See the corresponding introduction, editorial, and article in this issue, pp 219–222 and pp 233–246.

**J Neurosurg 112:**223–232, 2010

# Highly cited works in neurosurgery. Part I: the 100 top-cited papers in neurosurgical journals

## A review

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*Object*. The number of citations a published article receives is a measure of its impact in the scientific community. This study identifies and characterizes the current 100 top-cited articles in journals specifically dedicated to neurosurgery.

*Methods*. Neurosurgical journals were identified using the Institute for Scientific Information Journal Citation Reports. A search was performed using Institute for Scientific Information Web of Science for articles appearing in each of these journals. The 100 top-cited articles were selected and analyzed.

*Results*. The 100 most cited manuscripts in neurosurgical journals appeared in 3 of 13 journals dedicated to neurosurgery. These included 79 in the *Journal of Neurosurgery,* 11 in the *Journal of Neurology, Neurosurgery and Psychiatry*, and 10 in *Neurosurgery*. The individual citation counts for these articles ranged from 287 to 1515. Seventy-seven percent of articles were published between 1976 and 1995. Representation varied widely across neurosurgical disciplines, with cerebrovascular diseases leading (43 articles), followed by trauma (27 articles), stereotactic and functional neurosurgery (13 articles), and neurooncology (12 articles). The study types included 5 randomized trials, 5 cooperative studies, 1 observational cohort study, 69 case series, 8 review articles, and 12 animal studies. Thirty articles dealt with surgical management and 12 with nonsurgical management. There were 15 studies of natural history of disease or outcomes after trauma, 11 classification or grading scales, and 10 studies of human pathophysiology.

*Conclusions*. The most cited articles in neurosurgical journals are trials evaluating surgical or medical therapies, descriptions of novel techniques, or systems for classifying or grading disease. The time of publication, field of study, nature of the work, and the journal in which the work appears are possible determinants of the likelihood of citation and impact. *(DOI: 10.3171/2009.12.JNS091599)*

**Key Words • citation analysis • neurosurgery • bibliometrics • landmark articles**

A small number of studies have a disproportionate impact in neurosurgery. These are the studies that have helped define the way that our discipline is practiced by serving as the foundation for new methods, procedures, or concepts. A surrogate for measuring the impact of a new idea or finding in the scientific or medical community is the number of times that article has been cited (the citation count). The purpose of this study is to identify, using the citation count, works that have made key contributions in the field and are driving or have driven the practice of neurosurgery.

This issue has been previously considered. Between 1962 and 1965, Wilkins[10] presented a collection of personally so-designated classic works relating to the development or practice of neurosurgery. These were published in a series of installments in the *Journal of Neurosurgery*, and later appeared in book form as *Neurosurgical Classics*.[10]

*Abbreviations used in this paper:* ACD = anterior cervical discectomy; AVM = arteriovenous malformation; CM = cavernous malformation; DAVF = dural arteriovenous fistula; DBS = deep brain stimulation; *JNNP = Journal of Neurology, Neurosurgery and Psychiatry*; PD = Parkinson disease; SAH = subarachnoid hemorrhage; SCI = spinal cord injury; SHI = severe head injury.

In 1962, the Science Citations Index was initiated at the Institute for Scientific Information with the purpose of maintaining a systematic ongoing measurement of the citation counts for scientific journals. The study and analysis of citation indexes, or bibliometrics, have resulted in the development of various metrics to assess the impact of scientific journals or individual investigators based on the number of citations to their respective works. In the present study, we take advantage of these tools, not readily available in the past, to identify the important works in neurosurgery.

The study is presented in 2 parts. In this first part, we identify the 100 top-cited articles published in neurosurgical journals since 1950 and provide an analysis of the fields and types of study represented in these articles. In Part II,[6] we will identify peer-reviewed articles pertinent to clinical neurosurgery that have received more than 400 citations—the operational definition of a citation classic.[4,7]

## Methods

The focus of this part of the study is limited to journals specifically dedicated to neurosurgery. Such a restriction provides a starting point from which to identify topics that draw the most citations. The source of the data presented in this study is the web-based bibliometric database Web of Science and Journal Citation Report, both by the Institute for Scientific Information. We identified 11 neurosurgical journals by searching the Journal Citation Report database for publications with the words "neurosurgery" or "neurosurgical" in the title. This search identified a journal specializing in neurosurgical anesthesiology, which was excluded from our analysis. The journals *Surgical Neurology* and *Acta Neurochirurgica*, not captured using this approach, were also included. A search was then performed on Web of Science of each journal under "Publication Name," and results were sorted by the category "Times Cited." This provided a list of all articles appearing in a given journal ranked by citation count.

The journal *Spine* was also considered for inclusion, and 32 articles were found in *Spine* that had been cited over 265 times (a cutoff value corresponding to the number of citations for the 100th most cited article in the *Journal of Neurosurgery*). None of these articles were written primarily by a neurosurgeon; thus, despite the overlap and relevance of the topics covered in *Spine* with neurosurgery, the journal was not considered a neurosurgical journal for the purposes of this study. Highly cited neurosurgical papers appearing in general medical journals are considered in Part II.[6] Journals specific to neuroradiology and stroke were also omitted. The database for this study was compiled in August 2009, and the numbers presented thus reflect the citation counts at that time.

## Results

### *Sources and Citations*

Thirteen journals were identified that met the aforementioned criteria and are shown in Table 1. The top-cited articles from each journal were identified using the Web of Science. Given that many articles in the *JNNP* are specific to neurology or psychiatry, we limited the articles from this journal to those pertinent to neurosurgery. The title and abstract of the 58 articles in *JNNP* that had been cited > 265 times were reviewed, as well as the number of citations to these articles made by other neurosurgical journals. There were 46 articles in *JNNP* that were determined to be nonneurosurgical.

**TABLE 1: List of screened neurosurgical journals**

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|---|
| *Acta Neurochirurgica* |
| *British Journal of Neurosurgery* |
| *Clinical Neurology and Neurosurgery* |
| *Journal of Neurology, Neurosurgery and Psychiatry* |
| *Journal of Neurosurgery* |
| *Minimally Invasive Neurosurgery* |
| *Neurosurgery* |
| *Neurosurgery Clinics of North America* |
| *Neurosurgical Review* |
| *Neurosurgery Quarterly* |
| *Pediatric Neurosurgery* |
| *Stereotactic and Functional Neurosurgery* |
| *Surgical Neurology* |

The most cited articles in all 13 neurosurgical journals were sorted by the citation counts. Among the 100 top-cited papers (Table 2), there were 79 articles from the *Journal of Neurosurgery*, 11 from *JNNP*, and 10 from *Neurosurgery* (Table 3). The citation counts ranged from 287 to 1515, and the years of publication ranged from 1956 to 2001, with 77 having been published between 1976 and 1995, 19 before 1976, and 4 after 1995.

In the following sections, the numbers in parentheses represent the ranking of the articles in terms of number of citations. The corresponding articles can be found in Table 2.

### *Field of Study*

The articles were categorized as studies concerning cerebrovascular disease, trauma, tumors, or functional neurosurgery. Spinal cord injury was included under trauma, and stereotaxy, epilepsy, and pain were included under functional neurosurgery. Ninety-five of the articles fell under 1 of these 4 categories; in addition, 5 articles were about syringomyelia, hydrocephalus, infection, and spine surgery (Table 4).

The greatest number of articles in the top 100 were in the field of cerebrovascular disease (43 articles). These included 19 articles on the management of intracranial aneurysms, of which 5 were studies on vasospasm (Nos. 3, 42, 43, 70, 100), 5 were studies on endovascular techniques (Nos. 11, 19, 25, 26, 46), 4 were cooperative studies on SAH (Nos. 6, 15, 31, 51), 3 were grading systems concerning SAH (Nos. 1, 3, 39), 1 was a technical note for microneurosurgery (No. 68), and 1 was a laboratory study (No. 92). There were 8 articles on AVMs, including 3 papers on the natural history (Nos. 49, 58, 76), 2 on

**TABLE 2: Top 100 cited articles in neurosurgical journals ranked in order of citations received**

| Rank | Article | No. of Times Cited |
|---|---|---|
| 1. | Hunt WE, Hess RM: Surgical risk as related to time of intervention in the repair of intracranial aneurysms. **J Neurosurg 28:** 14–20, 1968 | 1515 |
| 2. | Aaslid R, Markwalder TM, Nornes H: Noninvasive transcranial Doppler ultrasound recording of flow velocity in basal cerebral arteries. **J Neurosurg 57:**769–774, 1982 | 1464 |
| 3. | Fisher CM, Kistler JP, Davis JM: Relation of cerebral vasospasm to subarachnoid hemorrhage visualized by computerized tomographic scanning. **Neurosurgery 6:**1–9, 1980 | 1211 |
| 4. | Levy RM, Bredesen DE, Rosenblum ML: Neurological manifestations of the acquired immunodeficiency syndrome (AIDS): experience at UCSF and review of the literature. **J Neurosurg 62:**475–495, 1985 | 1007 |
| 5. | Walker MD, Alexander E Jr, Hunt WE, MacCarty CS, Mahaley MS Jr, Mealey J Jr, Norrell HA, Owens G, Ransohoff J, Wilson CB, Gehan EA, Strike TA: Evaluation of BCNU and/or radiotherapy in the treatment of anaplastic gliomas. A cooperative clinical trial. **J Neurosurg 49:**333–343, 1978 | 930 |
| 6. | Kassell NF, Torner JC, Haley EC Jr, Jane JA, Adams HP, Kongable GL: The International Cooperative Study on the Timing of Aneurysm Surgery. Part 1: Overall management results. **J Neurosurg 73:**18–36, 1990 | 922 |
| 7. | Wada J, Rasmussen T: Intracarotid injection of sodium amytal for the lateralization of cerebral speech dominance. Experimental and clinical observations. **J Neurosurg 17:**266–282, 1960 | 876 |
| 8. | Cloward RB: The anterior approach for removal of ruptured cervical disks. **J Neurosurg 15:**602–617, 1958 | 725 |
| 9. | Laitinen LV, Bergenheim AT, Hariz MI: Leksell's posteroventral pallidotomy in the treatment of Parkinson's disease. **J Neurosurg 76:**53–61, 1992 | 668 |
| 10. | Siesjo BK: Pathophysiology and treatment of focal cerebral ischemia. Part I: Pathophysiology. **J Neurosurg 77:**169–184, 1992 | 667 |
| 11. | Guglielmi G, Vinuela F, Dion J, Duckwiler G: Electrothrombosis of saccular aneurysms via endovascular approach. Part 2: Preliminary clinical experience. **J Neurosurg 75:**8–14, 1991 | 660 |
| 12. | Jones TH, Morawetz RB, Crowell RM, Marcoux FW, Fitzgibbon SJ, Degirolami U, Ojemann RG: Thresholds of focal cerebral ischemia in awake monkeys. **J Neurosurg 54:**773–782, 1981 | 658 |
| 13. | Spetzler RF, Martin NA: A proposed grading system for arteriovenous malformations. **J Neurosurg 65:**476–483, 1986 | 651 |
| 14. | Simpson D: The recurrence of intracranial meningiomas after surgical treatment. **J Neurol Neurosurg Psychiatry 20:**22–39, 1957 | 636 |
| 15. | Locksley H: Natural history of subarachnoid hemorrhage, intracranial aneurysms and arteriovenous malformations. **J Neurosurg 25:**321–368, 1966 | 626 |
| 16. | Katayama Y, Becker DP, Tamura T, Hovda DA: Massive increases in extracellular potassium and the indiscriminate release of glutamate following concussive brain injury. **J Neurosurg 73:**889–900, 1990 | 556 |
| 17. | Rimel RW, Giordani B, Barth JT, Boll TJ, Jane JA: Disability caused by minor head injury. **Neurosurgery 9:**221–228, 1981 | 553 |
| 18. | Becker DP, Miller JD, Ward JD, Greenberg RP, Young HF, Sakalas R: The outcome from severe head injury with early diagnosis and intensive management. **J Neurosurg 47:**491–502, 1977 | 551 |
| 19. | Serbinen FA: Balloon catheterization and occlusion of major cerebral vessels. **J Neurosurg 41:**125–145, 1974 | 551 |
| 20. | Ojemann G, Ojemann J, Lettich E, Berger M: Cortical language localization in left, dominant hemisphere. An electrical stimulation mapping investigation in 117 patients. **J Neurosurg 71:**316–326, 1989 | 542 |
| 21. | Taylor DC, Falconer MA, Bruton CJ, Corsellis JA: Focal dysplasia of the cerebral cortex in epilepsy. **J Neurol Neurosurg Psychiatry 34:**369–387, 1971 | 540 |
| 22. | Obrist WD, Langfitt TW, Jaggi JL, Cruz J, Gennarelli TA: Cerebral blood flow and metabolism in comatose patients with acute head injury. Relationship to intracranial hypertension. **J Neurosurg 61:**241–253, 1984 | 536 |
| 23. | Siesjo BK: Pathophysiology and treatment of focal cerebral ischemia. Part II: Mechanisms of damage and treatment. **J Neurosurg 77:**337–354, 1992 | 531 |
| 24. | Tator CH, Fehlings MG: Review of the secondary injury theory of acute spinal cord trauma with emphasis on vascular mechanisms. **J Neurosurg 75:**15–26, 1991 | 523 |
| 25. | Viñuela F, Duckwiler G, Mawad M: Guglielmi detachable coil embolization of acute intracranial aneurysm: perioperative anatomical and clinical outcome in 403 patients. **J Neurosurg 86:**475–482, 1997 | 516 |
| 26. | Guglielmi G, Viñuela F, Sepetka I, Macellari V: Electrothrombosis of saccular aneurysms via endovascular approach. Part 1: Electrochemical basis, technique, and experimental results. **J Neurosurg 75:**1–7, 1991 | 511 |
| 27. | Benabid AL, Pollak P, Gao DM, Hoffmann D, Limousin P, Gay E, Payen I, Benazzouz A: Chronic electrical stimulation of the ventralis intermedius nucleus of the thalamus as a treatment of movement disorders. **J Neurosurg 84:**203–214, 1996 | 480 |

*(continued)*

**TABLE 2: Top 100 cited articles in neurosurgical journals ranked in order of citations received *(continued)***

| Rank | Article | No. of Times Cited |
|---|---|---|
| 28. | Dixon CE, Lyeth BG, Povlishock JT, Findling RL, Hamm RJ, Marmarou A, Young HF, Hayes RL: A fluid percussion model of experimental brain injury in the rat. **J Neurosurg 67:**110–119, 1987 | 480 |
| 29. | Hochberg FH, Miller DC: Primary central nervous system lymphoma. **J Neurosurg 68:**835–853, 1988 | 472 |
| 30. | Bamford J, Sandercock P, Dennis M, Burn J, Warlow C: A prospective study of acute cerebrovascular disease in the community: the Oxfordshire Community Stroke Project—1981-86. 2. Incidence, case fatality rates and overall outcome at one year of cerebral infarction, primary intracerebral and subarachnoid haemorrhage. **J Neurol Neurosurg Psychiatry 53:**16–22, 1990 | 469 |
| 31. | Kassell NF, Torner JC, Jane JA, Haley EC, Adams HP: The International Cooperative Study on the Timing of Aneurysm Surgery. Part 2: Surgical results. **J Neurosurg 73:**37–47, 1990 | 460 |
| 32. | Perret G, Nishioka H: Report on the cooperative study of intracranial aneurysms and subarachnoid hemorrhage. Arteriovenous malformations. An analysis of 545 cases of cranio-cerebral arteriovenous malformations and fistulae reported to the cooperative study. **J Neurosurg 25:**467–490, 1966 | 454 |
| 33. | Gardner WJ: Hydrodynamic mechanism of syringomyelia: its relationship to myelocele. **J Neurol Neurosurg Psychiatry 28:** 247–259, 1965 | 449 |
| 34. | Levin HS, Mattis S, Ruff RM, Eisenberg HM, Marshall LF, Tabaddor K, High WM Jr, Frankowski RF: Neurobehavioral outcome following minor head injury: a three-center study. **J Neurosurg 66:**234–243, 1987 | 447 |
| 35. | Mirimanoff RO, Dosoretz DE, Linggood RM, Ojemann RG, Martuza RL: Meningioma: analysis of recurrence and progression following neurosurgical resection. **J Neurosurg 62:**18–24, 1985 | 440 |
| 36. | Rosner MJ, Rosner SD, Johnson AH: Cerebral perfusion pressure: management protocol and clinical results. **J Neurosurg 83:** 949–962, 1995 | 434 |
| 37. | Muizelaar JP, Marmarou A, Ward JD, Kontos HA, Choi SC, Becker DP, Gruemer H, Young HF: Adverse effects of prolonged hyperventilation in patients with severe head injury: a randomized clinical trial. **J Neurosurg 75:**731–739, 1991 | 432 |
| 38. | Miller JD, Becker DP, Ward JD, Sullivan HG, Adams WE, Rosner MJ: Significance of intracranial hypertension in severe head injury. **J Neurosurg 47:**503–516, 1977 | 423 |
| 39. | Drake CG: Report of World Federation of Neurological Surgeons Committee on a universal subarachnoid hemorrhage grading scale. **J Neurosurg 68:**985–986, 1988 | 409 |
| 40. | Backlund EO, Granberg PO, Hamberger B, Knutsson E, Mårtensson A, Sedvall G, Seiger A, Olson L: Transplantation of adrenal medullary tissue to striatum in parkinsonism. First clinical trials. **J Neurosurg 62:**169–173, 1985 | 407 |
| 41. | Racine R: Kindling: the first decade. **Neurosurgery 3:**234–252, 1978 | 402 |
| 42. | Kassell NF, Peerless SJ, Durward QJ, Beck DW, Drake CG, Adams HP: Treatment of ischemic deficits from vasospasm with intravascular volume expansion and induced arterial hypertension. **Neurosurgery 11:**337–343, 1982 | 395 |
| 43. | Aaslid R, Huber P, Nornes H: Evaluation of cerebrovascular spasm with transcranial Doppler ultrasound. **J Neurosurg 60:**37–41, 1984 | 393 |
| 44. | Woolsey CN, Erickson TC, Gilson WE: Localization in somatic sensory and motor areas of human cerebral cortex as determined by direct recording of evoked potentials and electrical stimulation. **J Neurosurg 51:**476–506, 1979 | 391 |
| 45. | Siesjo BK: Cerebral circulation and metabolism. **J Neurosurg 60:**883–908, 1984 | 386 |
| 46. | Guglielmi G, Viñuela F, Duckwiler G, Dion J, Lylyk P, Berenstein A, Strother C, Graves V, Halbach V, Nichols D, Hopkins N, Ferguson R, Sepetka I: Endovascular treatment of posterior circulation aneurysms by electrothrombosis using electrically detachable coils. **J Neurosurg 77:**515–524, 1992 | 385 |
| 47. | Jennett B, Snoek J, Bond MR, Brooks N: Disability after severe head injury: observations on the use of the Glasgow Outcome Scale. **J Neurol Neurosurg Psychiatry 44:**285–293, 1981 | 384 |
| 48. | Bouma G, Muizelaar J, Choi S, Newlon P, Young H: Cerebral circulation and metabolism after severe traumatic brain injury: the elusive role of ischemia. **J Neurosurg 75:**685–693, 1991 | 383 |
| 49. | Ondra SL, Troupp H, George ED, Schwab K: The natural history of symptomatic arteriovenous malformations of the brain: a 24-year follow-up assessment. **J Neurosurg 73:**387–391, 1990 | 382 |
| 50. | Kelly PJ, Daumas-Duport C, Kispert DB, Kall BA, Scheithauer BW, Illig JJ: Imaging-based stereotaxic serial biopsies in untreated intracranial glial neoplasms. **J Neurosurg 66:**865–874, 1987 | 372 |
| 51. | Locksley HB: Natural history of subarachnoid hemorrhage, intracranial aneurysms and arteriovenous malformations. Based on 6368 cases in the Cooperative Study. **J Neurosurg 25:**321–368, 1966 | 370 |
| 52. | Miller JD, Butterworth JF, Gudeman SK, Faulkner JE, Choi SC, Selhorst JB, Harbison JW, Lutz HA, Young HF, Becker DP: Further experience in the management of severe head injury. **J Neurosurg 54:**289–299, 1981 | 370 |

*(continued)*

**TABLE 2: Top 100 cited articles in neurosurgical journals ranked in order of citations received *(continued)***

| Rank | Article | No. of Times Cited |
|---|---|---|
| 53. | Robinson JR, Awad IA, Little JR: Natural history of the cavernous angioma. **J Neurosurg 75:**709–714, 1991 | 370 |
| 54. | Daumas-Duport C, Scheithauer BW, Chodkiewicz JP, Laws ER Jr, Vedrenne C: Dysembryoplastic neuroepithelial tumor: a surgically curable tumor of young patients with intractable partial seizures. Report of thirty-nine cases. **Neurosurgery 23:**545–556, 1988 | 363 |
| 55. | McCormick WF: The pathology of vascular ("arteriovenous") malformations. **J Neurosurg 24:**807–816, 1966 | 361 |
| 56. | Black PM, Moriarty T, Alexander E III, Stieg P, Woodard EJ, Gleason PL, Martin CH, Kikinis R, Schwartz RB, Jolesz FA: Development and implementation of intraoperative magnetic resonance imaging and its neurosurgical applications. **Neurosurgery 41:**831–845, 1997 | 356 |
| 57. | Lacroix M, Abi-Said D, Fourney DR, Gokaslan ZL, Shi W, DeMonte F, Lang FF, McCutcheon IE, Hassenbusch SJ, Holland E, Hess K, Michael C, Miller D, Sawaya R: A multivariate analysis of 416 patients with glioblastoma multiforme: prognosis, extent of resection, and survival. **J Neurosurg 95:**190–198, 2001 | 356 |
| 58. | Graf CJ, Perret GE, Torner JC: Bleeding from cerebral arteriovenous malformations as part of their natural history. **J Neurosurg 58:**331–337, 1983 | 355 |
| 59. | Rivlin AS, Tator CH: Objective clinical assessment of motor function after experimental spinal cord injury in the rat. **J Neurosurg 47:**577–581, 1977 | 355 |
| 60. | Jennett B, Teasdale G, Galbraith S, Pickard J, Grant H, Braakman R, Avezaat C, Maas A, Minderhoud J, Vecht CJ, Heiden J, Small R, Caton W, Kurze T: Severe head injuries in three countries. **J Neurol Neurosurg Psychiatry 40:**291–298, 1977 | 354 |
| 61. | Harper AM, Glass HI: Effect of alterations in the arterial carbon dioxide tension on the blood flow through the cerebral cortex at normal and low arterial blood pressures. **J Neurol Neurosurg Psychiatry 28:**449–452, 1965 | 352 |
| 62. | Laws ER, Taylor WF, Clifton MB, Okazaki H: Neurosurgical management of low-grade astrocytoma of the cerebral hemispheres. **J Neurosurg 61:**665–673, 1984 | 347 |
| 63. | Lunsford LD, Kondziolka D, Flickinger JC, Bissonette DJ, Jungreis CA, Maitz AH, Horton JA, Coffey RJ: Stereotactic radiosurgery for arteriovenous malformations of the brain. **J Neurosurg 75:**512–524, 1991 | 340 |
| 64. | Marmarou A, Foda MAA, Vandenbrink W, Campbell J, Kita H, Demetriadou K: A new model of diffuse brain injury in rats. Part I: Pathophysiology and biomechanics. **J Neurosurg 80:**291–300, 1994 | 338 |
| 65. | Strich SJ: Diffuse degeneration of the cerebral white matter in severe dementia following head injury. **J Neurol Neurosurg Psychiatry 19:**163–185, 1956 | 331 |
| 66. | Evans AE, Jenkin RD, Sposto R, Ortega JA, Wilson CB, Wara W, Ertel IJ, Kramer S, Chang CH, Leikin SL, Hammond GD: The treatment of medulloblastoma. Results of a prospective randomized trial of radiation therapy with and without CCNU, vincristine, and prednisone. **J Neurosurg 72:**572–582, 1990 | 329 |
| 67. | Harper AM, Glass HI: Effect of alterations in the arterial carbon dioxide tension on the blood flow through the cerebral cortex at normal and low arterial blood pressures. **J Neurol Neurosurg Psychiatry 28:**449–452, 1965 | 329 |
| 68. | Botterell EH, Lougheed WM, Scott JW, Vandewater SL: Hypothermia, and interruption of carotid, or carotid and vertebral circulation, in the surgical management of intracranial aneurysms. **J Neurosurg 13:**1–42, 1956 | 327 |
| 69. | Bracken MB, Shepard MJ, Collins WF Jr, Holford TR, Baskin DS, Eisenberg HM, Flamm E, Leo-Summers L, Maroon JC, Marshall LF, Perot PL, Piepmeier J, Sonntag VKH, Wagner FC, Wilberger JL, Winn HR, Young W: Methylprednisolone or naloxone treatment after acute spinal cord injury: 1-year follow-up data. Results of the second National Acute Spinal Cord Injury Study. **J Neurosurg 76:**23–31, 1992 | 326 |
| 70. | Weir B, Grace M, Hansen J, Rothberg C: Time course of vasospasm in man. **J Neurosurg 48:**173–178, 1978 | 325 |
| 71. | Marshall LF, Smith RW, Shapiro HM: The outcome with aggressive treatment in severe head injuries. Part I: the significance of intracranial pressure monitoring. **J Neurosurg 50:**20–25, 1979 | 323 |
| 72. | Barker AT, Freeston IL, Jalinous R, Jarratt JA: Magnetic stimulation of the human brain and peripheral nervous system: an introduction and the results of an initial clinical evaluation. **Neurosurgery 20:**100–109, 1987 | 322 |
| 73. | Jennings MT, Gelman R, Hochberg F: Intracranial germ-cell tumors: natural history and pathogenesis. **J Neurosurg 63:**155–167, 1985 | 321 |
| 74. | Narayan RK, Greenberg RP, Miller JD, Enas GG, Choi SC, Kishore PRS, Selhorst JB, Lutz HA III, Becker DP: Improved confidence of outcome prediction in severe head injury. A comparative analysis of the clinical examination, multimodality evoked potentials, CT scanning, and intracranial pressure. **J Neurosurg 54:**751–762, 1981 | 321 |
| 75. | Jennett B, Teasdale G, Braakman R, Minderhoud J, Heiden J, Kurze T: Prognosis of patients with severe head injury. **Neurosurgery 4:**283–289, 1979 | 319 |

*(continued)*

**TABLE 2: Top 100 cited articles in neurosurgical journals ranked in order of citations received *(continued)***

| Rank | Article | No. of Times Cited |
|---|---|---|
| 76. | Crawford PM, West CR, Chadwick DW, Shaw MD: Arteriovenous malformations of the brain: natural history in unoperated patients. **J Neurol Neurosurg Psychiatry 49:**1–10, 1986 | 313 |
| 77. | Jannetta PJ: Arterial compression of the trigeminal nerve at the pons in patients with trigeminal neuralgia. **J Neurosurg 26 Suppl:**159–162, 1967 | 313 |
| 78. | Simard JM, Garciabengochea F, Ballinger WE, Mickle JP, Quisling RG: Cavernous angioma: a review of 126 collected and 12 new clinical cases. **Neurosurgery 18:**162–172, 1986 | 313 |
| 79. | Duhaime AC, Gennarelli TA, Thibault LE, Bruce DA, Margulies SS, Wiser R: The shaken baby syndrome. A clinical, pathological, and biomechanical study. **J Neurosurg 66:**409–415, 1987 | 312 |
| 80. | Steiner L, Lindquist C, Adler JR, Torner JC, Alves W, Steiner M: Clinical outcome of radiosurgery for cerebral arteriovenous malformations. **J Neurosurg 77:**1–8, 1992 | 312 |
| 81. | Rigamonti D, Drayer BP, Johnson PC, Hadley MN, Zabramski J, Spetzler RF: The MRI appearance of cavernous malformations (angiomas). **J Neurosurg 67:**518–524, 1987 | 311 |
| 82. | Bouma GJ, Muizelaar JP, Stringer WA, Choi SC, Fatouros P, Young HF: Ultra-early evaluation of regional cerebral blood flow in severely head-injured patients using xenon-enhanced computerized tomography. **J Neurosurg 77:**360–368, 1992 | 309 |
| 83. | Lasjaunias P, Chiu M, Terbrugge K, Tolia A, Hurth M, Bernstein M: Neurological manifestations of intracranial dural arteriovenous malformations. **J Neurosurg 64:**724–730, 1986 | 306 |
| 84. | Gennarelli TA, Spielman GM, Langfitt TW, Gildenberg PL, Harrington T, Jane JA, Marshall LF, Miller JD, Pitts LH: Influence of the type of intracranial lesion on outcome from severe head injury. A multicenter study using a new classification system. **J Neurosurg 56:**26–32, 1982 | 305 |
| 85. | Marmarou A, Shulman K, Lamorgese J: Compartmental analysis of compliance and outflow resistance of the cerebrospinal fluid system. **J Neurosurg 43:**523–534, 1975 | 304 |
| 86. | Awad IA, Little JR, Akrawi WP, Ahl J: Intracranial dural arteriovenous malformations: factors predisposing to an aggressive neurological course. **J Neurosurg 72:**839–850, 1990 | 303 |
| 87. | Oldfield EH, Muraszko K, Shawker TH, Patronas NJ: Pathophysiology of syringomyelia associated with Chiari I malformation of the cerebellar tonsils. Implications for diagnosis and treatment. **J Neurosurg 80:**3–15, 1994 | 303 |
| 88. | Giller CA, Bowman G, Dyer H, Mootz L, Krippner W: Cerebral arterial diameters during changes in blood pressure and carbon dioxide during craniotomy. **Neurosurgery 32:**737–742, 1993 | 302 |
| 89. | Yoshida S, Inoh S, Asano T, Sano K, Kubota M, Shimazaki H, Ueta N: Effect of transient ischemia on free fatty acids and phospholipids in the gerbil brain. Lipid peroxidation as a possible cause of postischemic injury. **J Neurosurg 53:**323–331, 1980 | 302 |
| 90. | Jannetta PJ, Abbasy M, Maroon JC, Ramos FM, Albin MS: Etiology and definitive microsurgical treatment of hemifacial spasm. Operative techniques and results in 47 patients. **J Neurosurg 47:**321–328, 1977 | 300 |
| 91. | Roberts DW, Strohbehn JW, Hatch JF, Murray W, Kettenberger H: A frameless stereotaxic integration of computerized tomographic imaging and the operating microscope. **J Neurosurg 65:**545–549, 1986 | 300 |
| 92. | Ferguson G: Physical factors in the initiation, growth, and rupture of human intracranial saccular aneurysms. **J Neurosurg 37:** 666–677, 1972 | 299 |
| 93. | Graham DI, Ford I, Adams JH, Doyle D, Teasdale GM, Lawrence AE, McLellan DR: Ischaemic brain damage is still common in fatal non-missile head injury. **J Neurol Neurosurg Psychiatry 52:**346–350, 1989 | 298 |
| 94. | Barrow DL, Spector RH, Braun IF, Landman JA, Tindall SC, Tindall GT: Classification and treatment of spontaneous carotid-cavernous sinus fistulas. **J Neurosurg 62:**248–256, 1985 | 296 |
| 95. | Shiozaki T, Sugimoto H, Taneda M, Yoshida H, Iwai A, Yoshioka T, Sugimoto T: Effect of mild hypothermia on uncontrollable intracranial hypertension after severe head injury. **J Neurosurg 79:**363–368, 1993 | 295 |
| 96. | Benda P, Someda K, Messer J, Sweet WH: Morphological and immunochemical studies of rat glial tumors and clonal strains propagated in culture. **J Neurosurg 34:**310–323, 1971 | 293 |
| 97. | Yaşargil MG, Curcic M, Kis M, Siegenthaler G, Teddy PJ, Roth P: Total removal of craniopharyngiomas. Approaches and long-term results in 144 patients. **J Neurosurg 73:**3–11, 1990 | 293 |
| 98. | Astrup J: Energy-requiring cell functions in the ischemic brain. Their critical supply and possible inhibition in protective therapy. **J Neurosurg 56:**482–497, 1982 | 292 |
| 99. | Marion DW, Obrist WD, Earlier PM, Penrod LE, Darby JM: The use of moderate therapeutic hypothermia for patients with severe head injuries: a preliminary report. **J Neurosurg 79:**354–362, 1993 | 290 |
| 100. | Varsos VG, Liszczak TM, Han DH, Kistler JP, Vielma J, Black PM, Heros RC, Zervas NT: Delayed cerebral vasospasm is not reversible by aminophylline, nifedipine, or papaverine in a “two-hemorrhage” canine model. **J Neurosurg 58:**11–17, 1983 | 287 |

**TABLE 3: Articles appearing in neurosurgical journals per 5-year epoch***

| Publication Yr | Total | *JNS* | *JNNP* | *Neurosurgery* |
|---|---|---|---|---|
| 1956–1960 | 5 | 3 | 2 | 0 |
| 1961–1965 | 2 | 0 | 2 | 0 |
| 1966–1970 | 7 | 6 | 1 | 0 |
| 1971–1975 | 5 | 4 | 1 | 0 |
| 1976–1980 | 13 | 9 | 1 | 3 |
| 1981–1985 | 20 | 17 | 1 | 2 |
| 1986–1990 | 24 | 18 | 3 | 3 |
| 1991–1995 | 20 | 19 | 0 | 1 |
| 1996–2000 | 3 | 2 | 0 | 1 |
| 2001–2005 | 1 | 1 | 0 | 0 |
| 2006–present | 0 | 0 | 0 | 0 |
| total | 100 | 79 | 11 | 10 |

* *JNS = Journal of Neurosurgery.*

radiosurgical treatment (Nos. 63, 80), 1 cooperative study (No. 32), 1 grading system (No. 13), and 1 surgical pathology study (No. 55). The subject of 7 articles was ischemic stroke, including 4 mechanistic reviews (Nos. 10, 23, 45, 98), 2 animal studies (Nos. 12, 89), and 1 community-based observational study of stroke (No. 30), which included incidents of SAH and intracerebral hemorrhage. Three articles were studies of normal vascular physiology, including 2 studies performed on animals (Nos. 61, 67) and 1 using intraoperative data from humans (No. 88). In addition, there were 3 articles on CMs (Nos. 53, 78, 81), 2 on DAVFs (Nos. 83, 86), and 1 on cavernous-carotid fistulas (No. 94).

There were 27 articles on trauma, including 22 on SHI, 2 on minor head injuries, and 3 on SCI. Eleven articles on SHI underscored the effect of particular management strategies on outcome, including control of intracranial pressure in 7 (Nos. 18, 22, 36, 38, 52, 71, 74), hypothermia in 2 (Nos. 95, 99), cerebral blood flow using Xe-CT scanning in 1 (No. 82), and 1 article demonstrating the adverse effects associated with hyperventilation (No. 37). Other articles about SHI included 5 laboratory studies (Nos. 16, 28, 64, 65, 79), 3 applications of classification systems (the Glasgow Outcome Scale [No. 47] and Glasgow Coma Scale [Nos. 60, 75]), 2 addressing the role of ischemia in SHI (Nos. 48, 93), and 1 correlating the type of posttraumatic intracranial lesion with outcome (No. 84). The 2 articles on minor head injury assessed neurobehavioral outcomes and disability (Nos. 17, 34). The articles on SCI included 1 randomized trial of methylprednisolone therapy (No. 69), 1 animal study (No. 59), and 1 review of vascular mechanisms in secondary injury (No. 24).

Thirteen articles were classified as functional and stereotactic neurosurgery. Three articles were on movement disorders, including pallidotomy (No. 9) and transplantation (No. 40) for PD and DBS for tremor (No. 27). Three articles described techniques for functional localization, including the Amytal test for lateralizing language dominance (No. 7), and cortical mapping of language (No. 20) and motor and sensory function (No. 44). Results from microvascular decompression were presented in 2 articles, 1 for hemifacial spasm (No. 77) and 1 for trigeminal neuralgia (No. 90). Two articles were in the epilepsy domain, including a surgical pathology series describing cortical dysplasia (No. 21) and a review of "kindling" (No. 41). In addition, there were experiences reported on the use of intraoperative MR imaging (No. 56) and on the integration of frameless intraoperative stereotaxy with the operating microscope (No. 91), as well as a clinical description of therapeutic magnetic stimulation of the brain and peripheral nervous system (No. 72).

There were 12 tumor studies in the top 100 cited articles. Five of these were on glial tumors, including 1 correlating prognosis of glioblastoma multiforme with the extent of resection (No. 57), 1 on radiation therapy and chemotherapy for anaplastic astrocytoma (No. 5), 1 on surgical treatment of low-grade astrocytomas (No. 62), 1 on stereotactic biopsies of gliomas (No. 50), and 1 animal study (No. 96). There were 2 concerning recurrence of meningioma after resection (Nos. 14, 35). There was a randomized study evaluating radiation therapy for medulloblastoma (No. 66), there were surgical series on craniopharyngiomas (No. 97) and dysembryoplastic neuroepithelial tumors (No. 54), and there were reviews on CNS lymphoma (No. 29) and germ cell tumors (No. 73). Additional topics included the technique for ACD (No. 8), the pathophysiology of syringomyelia (Nos. 33, 87), CSF dynamics and hydrocephalus (No. 85), and manifestations of AIDS in neurosurgery (No. 4).

**TABLE 4: Categorization of articles based on type and field of study**

| Type of Study | Total | Field of Study | | | | |
|---|---|---|---|---|---|---|
| | | Vascular | Trauma | Tumor | Functional | Other |
| total | 100 | 43 | 27 | 12 | 13 | 5 |
| operative management | 30 | 10 | 0 | 8 | 11 | 1 |
| laboratory* | 21 | 9 | 7 | 1 | 1 | 3 |
| natural history | 15 | 8 | 7 | 0 | 0 | 0 |
| nonoperative management | 12 | 3 | 9 | 0 | 0 | 0 |
| classification | 11 | 7 | 3 | 1 | 0 | 0 |
| review | 11 | 6 | 1 | 2 | 1 | 1 |

* Laboratory includes animal models, basic science, and physiological studies in humans.

Two areas that were not categorized separately due to overlap with the aforementioned topics included radiation therapy and pediatrics. There were 4 articles that focused on radiation therapy, including 2 regarding radiosurgical treatment of AVMs, and 2 randomized trials of radiation therapy and chemotherapy for malignant glial tumors and for medulloblastoma. In addition to the latter study, in which children were treated, the other pediatric study was a biomechanical study concerning shaken-baby syndrome. Topics related, but not specific, to pediatrics included 2 pathophysiological studies on syringomyelia and 1 animal study of hydrocephalus.

*Type of Study*

There were 5 randomized trials, 5 cooperative studies, and 1 observational cohort. There were 69 additional articles that consisted of case series, some of which were topic reviews or laboratory studies that were supplemented by patient data. Articles that did not present clinical data included 8 topic reviews and 12 laboratory studies.

Articles were categorized as follows: surgical management, nonsurgical management, natural history, classifications, reviews, and laboratory studies. Surgical management included endovascular and radiation therapies, as well as surgical procedures performed for diagnostic purposes. Nonsurgical management included intensive care unit management, medication-based therapies, and nonsurgical diagnostic studies. Natural history studies included observational studies of diseases and outcomes after head trauma. Laboratory studies included surgical and postmortem pathology series, animal studies, and intraoperative data obtained from humans to study physiology. Table 4 relates the field of study with the type of study.

Thirty articles were studies involving surgical management. There were 17 articles presenting surgical results, including microvascular decompression, movement disorder surgery, tumor resection or biopsy, AVM and aneurysm surgery, ACD, and magnetic stimulation. There were 4 articles on endovascular techniques, including 3 on aneurysm coiling (an additional article was a study of coiling using an animal model). Four articles focused on radiation therapy, 3 articles were on surgical or endovascular techniques for functional localization, and 2 were about new stereotactic technologies.

There were 12 articles about nonsurgical management strategies, including 3 on diagnostic techniques (transcranial Doppler ultrasonography and Xe-CT scanning). Nine studies described medical management of neurosurgical problems, including 7 studies on head trauma (hypothermia, intracranial pressure management, and hyperventilation), triple-H therapy for vasospasm, and methylprednisolone therapy for acute SCI. The studies on head trauma included 4 randomized trials and 3 prospective studies.

Fifteen articles were classified as being on natural history, which included studies of outcomes following trauma when the emphasis was not on therapy or diagnostic techniques. This included 6 studies of prognostic factors related to outcomes following head trauma, of which 2 addressed the effects of minor head trauma. There were 8 studies on the natural history of cerebrovascular diseases, including 4 on aneurysms (1 on the time course of vasospasm), 3 on AVMs, 1 on CMs, and 1 cohort study on the outcomes after stroke (including SAH and intraparenchymal hemorrhage).

Eleven articles focused on classification schemes, either initial proposals or prospective applications. This included 7 grading systems for cerebrovascular disease: 3 for SAH (Fisher, Hunt and Hess, and World Federation of Neurological Societies); the Spetzler-Martin grading system for AVM; and 1 each for cavernous-carotid fistulas, DAVFs, and CMs. There were 3 for either the Glasgow Outcome Scale or Glasgow Coma Scale and 1 for the Simpson grading system for extent of meningioma resection.

There were 21 articles that were categorized as laboratory studies. This included 12 animal studies: 1 histological study of an animal model of glial tumors; 1 surgical study of coiling; 1 study of vasospasm; 6 pathophysiology studies on CSF dynamics, SHI, SCI, and stroke; and 3 physiology studies of ischemia, and cerebral blood flow relationship to systolic blood pressure and $CO_2$. There were 7 human studies: 4 pathology studies of dementia and head injury, cortical dysplasia and epilepsy, AVM, and ischemia in fatal SHI; and 3 pathophysiology studies, including 2 of syringomyelia, and 1 on the effect of $CO_2$ on arterial diameter. There were also 2 ex vivo models: 1 of aneurysms using a glass model and 1 of the shaken-impact syndrome using a doll model.

There were 11 review articles, including 5 pathophysiological reviews. Topics included ischemia of the brain and spine, tumors, DAVFs, CMs, "kindling," and neurological manifestations of AIDS.

## Discussion

We identified the most cited articles appearing in neurosurgical journals. The top 100 cited papers appeared in 3 of the 13 neurosurgery-dedicated journals: the *Journal of Neurosurgery, JNNP,* and *Neurosurgery*. The most common format was clinical case series, and 8 papers were reviews. Five studies were structured as randomized, controlled trials, and 6 articles were prospective multiinstitutional cooperative studies or population-based cohort studies.

*Citations Over Time*

One limitation of the use of the total citations a paper has accumulated as a measure of impact is that such a method favors older publications and older journals. Indeed, in our list of journals, *JNNP* is the oldest journal, first published in 1920, followed by the *Journal of Neurosurgery,* first published in 1944. Ninety of the 100 articles appeared in these 2 journals. However, the peak period for highly cited papers was between 1976 and 1995, during which time 77 of the top 100 cited articles were published. The presence of only 1 article published since 1997 is likely accounted for by not enough time having elapsed for important studies to accumulate citations, or could reflect the referral of more recent high-impact papers to more generic journals. In contrast, the relatively small number of contributions from papers in the 1950–1975

epochs may relate to a number of variables, including loss of immediacy and awareness, and limitations in bibliometric databases for tracking older articles. In addition, some classic works in neurosurgery have escaped detection and analysis because they have appeared in textbook rather than manuscript form, for example, the founding work of microneurosurgery by Yaşargil,[11] documented in his 4-volume textbook *Microneurosurgery*.

*Citations by Subspecialty Field in Neurosurgery*

We noted an overrepresentation of cerebrovascular neurosurgery as the most common topic among the 100 most cited articles. Trauma came in second, followed by tumor and functional papers. It is not entirely clear why there is an overweighting of cerebrovascular papers and underrepresentation of tumor papers among the top 100. This cannot be explained by the relative contributions of these pathologies in the neurosurgical arena. Cerebrovascular neurosurgery has attracted some of the most academic and scholarly practitioners in our specialty. In addition, as neurooncology lends itself to laboratory study, perhaps the preponderance of highly cited studies in this domain are skewed toward the basic sciences and are more likely to be published in nonneurosurgical journals, reflecting the notion that the major progress and advances in brain tumors may still be largely found in the laboratory rather than in the operating room.[2]

There has been variable interest in functional neurosurgery over time. The interest in functional neurosurgery waned in the late 1960s, when advances in medical therapy for PD resulted in a decreased need for surgical intervention. However, the development of DBS, along with increased PD-related disability from disease progression and drug-related side effects, has brought about a renewed enthusiasm and renaissance for the subspecialty in the past 20 years, and this is reflected in the articles on functional neurosurgery, in particular DBS. This area of neurosurgery is in active growth and should exert a greater footprint among the top-cited papers of the future.

Spine as a subspecialty is virtually absent among the topics addressed in the top 100 cited papers, despite comprising a large proportion of most neurosurgical practices.[9] This is perhaps related to the recent incorporation of spinal surgery into the neurosurgery mainstream. The involvement of neurosurgeons in modern spinal surgery, particularly spinal instrumentation, did not occur until the late 1980s, and is thus a relatively recent field in neurosurgery.[9] While the highly cited works in *Spine* were written by orthopedic surgeons, and often nonsurgeons, this study does include an early description of the ACD and a study on the medical management of SCI. Spinal surgery articles are likely to be more prominent among the most cited in years to come.

*Limitations of the Present Study*

There are several weaknesses inherent to a study of this sort, including the bias associated with relying on the total number of times an article is cited, the journals included and excluded, the exclusion of textbooks, and the shortcomings of the database used.

First, inherent problems of citation analyses have been described, including that such methods favor older studies.[5,8] The scope of this article thus almost certainly omits the landmark articles from the past 10 years. Furthermore, we suggest that the presence of only 19 papers between 1950 and 1975 may be related to limitations of the database for tracking citations to older articles. Indeed, when particular journals were searched on the Web of Science and sorted by date, the first volumes were typically absent. This limitation has been identified as being even more pronounced with newer bibliometric sources such as Google Scholar and Scopus.[1,3]

Second, we limited our search to neurosurgical journals. Our methods included journals with the term "neurosurgery" or "neurosurgical" in their titles, as well as 2 related journals without either term. We may have missed an important neurosurgical journal with articles that would have qualified as one of the top 100 cited papers. However, it is worth noting that all 100 top-cited articles were found in only 3 journals. On the other hand, this study also omits neurosurgical articles that have been published in general medical journals, such as those with higher impact and broader readership such as the *New England Journal of Medicine, Journal of the American Medical Association,* or *Lancet*. For example, not one article on the list of the 100 most cited articles in neurosurgery journals concerned carotid endarterectomy, one of the most rigorously studied surgical procedures. An appraisal of the most highly cited neurosurgical articles in all journals including the general medicine journals is addressed in the companion part of this study.[6]

Third, we rely on the comprehensiveness and accuracy of the Web of Science database. The database includes citations by select sources and does not include citations made by textbooks or journals written in foreign languages or citations to textbooks. Databases such as Google Scholar reportedly draw on a wider range of sources for citations, although they are weaker at tracking older publications.

## Conclusions

Identifying the most cited articles in neurosurgical journals is one method of assessing the drivers of progress in neurosurgery, where our field has been, and where it is headed. An appraisal of top-cited papers in neurosurgery is of value on several fronts. It identifies seminal contributions and their originators, and it facilitates the understanding of and discourse about modern neurosurgical history. It also identifies the attributes of the works, discoveries, and findings that are driving our field. As such, the list serves as a statement of what is important and what it takes to have impact in our field. The list is dynamic, and the papers that are included will change as a function of time as our discipline changes and evolves.

### Disclosure

Dr. Ponce is supported by St. Joseph's Hospital and Medical Center in Phoenix, Arizona. Dr. Lozano is a Canada Research Chair (Tier 1) in Neuroscience, and serves as a consultant for Medtronic, Inc.

Author contributions to the study and manuscript preparation include the following: Conception and design: AM Lozano, FA Ponce. Acquisition of data: FA Ponce. Analysis and interpretation of data: AM Lozano, FA Ponce. Drafting the article: AM Lozano, FA Ponce. Critically revising the article: AM Lozano, FA Ponce. Reviewed final version of the manuscript and approved it for submission: AM Lozano, FA Ponce. Statistical analysis: FA Ponce.

### References


1. Bakkalbasi N, Bauer K, Glover J, Wang L: Three options for citation tracking: Google Scholar, Scopus and Web of Science. **Biomed Digit Libr 3:**7, 2006
2. Dunn IF, Black PM: The neurosurgeon as local oncologist: cellular and molecular neurosurgery in malignant glioma therapy. **Neurosurgery 52:**1411–1424, 2003
3. Falagas ME, Pitsouni EI, Malietzis GA, Pappas G: Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses. **FASEB J 22:**338–342, 2008
4. Garfield E: **What is a citation classic?** (http://garfield.library.upenn.edu/classics.html) [Accessed December 3, 2009]
5. Gisvold SE: Citation analysis and journal impact factors—is the tail wagging the dog? **Acta Anaesthesiol Scand 43:**971–973, 1999
6. Ponce FA, Lozano AM: Highly cited works in neurosurgery. Part II: the citation classics. A review. **J Neurosurg 112:** 233–246, 2010 [epub ahead of print January 15, 2010. DOI: 10.3171/2009.12.JNS091600]
7. Qin J: F. W. Lancaster: a bibliometric analysis. **Libr Trends 56:**954–967, 2008
8. Seglen PO: Citation rates and journal impact factors are not suitable for evaluation of research. **Acta Orthop Scand 69:** 224–229, 1998
9. Sonntag VKH: The development of spinal neurosurgery: a historical perspective. **Neurosurgery 60:**587–588, 2007
10. Wilkins RH: **Neurosurgical Classics.** Park Ridge, IL: American Association of Neurological Surgeons, 1992
11. Yaşargil MG: **Microneurosurgery.** Stuttgart: Thieme, 1984


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Manuscript submitted October 20, 2009.
Accepted December 1, 2009.
Please include this information when citing this paper: published online January 15, 2010; DOI: 10.3171/2009.12.JNS091599.

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