field.

2. Methods

We searched all databases within Thomson Reuters's Web of Science for articles pertaining to primary tumors of the spine. The search was limited to articles published in English, and between 2016 and 1945, which was the earliest date available in the search engine. The search command was entered under the "topic" category as follows:

(spine or spinal or vertebral or column or canal) and (primary* or tumor*).

Impertinent articles were excluded. Total citation count was determined after accounting for self-citation. To eliminate self-citations, we performed two independent searches. First, a "cited reference search" was used to generate a list of all articles citing the article of interest. We next performed an "author" search including all authors of the article of interest in order to identify all articles published by these authors. The results of these searches were then cross-matched so as to determine how many times any author from a given article self-cited that article. The number of self-citations was subtracted from the initial number of citations obtained from the search so as to determine true total citation count. The articles were then sorted based on decreasing citation count. From this list, the top 50 most cited articles were chosen for final analysis.

3. Results

The results of the search included 4,571 articles. The 50 most cited articles relevant to primary spine tumors were included in the final list. Information collected on each article including their

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Table 1
List of 50 most cited articles on primary tumors of the spine. Information is provided on rank based on total number of citations, article title, first author's name, journal, article summary, article type, level of evidence, total number of citations, citation rate, defined as number of citations per year since publication and rank based on citation rate.

Rank	Article	Article topic/ Tumor type	Article summary	Article type	Level of evidence	Citations	Citation rate (rank)
1	Tomita, K., Kawahara, N., Baba, H., Tsuchiya, H., Fujita, T., Toribatake, Y. Total en bloc spondylectomy – A new surgical technique for primary malignant vertebral tumors. Spine, 1997. 22(3): p. 324–333 [9].	Surgical technique-Vertebral tumors	Authors describe a new surgical technique, "total en bloc spondylectomy", consisting of en bloc laminectomy and en bloc corpectomy followed by anterior instrumentation with spacer grafting and posterior spinal instrumentation in patients with primary malignant vertebral tumors	Case Series	IV	199	12.9 (1st)
2	Cooper, P.R., Epstein, F.J. Radical resection of intramedullary spinal-cord tumors in adults- Recent experience in 29 patients. J Neurosurg.1985. 63(4): p. 492–499 [6].	Outcome-Intramedullary	Neurological outcome of 29 patients with primary intramedullary tumors who underwent radical resection	Case Series	IV	167	6.2 (9th)
3	Cooper P.R. Outcome after operative treatment of intramedullary spinal-cord tumors in adults- intermediate and long-term results in 51 patients. Neurosurgery, 1989. 25(6): p. 855–859 [10].	Outcome-Intramedullary	Neurological and functional outcome of 51 patients who underwent operative management of intramedullary spinal cord tumors at mean follow up time of 38 months	Case Series	IV	152	5.9 (13th)
4	Constantini, S., Miller, D. C., Allen, J. C., Rorke, L.B., Freed, D., Epstein, F. J., Radical excision of intramedullary spinal cord tumors: surgical morbidity and long-term follow-up evaluation in 164 children and young adults. J Neurosurg. 2000. 93(2): p. 183–193 [5].	Outcome-Intramedullary	Neurological, functional outcome and survival of 164 patients 21 years old or younger who underwent surgical management of intramedullary spinal cord tumors at 5 years of follow up	Case Series	IV	145	10.3 (3rd)
5	Cristante L., Herrmann H.D. Surgical management of intramedullary spinal-cord tumors- Functional outcome and sources of morbidity. Neurosurgery, 1994. 35(1): p. 69–74 [22].	Outcome-Intramedullary	Functional outcome of 69 patients with intramedullary spinal cord tumor who underwent surgical resection at mean follow up time of 54 months	Case Series	IV	125	6 (11th)
6	Tefft M., Vawter G.F., Mitus A., Paravertebral round cell tumors in children. Radiology, 1969. 92(7): p. 1501–1509 [53].	Radiology-extramedullary	Radiographic appearance of paravertebral tumors in 5 patients	Case Series	IV	114	2.5 (36th)
7	Roelvink N.C.A., Kamphorst W., Vanalphen H. A. M., Rao B. R. Pregnancy-related primary brain and spinal tumors. Arch Neurol, 1987. 44 (2): p. 209–215 [51].	Natural history-Other	Case report of 4 patients with primary spinal vascular tumors and their clinical presentation during pregnancy	Case Series	V	113	4.1 (20th)
8	Murphey M.D., Andrews C. I., Flemming D. J., Temple H.T., Smith W. S., Smirniotopoulos J. G. From the archives of the FIP - Primary tumors of the spine: Radiologic-pathologic correlation. Radiographics, 1996. 16(5): p. 1131–1158 [43].	Radiology- Mixed	Review of radiological appearance of various primary tumors of the spine	Review	V	110	6 (12th)
9	Morota, N., Deletis, V., Constantini, S., Kofler, M., Cohen, H., Epstein, F. J. The role of motor evoked potentials during surgery for intramedullary spinal cord tumors. Neurosurgery, 1997. 41(6): p. 1327–1336 [8].	Electrophysiology-Intramedullary	Methodology and utility of evoked potential in surgery for patients with intramedullary spinal cord tumors	Prospective cohort series	II	106	7.2 (7th)
10	Constantini S., Houten J., Miller D. C., et al. Intramedullary spinal cord tumors in children under the age of 3 years. J Neurosurg, 1996. 85(6): p. 1036–1043 [4].	Outcome-Intramedullary	Neurological and functional outcome and survival rate of 13 patients under 3 years old who underwent operative management of intramedullary spinal cord tumors	Case Series	IV	105	6.2 (10th)
11	Sala, F., Palandri, G., Basso, E., et al., Motor evoked potential monitoring improves outcome after surgery for intramedullary spinal cord tumors: A historical control study. Neurosurgery, 2006. 58(6): p. 1129–1141 [11].	Electrophysiology-Intramedullary	Utility of intraoperative neurophysiological monitoring during surgical resection of intramedullary spinal cord tumors	Case Control	III	103	12.8 (2nd)
12	Riggs H.E., Clary W.U. A case of intramedullary sheath cell tumor of the spinal cord – Consideration of vascular nerves as a source of origin. J Neuropathol Exp Neurol, 1957. 16(3): p. 332–336 [50].	Pathology-Intramedullary	A case report of a "sheath cell tumor "originating from the parenchyma of the spinal cord	Case report	IV	102	1.8 (41st)

Table 1 (*continued*)

Rank	Article	Article topic/ Tumor type	Article summary	Article type	Level of evidence	Citations	Citation rate (rank)
13	Kopelson G., Linggood R. M., Kleinman G. M., Doucette J., Wang C. C. Management of intra-medullary spinal-cord tumors. Radiology, 1980. 135(2): p. 473–479 [35].	Natural history-intramedullary	Neurological outcome, and 5- and 10-year survival of patients who underwent resection, irradiation, or a combination therapy for management of intramedullary spinal cord tumors	Case Series	IV	99	2.9 (32nd)
14	Weinstein J.N., McLain R.F. Primary tumors of the spine. Spine, 1987. 12(9): p. 843–851 [55].	Natural history-Mixed	Neurological and radiological outcome and survival rate of 82 patients with benign or malignant primary tumors of the spine with follow up of 4–10 years	Case Series	IV	98	3.6 (26th)
15	Malis, L.I. Intramedullary spinal cord tumors. Clin Neurosurg, 1978. 25: p. 512–539 [38].	Outcome -' Intramedullary	Clinical outcome of the author's experience in surgical management of patients with intramedullary spinal cord tumors between 1967 and 1977	Case Series	IV	86	4.1 (21st)
16	Osullivan C., Jenkin R. D., Doherty M. A., Hoffman H. J., Greenberg M. L. Spinal-cord tumors in children – Long-term results of combined surgical and radiation treatment. J Neurosurg, 1994. 81(4): p. 507–512 [45].	Radiation-Intramedullary	Ten and 20-year survival and relapse rate in 31 patients under age of 17 years who underwent radiation therapy after operative management of intramedullary spinal cord tumors	Case Series	IV	86	2.4 (38th)
17	Linstadt D.E., Wara W. M., Leibel S. A., Gutin P. H., Wilson C. B., Sheline G. E. Postoperative radiotherapy of primary spinal-cord tumors. Int J Radiat Oncol Biol Phys, 1989. 16(6): p. 1397–1403 [36].	Radiation-Intramedullary	Ten-year survival rate of 41 patients with intramedullary spinal cord tumors who underwent postoperative irradiation	Case Series	IV	84	3.6 (27th)
18	Raco, A., Esposito, V., Lenzi, J., Piccirilli, M., Delfini, R., Cantore, G. Long-term follow-up of intramedullary spinal cord tumors: A series of 202 cases. Neurosurgery, 2005. 56(5): p. 972–979 [49].	Outcome-Intramedullary	Functional outcome and recurrence rate in 202 patients who underwent surgical resection of intramedullary spinal cord tumors	Case Series	IV	80	8.3 (5th)
19	Papagelopoulos, P.J., Peterson, H. A., Ebersold, M. J., Emmanuel, P. R. Choudhury, S. N. Quast, L. M. Spinal column deformity and instability after lumbar or thoracolumbar laminectomy for intraspinal tumors in children and young adults. Spine, 1997. 22(4): p. 442–451 [46].	Spinal instability-Mixed	Occurrence of spinal instability and/or deformity in 36 patients who underwent multilevel thoracolumbar laminectomy for removal of intraspinal tumors	Case Series	IV	79	5.1 (15th)
20	Arseni C., Maretsis M. Tumors of lower spinal cord associated with increased intracranial pressure and papilledema. J Neurosurg, 1967. 27(2): p. 105–110 [18].	Other-Mixed	Report of 3 patients with primary spine tumors with associated intracranial pressure and papilledema	Case Series	IV	77	2.7 (35th)
21	Garcia D.M. Primary spinal-cord tumors treated with surgery and postoperative irradiation. Int J Radiat Oncol Biol Phys, 1985. 11(11): p. 1933–1939 [25].	Radiation-Intramedullary	Five- and 10- survival of patient with intramedullary spinal cord tumor who underwent postoperative irradiation	Case Series	IV	77	1.7 (42nd)
22	Katsumi Y., Honma T., Nakamura T. Analysis of cervical instability from laminectomies for removal of spinal-cord tumor. Spine, 1989. 14(11): p. 1171–1176 [32].	Spinal instability-Mixed	Incidence of spinal instability in 34 patients who underwent laminectomy for resection of primary cervical spine tumor	Case Series	IV	73	4.2 (19th)
23	Alston S.R., Francel P.C., Jane J.A. Solitary fibrous tumor of the spinal cord. Am J Surg Pathol, 1997. 21(4): p. 477–483 [17].	Pathology-Intramedullary	A case report of the a an intramedullary solitary fibrous tumor of the thoracic spine	Case Report	IV	73	3.8 (25th)
24	Cooper I.S., Craig W.M., Kernohan J.W. Tumors of the spinal cord – Primary extramedullary gliomas. Surg Gynecol Obstet, 1951. 92(2): p. 183–190 [21].	Outcome-Extramedullary	Clinical presentation, histopathological findings, and outcome of 15 patients with extramedullary gliomas of the spine without having arisen from a primary intramedullary glial or intracerebral neoplasms	Case Series	IV	71	1.1 (49th)
25	Goy A.M.C., Pinto R. S., Raghavendra B. N., Epstein F. J., Kricheff, II. Intramedullary spinal-cord tumors – MR imaging, with emphasis on associated cysts. Radiology, 1986. 161 (2): p. 381–386 [7].	Radiology-Intramedullary	Imaging characteristics of intramedullary spinal cord tumors on preoperative MRI and intraoperative spinal sonography	Case Series	IV	70	2.5 (37th)
26	Haft H., Ransohoff J., Carter S. Spinal cord tumors in children. Pediatrics, 1959. 23(6): p. 1152–1159 [27].	Natural history-Mixed	Natural history of spinal tumors, intra- and extramedullary, in 30 children below the age of 15 years	Case Series	IV	70	1.3 (47th)

(*continued on next page*)

Table 1 (*continued*)

Rank	Article	Article topic/ Tumor type	Article summary	Article type	Level of evidence	Citations	Citation rate (rank)
27	Brotchi J., Dewitte O., Levivier M. A survey of 65 tumors within the spinal-cord – Surgical results and the importance of preoperative magnetic-resonance-imaging. Neurosurgery, 1991. 29(5): p. 651–657 [20].	Outcome-Intramedullary	Three-month Outcome in 65 cases of intramedullary spinal cord tumors	Case Series	IV	69	3.3 (31st)
28	Barwick K.W., Huvos A.G., Smith J. Primary osteogenic-sarcoma of the vertebral column - A clinicopathologic correlation of 10 patients. Cancer, 1980. 46(3): p. 595–604 [19].	Natural history-Vertebral tumors	Clinical and pathological findings of 10 patients with osteogenic sarcoma of the vertebral column	Case Series	IV	69	2.1 (40th)
29	Woltman H.W., Kernohan J. W., Adson A. W., Craig W. M., et al. Intramedullary tumors of spinal cord and gliomas of intradural portion of filum terminale – Fate of patients who have these tumors. Ama Arch Neurol Psychiatry, 1951. 65 (3): p. 378–395 [2].	Natural history-Mixed	Clinical presentation and natural history of 124 patients with intramedullary spinal cord tumors, glioma of intradural filum terminale, and extramedullary gliomas	Case Series	IV	67	1.1 (50th)
30	Nassar S.I., Correll J.W. Subarachnoid hemorrhage due to spinal cord tumors. Neurology, 1968. 18(1P1): p. 87–94 [44].	Outcome- Mixed	Clinical presentation, histopathological findings and postoperative course of 4 patients with spine tumors who presented with subarachnoid hemorrhage of the spine	Case Series	IV	66	1.4 (46th)
31	Sanjay B.K.S., Sim F. H. Unni K. K., McLeod R. A. Klassen R. A. Giant-cell tumors of the spine. J Bone Joint Surg Br, 1993. 75(1): p. 148–154 [52].	Outcome-Vertebral tumors	Clinical outcome of 24 patients who were treated for vertebral giant cell tumors	Case Series	IV	65	3.4 (29th)
32	Parizel P.M., Baleriaux D. Rodesch G. GD-DTPA-enhanced MR imaging of spinal tumors. AJNR Am J Neuroradiol, 1989. 10(2): p. 249–258 [47].	Radiology- Mixed	Utility of GF-DTPA enhanced MR imaging for evaluation of spinal tumors	Case Series	IV	65	2.8 (34th)
33	Kiel F.W., Hansen J.L., Starr L.B. Primary melanoma of spinal. J Neurosurg, 1961. 18(5): p. 616–629 [33].	Other-Intramedullary	Case report of 33 year old female who was found on autopsy to have a primary melanoma of the spinal cord	Case Report	IV	65	1.2 (48th)
34	Thomas J.E., Miller R.H. Lipomatous tumors of spinal canal – Study of their clinical range. Mayo Clin Proc, 1973. 48 (6): p. 393–400 [54].	Outcome-Extramedullary	Clinical presentation and outcome of 60 patients with intra- or extradural lipomatous tumors of the spine	Case Series	IV	64	1.6 (44th)
35	Mautner V.F., Tatagiba M. Lindenau M., et al. Spinal tumors in patients with neurofibromatosis type-2 – MR-imaging study of frequency, multiplicity, and variety. AJR Am J Roentgenol, 1995. 165(4): p. 951–955 [39].	Radiology-Extramedullary	Radiological characteristics of spinal tumors in patients with known diagnosis of neurofibromatosis 2	Case Series	IV	60	4.1 (22nd)
36	Lunardi P., Missori P., Gagliardi F. M., Fortuna A. Long-term results of the surgical-treatment of spinal dermoid and epidermoid tumors. Neurosurgery, 1989. 25(6): p. 860–864 [37].	Outcome- Other	Outcome of 16 patients with spinal dermoid or epidermoid tumors	Case Series	IV	60	2.3 (39th)
37	McCormick, P.C. Surgical management of dumbbell and paraspinal tumors of the thoracic and lumbar spine. Neurosurgery, 1996. 38(1): p. 67–74 [41].	Surgical technique-Mixed	Outcome of single-staged lateral extracavitary approach for resection of thoracic spinal tumors	Case Series	IV	58	3.8 (24th)
38	McCormick, P.C. Surgical management of dumbbell tumors of the cervical spine. Neurosurgery, 1996. 38(2): p. 294–299 [40].	Surgical technique-Extramedullary	Surgical considerations of benign cervical extramedullary tumors illustrated in 12 patients	Case Series	IV	57	4.4 (17th)
39	Hart R.A., Boriani S., Biagini R., Currier B., Weinstein J. N.A system for surgical staging and management of spine tumors - A clinical outcome study of giant cell tumors of the spine. Spine, 1997. 22(15): p. 1773–1782 [29].	Outcome-Vertebral tumors	Application of Weinstein-Boriani-Biagini system to development of treatment plan and predicting outcomes in patients with giant cell tumors of the spine	Case Series	IV	57	4.3 (18th)
40	Fraser R.D., Paterson D.C. Simpson D.A. Orthopedic aspects of spinal tumors in children. J Bone Joint Surg Br, 1977. 59 (2): p. 143–151 [24].	Outcome-Mixed	Clinical presentation and surgical management of pediatric patients with spinal tumors with emphasis on post-operative spinal deformity and instability	Case Series	IV	57	1.6 (45th)

Table 1 (*continued*)

Rank	Article	Article topic/ Tumor type	Article summary	Article type	Level of evidence	Citations	Citation rate (rank)
41	Yeh J.S., Sgouros S., Walsh A. R., Hockley A. D. Spinal sagittal misalignment following surgery for primary intramedullary tumours in children. Pediatr Neurosurg, 2001. 35(6): p. 318–324 [56].	Outcome-Intramedullary	Factors that predict spinal sagittal misalignment in 27 pediatric patients with intramedullary spinal cord tumors	Case Series	IV	55	4.6 (16th)
42	Grubb M.R., Currier B. L., Pritchard D. J., Ebersold M. J. Primary ewings-sarcoma of the spine. Spine, 1994. 19(3): p. 309–313 [26].	Outcome-Vertebral tumors	Outcome of 36 patients with primary Ewing's sarcoma of the spine who underwent radiation therapy with or without decompressive laminectomy	Case Series	IV	55	3.4 (30th)
43	Klekamp J., Samii M. Surgery of spinal nerve sheath tumors with special reference to neurofibromatosis. Neurosurgery, 1998. 42(2): p. 279–289 [34].	Outcome-Extramedullary	Clinical outcome of 87 patients with neurofibromatosis 1 or 2 who underwent surgical resection of spinal nerve sheath tumors	Case Series	IV	55	2.9 (33rd)
44	Jinnai, T., Hoshimaru, M., Koyama, T. Clinical characteristics of spinal nerve sheath tumors: Analysis of 149 cases. Neurosurgery, 2005. 56(3): p. 510–515 [31].	Anatomical study-Extramedullary	Anatomical description of growth pattern of spinal nerve sheath tumors along the spinal nerve root at different spinal levels	Case Series	IV	54	8.9 (4th)
45	Quinones-Hinojosa, A., Lyon, R., Zada, G. Chances in transcranial motor evoked potentials during intramedullary spinal cord tumor resection correlate with postoperative motor function. Neurosurgery, 2005. 56(5): p. 982–992 [48].	Electrophysiology-Intramedullary	Utility of transcranial motor evoked potential to predict postoperative motor deficits in patients who undergo surgical resection of intramedullary spinal cord tumors	Case Series	IV	54	7.5 (6th)
46	Moran, C.A., Rush, W., Mena, H. Primary spinal paragangliomas: A clinicopathological and immunohistochemical study of 30 cases. Histopathology, 1997. 31(2): p. 167–173 [42].	Pathology-Mixed	Histopathological features of spinal paraganglioma as studied in 30 patients	Case Series	IV	54	6.3 (8th)
47	Schellinger K.A., Propp J. M., Villano J. L., McCarthy B. J. Descriptive epidemiology of primary spinal cord tumors. J Neurooncol, 2008. 87(2): p. 173–179 [3].	Epidemiology-Mixed	Epidemiological description of malignant and benign tumors of the spinal cord, spinal meninges and cauda equina	Epidemiological study	IV	54	4 (23rd)
48	Isaacson S.R. Radiation therapy and the management of intramedullary spinal cord tumors. J Neurooncol, 2000. 47(3): p. 231–238 [30].	Radiation-Intramedullary	Review of outcome of radiation therapy for intramedullary spinal cord tumors	Review	V	54	3.4 (28th)
49	Hakuba A, Komiyama M., Tsujimoto, T. Transuncodiscal approach to dumbbell tumors of the cervical spinal canal. J Neurosurg, 1984. **61**(6): p. 1100–1106 [28].	Surgical technique-Extramedullary	Authors describe a new technique, transincudiscal approach, which is a combined anterolateral approach to the anterior cervical spinal canal with fusion, in management of 5 patients with extramedullary dumbbell tumors of cervical spine	Case Series	IV	54	1.7 (43rd)
50	Dodd RL, Ryu, M. R., Kamnerdsupaphon, P., Gibbs, I. C., Chang, S. D., Adler, J. R. CyberKnife radiosurgery for benign intradural extramedullary spinal tumors. Neurosurgery, 2006. **58**(4): p. 674–685 [23].	Radiation-Extramedullary	Clinical outcome of 51 patients who underwent radiosurgical management of 55 intradural extramedullary tumors by cyberknife	Case Series	IV	52	5.8 (14th)

references, article topic, article summary, article type, level of evidence, total number of citations, and citation rate (average citations per year), are shown in Table 1. Publication years ranged from 1951 to 2008 with 1997 (6) and 1989 (5) yielding the most articles (Fig. 1). The oldest article was published in 1951 by Woltman et al., describing the clinical presentation and natural history of 119 patients with primary spinal tumors [2]. Schellinger's 2008 report on the epidemiology of non-malignant and malignant primary spinal cord tumors and associated survival rates was the most recently published article [3].

The most common article topic (Table 1) were outcome studies (14) followed by studies on natural history (6) and radiation (5). Spinal instability was the least common article topic, with only two studies ranked at 19th and 22nd (Table 1).

We divided the studies based on the type of primary spinal tumor, into intramedullary, extramedullary, and vertebral column. Two articles were categorized as "Other" which included articles on spinal dermoid and epidermoids, and spinal vascular tumors [36,50]. If more than one type of tumor was included in a study, the article was categorized as "mixed" (Table 1). Intramedullary tumors were studied in 21 articles, including 6 of the top 10 ranked articles (Fig. 2). Thirteen articles studied mixed types of tumors. Extramedullary and tumors of vertebral column were studied in 9 and 5 articles, respectively.

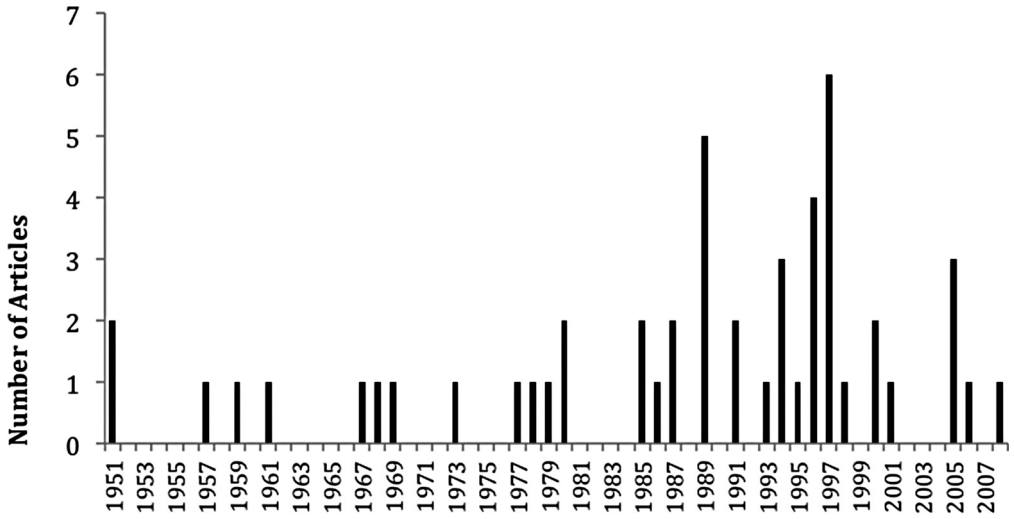

Fig. 1. Number of top-cited articles published each year.

Articles on the final list were published in 22 different journals (Fig. 3). Most articles were published in the following journals: *Neurosurgery* (12), *Journal of Neurosurgery* (8), and *Spine* (6). The most cited authors were F.J. Epstein [5–8] and S. Constantini [4,5,8] with authorship of 4 and 3 articles, respectively.

Tomita et al.'s 1997 paper in Spine was the most cited article with 199 citations [9]. It has been cited every year since its publication, with 2009 (23 citations) as its most-cited year. The second most cited article was published by Cooper et al. in 1985 which describes the neurological outcome of 29 patients with primary intramedullary tumors who underwent radical resection [6]. This article was cited most frequently in 2005 having had 13 citations. Cooper et al. authored the third-most cited article in 1989 [10]. In this report, the author expands on a previous report examining patient outcomes following resection of intramedullary spinal cord tumors with increased patient numbers, and longer follow-up. This article was most frequently cited in 2007 with 12 citations.

The citation rate – average number of citations per year – for each article is shown in Table 1. Tomita et al.'s article in 1997 on total en bloc spondylectomy received citations at the highest rate (12.9 citations per year). Sala et al.'s 2006 neurophysiological report was the study with the second highest rate of citation at 12.8 citations per year [11]. The authors described the utility of motor evoked potential to improve the long-term motor outcome in patients undergoing surgical resection of intramedullary spinal cord tumor (ISCT). The study with third highest rate of citation at 10.3 citations annually was Constantini et al.'s report in 2000 describing the neurological outcome and survival of 164 patients 21 years old or younger who underwent surgical resection of ISCT at 5 years of follow up [5] .

4. Discussion

The present study utilizes citation analysis – the measure of an articles impact based on the number of times it has been cited [12] –to identify the articles, authors, and journals that reflect innovations in the field of primary tumors of the spine and provide historical perspectives on the trends and topics that have been the focus of research in the field.

Studies using citation analysis as a bibliometric indicator serve various functions for readers. For the vast majority, they serve as a centralized reference of articles, both old and new, that have left their mark on the field and its members. It is our intent that readers refer to this list as a basis for understanding critical developments in the field of management of primary tumors of the spine.

Publication dates among the top 50 most cited articles ranged between 1951 and 2008. The oldest article was published by Woltman et al. The authors discussed the clinical presentation and natural history of 79 patients with intramedullary spinal cord tumors, 45 patients with glioma of the intradural filum terminale and 5 patients with extramedullary gliomas that had presented to Mayo Clinic between 1916 and 1939 [2]. In the most recent article on our list, Schellinger et al. used epidemiological data from 1998 to 2002 in 16 Central Brain Tumor Registries of the Unites States to estimate the incidence of both non-malignant and malignant primary spinal cord tumors. They also estimate survival rate, year by year from the time of diagnosis up to 10 years post-diagnosis, of patients with primary malignant astrocytoma and ependymoma, stratified by age at the time of diagnosis [3]. Our search criteria included all English articles published between 1945 and 2016, however, there is an inherent bias in citation analysis favoring older articles. That is, an article is more likely to accumulate citations the longer it has remained in the literature. Such a trend is not substantiated by this series of articles. In our report, the median publication year was 1991 with most articles having been published in 1997.

We made several observations concerning the characteristics of articles. The greatest proportion of articles pertained to intramedullary tumors (21 articles, 42%). Furthermore, four of the top five ranked articles pertain to intramedullary tumors. The majority of articles were outcome studies (18 articles, 36%). Case series predominated the list with 42 articles (84%). The highest level of evidence (II) was from a 1997 study by Morota et al. who conducted a prospective study of 32 consecutive patients investigating the utility of motor-evoked potential in predicting motor outcomes of patients undergoing resection of intramedullary tumors [8]. This article was ranked 9th based on total number of citations. Of note, there is a distinct lack of level I evidence with level IV studies comprising nearly the entire list (45 articles, 90%).

Despite the intramedullary tumors being the most common, the most cited article, in terms of both total citations and citation rank, was about vertebral tumors published in 1997 by Tomita et al. [9]. The authors present a novel technique, total en bloc spondylectomy, consisting of en bloc laminectomy and en bloc corpectomy followed by anterior instrumentation with spacer grafting and posterior spinal instrumentation. In a retrospective case series, authors describe the clinical outcome of 7 patients, 5 with primary

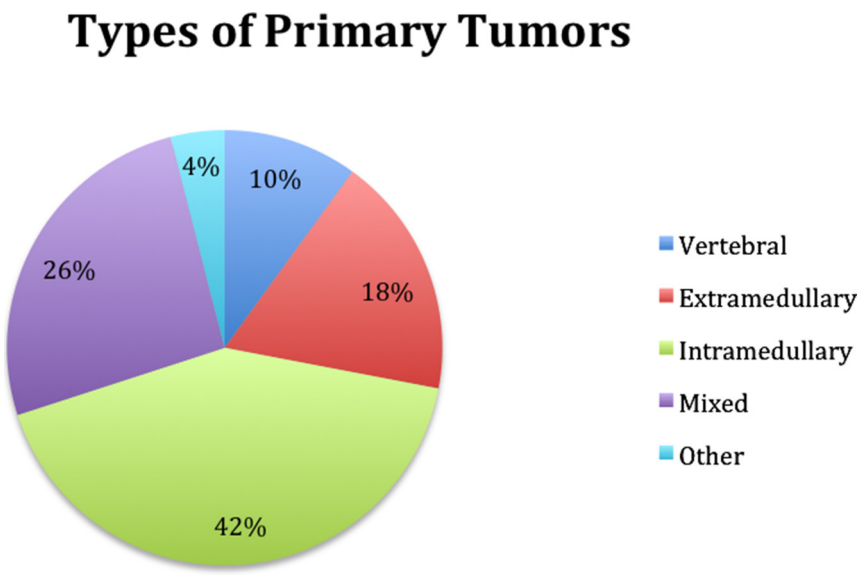

Fig. 2. Percentage of articles based on type of primary spinal tumors. Other designates articles (total of 2) that studied spinal dermoid and epidermoids, spinal vascular tumors.

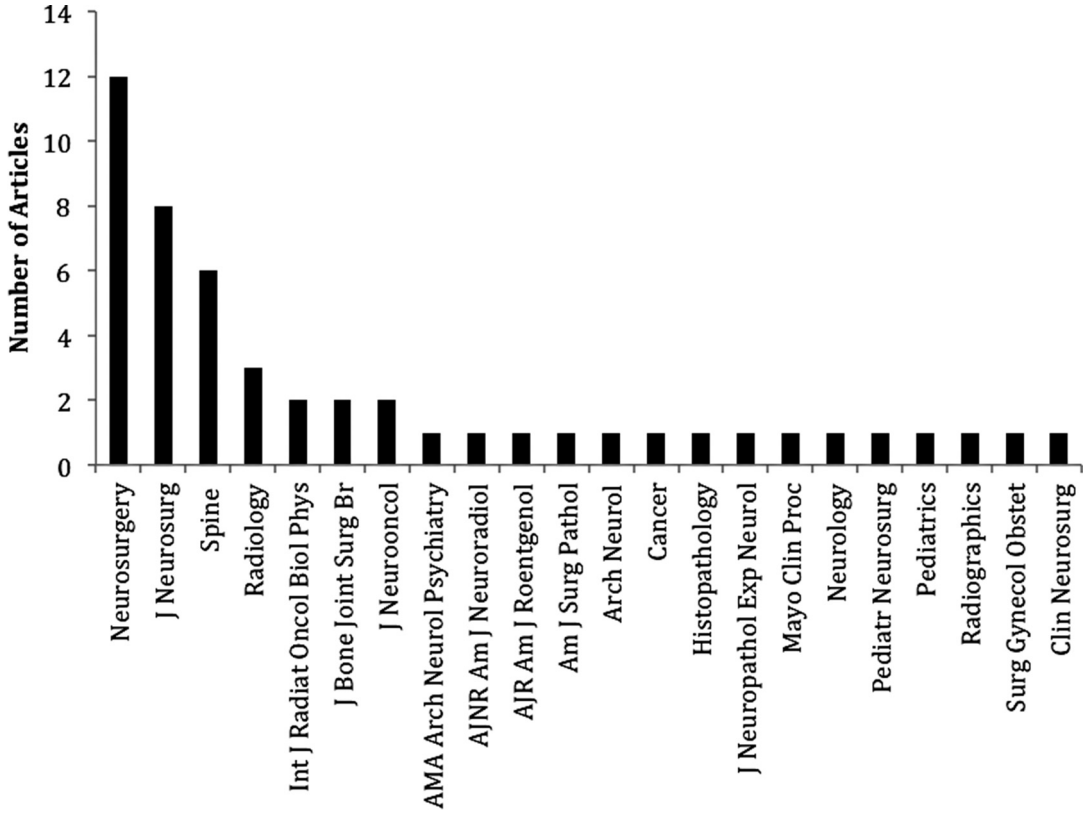

Fig. 3. Number of articles published by each journal.

malignant tumors of the vertebral column and 2 with giant cell tumors who had undergone surgical resection utilizing this new technique. Since its publication in 1997, Tomita's study has been cited 199 times, and at 12.9 citations per year.

Although the use of citation analysis has become widespread, the technique has been criticized on many accounts [13–15]. An article's total number of citations may not accurately reflect its impact. Naturally, articles that were published earlier would have a higher chance of being cited and hence being included in the 50 most cited list. This is an inherent bias. Nevertheless, we believe providing the data on the total number of citations provides a historical perspective, allowing the readers to be exposed to articles that have been referenced throughout the years. In an attempt to address the bias, and to refine our interpretation of an article's impact, we calculated an articles citation rate, defined as the average number of citations per year. We provided a separate ranking

based on this variable to supplement the ranking based on the total number of citations. The two variables, total number of citations and number of citations per year, when considered together, would provide the best perspective on both historically important articles and articles that have had a more rapid impact on the literature in the field of primary tumors of the spine. Tomita et al.'s 1997 article has been cited at the fastest rate (12.9 citations per year). The impact of this article is made evident by the fact that it has accumulated the most citations amongst papers on the final list in a relatively short time period. Furthermore, this work has continued to be highly cited in recent years, including 13 citations in 2015, suggesting that its impact has persisted since its publication.

Throughout the derivation of this list, several measures were taken in order to account for potential limitations. Citation analysis is complicated by self-citation, whereby authors will cite their own publications in subsequent articles [16]. Self-citation could potentially inflate the number of citations for a given article, artificially exaggerating the importance of the article's contribution to the field. This may not always be true. Alternatively, authors of pioneering studies with novel findings will often self-cite as their work represents the quintessential study pertaining to the article topic. However, we reasoned that the association between citation count and an article's impact is best interpreted when only considering citations made by others (non-authors) in the field. As such, we excluded self-citations in our analyses. Using our method to determine self-citations, we found that an average of 8 self-citations were removed per article.

Despite the attempts to eliminate potential flaws in our citation analysis, there are concerns intrinsic to this method that complicate the interpretation of our results. In order to reflect the most influential articles in the field of primary tumors of the spine, we chose to include articles that had at least 50 citations upon exclusion of self-citations. This limited the number of articles to 75 of which we hereby present the top 50. Citation analysis is not devoid of bias. One assumption that must be considered for citation analysis is the size of the target audience of an article. Factors including article topic, article type, journal, and year published affect the number of readers an article attracts. In order to appropriately account for audience size, normalization of this variable would be necessary. Another assumption of citation analysis is that articles being cited are integral to the work of authors citing them. Authors, however, may cite articles without reading the manuscript in its entirety, thus complicating the interpretation that citing an article reflects the merit and impact of the article on the citing author. Finally, we must acknowledge the idea of implicit citations which postulates that scientific concepts that are widely known no longer require citation as they are accepted as common knowledge in the field [14]. Overall, despite these limitations, which we have attempted to address when possible, citation analysis of articles of primary tumors of the spine provides a valuable bibliographic profile of the field.

5. Conclusion

We identified the 50 most cited articles related to the primary tumors the spine using citation analysis. The information collected can be used to identify the trends of research focus in the field of primary tumors of the spine and provide readers with an understanding of the studies that have impacted the field. Distinct absence of level I evidence and predominance of case series and level IV evidence studies is reflective of the rarity and heterogeneity of the primary tumors of the spine, underlining the need for higher quality studies via multidisciplinary, multicenter collaboration.

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