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Highly cited works in neurosurgery. Part II: the citation classics

A review

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Object. The term "citation classic" has been used in reference to an article that has been cited more than 400 times. The purpose of this study is to identify such articles that pertain to clinical neurosurgery.

Methods. A list of search phrases relating to neurosurgery was compiled. A topic search was performed using the Institute for Scientific Information Web of Science for phrases. Articles with more than 400 citations were identified, and nonclinical articles were omitted. The journals, year of publication, topics, and study types were analyzed.

Results. There were 106 articles with more than 400 citations relating to clinical neurosurgery. These articles appeared in 28 different journals, with more than half appearing in the *Journal of Neurosurgery* or the *New England Journal of Medicine*. Fifty-three articles were published since 1990. There were 38 articles on cerebrovascular disease, 21 on stereotactic and functional neurosurgery, 21 on neurooncology, 19 on trauma, 4 on nontraumatic spine, 2 on CSF pathologies, and 1 on infection. There were 29 randomized trials, of which 86% appeared in the *New England Journal of Medicine, Lancet*, or the *Journal of the American Medical Association*, and half concerned the prevention or treatment of stroke. In addition, there were 16 prospective studies, 15 classification or grading systems, and 7 reviews. The remaining 39 articles were case series, case reports, or technical notes.

Conclusions. More than half of the citation classics identified in this study have been published in the past 20 years. Case series, classifications, and reviews appeared more frequently in neurosurgical journals, while randomized controlled trials tended to be published in general medical journals. *(DOI: 10.3171/2009.12.JNS091600)*

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

How do we measure scientific impact in neurosurgery? Which discoveries change our concepts and practice? Which new operations provide value? While there may be several ways to probe theses questions, we have chosen to use the number of times a particular work is cited as a surrogate measure of its importance and impact in the field of neurosurgery. In the first part of this 2-part series, we identified the 100 most cited papers appearing in journals dedicated to neurosurgery.[15] In Part II, we consider highly cited clinical papers on neurosurgical topics in all journals tracked by the Institute for Scientific Information Web of Science. The focus of this study is restricted to articles considered to be "citation classics" in clinical neurosurgery. Eugene Garfield, the founder of the Institute for Scientific Information, designated articles as such if they had been cited 400 or more times.[8,16]

Abbreviations used in this paper: AVM = arteriovenous malformation; CEA = carotid endarterectomy; DBS = deep brain stimulation; EC-IC = extracranial-intracranial; GCS = Glasgow Coma Scale; GOS = Glasgow Outcome Sacle; ICP = intracranial pressure; *JAMA* = *Journal of the American Medical Association*; JIF = journal impact factor; *JNNP* = *Journal of Neurology, Neurosurgery and Psychiatry*; *NEJM* = *New England Journal of Medicine*; PD = Parkinson disease; SAH = subarachnoid hemorrhage; SCI = spinal cord injury.

Methods

The results from the companion first part of this study[15] provided a preliminary catalog of key words or phrases across neurosurgical topics, on which to build (Table 1). Searches for these phrases were performed by

TABLE 1: Search phrases used

Field	Search Strings
general/other	brain surgery – neurosurgery – hydrocephalus – peripheral nerve surgery
vascular	aneurysm surgery – arteriovenous malformation* – carotid endarterectomy – cavernous malformation – extracranial intracranial bypass – intracranial aneurysm* – [intracranial or intracerebral] and [hematoma or hemorrhage] – subarachnoid hemorrhage – vasospasm
tumor	brain tumor surgery – meningioma – glioblastoma* – glioma – meningioma – radiosurgery – radiotherapy
trauma	brain injury – coma – head injury – brain damage – spinal injury
functional	deep brain stimulation – epilepsy surgery – Parkinson's surgery – spinal cord stimulation – trigeminal neuralgia – stereotactic – stereotaxic – stereotaxy
spine	spine fusion – spine fixation – spine surgery – spinal surgery – spinal fusion – spinal fixation – [cervical or thoracic or lumbar] and [disc* or disk*]

* The asterisk was included in the search string as a wild card character. For example, the search "disc*" would return results for "disc" or "discs" or "discectomy."

"topic" using the bibliometric database Web of Science up to August of 2009.

The resulting list of publications was edited for duplications and limited to studies concerning the treatment of humans. In particular, while clinical reviews were included, laboratory studies in basic science and those involving animals primarily were excluded. In addition, 10 clinical articles with more than 400 citations from neurosurgical journals, which were identified in the first part of this study, escaped identification using this search method. These were also included.

Results

Sources

Using the aforementioned search methods, 106 citation classic articles were identified. The number of times articles were cited ranged from 402 to 4199 (Table 2). In the following sections, the numbers in parentheses represent the ranking of the articles in terms of citations. The corresponding articles can be found in Table 2. The type of journal in which these articles appeared was considered, as well as the JIF, provided by the Institute for Scientific Information Journal Citation Reports. The articles were distributed almost equally over 3 types of journals. There were 37 articles (35%) appearing in 3 neurosurgical journals (*Neurosurgery, Journal of Neurosurgery,* and *JNNP*), and 39 articles (37%) appearing in 3 general medicine journals, *NEJM*, *Lancet*, and *JAMA*. The remaining 30 articles (28%) appeared in 22 various journals (Table 3).

Topics

Among the citation classics, there were 38 articles on cerebrovascular disease, 21 on functional neurosurgery, 21 on brain tumors, and 19 on trauma (including spine trauma). In addition, there were 4 articles on nontraumatic spinal disorders, 2 on CSF pathologies, and 1 on infection. Table 4 includes the breakdown of citations by various topics, Table 5 shows in which journals and during which 5-year epoch the various topics appeared, and Table 6 shows the category of journal in which the various topics were published.

Cerebrovascular. Of the 38 cerebrovascular articles, 21 were about stroke, 15 concerned intracranial aneurysms, and 2 were about AVMs. The articles on stroke included 10 on CEA (Nos. 3, 4, 7, 10, 12, 26, 60, 65, 68b, 79b), 2 on EC-IC bypass (Nos. 65, 105), 2 on endovascular treatment of acute stroke (Nos. 13, 95a), 2 comparing carotid artery stenting to CEA (Nos. 27, 56), 2 on intraparenchymal hemorrhage (Nos. 70, 97b), 2 on the pathophysiology of stroke (Nos. 29, 59), and 1 cohort study on the incidence and outcome of stroke, intraparenchymal hemorrhage, and SAH (No. 75).

Among the 15 studies of aneurysms, 11 were studies of ruptured aneurysms. Five studies related to vasospasm, including 1 review (No. 50a), 2 trials of nimodipine (Nos. 37, 94), 1 grading system (No. 8), and an early study on transcranial Doppler (No. 6). There were 2 additional grading scales for SAH (Nos. 5, 102). There were 2 studies on the outcomes after treatment of aneurysmal SAH in relation to timing of surgery (Nos. 18, 78). Four articles were on endovascular techniques, including 2 early experiences with coiling (Nos. 30, 64), 1 early experience occluding major cerebral vessels with endovascular balloons (No. 50b), and 1 study comparing coiling with microsurgical clipping (No. 23). The 2 articles on AVMs included the results of a cooperative study evaluating the natural history (No. 81a) and a grading system to predict surgical outcome (No. 31).

Functional. Articles categorized as pertaining to functional neurosurgery included 14 on movement disorders, 3 on epilepsy, 2 on stereotactic methods, and 2 on functional localization. The movement disorder articles included 12 on PD, 1 on tremor, and 1 on both topics. There were 6 articles on DBS, including 3 targeting the subthalamic nucleus (Nos. 22, 38, 84), 2 targeting the ventral intermediate nucleus (Nos. 57, 71), and 1 comparing the subthalamic nucleus to the pars interna of the globus pallidus (No. 61). Five articles were on transplantation for PD, including 3 with fetal dopamine neurons (Nos. 21, 40, 79a) and 2 with adrenal medullary cells (Nos. 62, 103). Three articles were on pallidotomy for PD (Nos. 21, 97a, 99).

The 3 articles on epilepsy included a study comparing surgery to medical treatment (No. 72), a surgical pathology

TABLE 2: Articles with more than 400 citations, ranked in order of citations received

Rank	Article	No. of Times Cited
1.	Jennett B, Bond M: Assessment of outcome after severe brain-damage. **Lancet 1:**480–484, 1975	4199
2.	Teasdale G, Jennett B: Assessment of coma and impaired consciousness. A practical scale. **Lancet 2:**81–84, 1974	3163
3.	Taylor DW: Beneficial effect of carotid endarterectomy in symptomatic patients with high-grade carotid stenosis. North American Symptomatic Carotid Endarterectomy Trial Collaborators. **N Engl J Med 325:**445–453, 1991	2912
4.	Executive Committee for the Asymptomatic Carotid Atherosclerosis Study: Endarterectomy for asymptomatic carotid artery stenosis. **JAMA 273:**1421–1428, 1995	2057
5.	Hunt WE, Hess RM: Surgical risk as related to time of intervention in the repair of intracranial aneurysms. **J Neurosurg 28:** 14–20, 1968	1518
6.	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
7.	MRC European Carotid Surgery Trial: Interim results for symptomatic patients with severe (70-99%) or with mild (0-29%) carotid stenosis. European Carotid Surgery Trialists' Collaborative Group. **Lancet 337:**1235–1243, 1991	1331
8.	Fisher CM, Kistler JP, Davis JM: Relation of cerebral vasospasm to subarachnoid hemorrhage visualized by computerized tomographic scanning. **Neurosurgery 6:**1–9, 1980	1215
9.	Stupp R, Mason WP, van den Bent MJ, Weller M, Fisher B, Taphoorn MJ, Belanger K, Brandes AA, Marosi C, Bogdahn U, Curschmann J, Janzer RC, Ludwin SK, Gorlia T, Allgeier A, Lacombe D, Cairncross JG, Eisenhauer E, Mirimanoff RO; European Organisation for Research and Treatment of Cancer Brain Tumor and Radiotherapy Groups; National Cancer Institute of Canada Clinial Trials Group: Radiotherapy plus concomitant and adjuvant temozolomide for glioblastoma. **N Engl J Med 352:**987–996, 2005	1174
10.	Barnett HJM, Taylor W, Eliasziw M, Fox AJ, Ferguson GG, Haynes RB, Rankin RN, Clagett GP, Hachinski VC, Sackett DL, Thorpe KE, Meldrum HE, Spence JD: Benefit of carotid endarterectomy in patients with symptomatic moderate or severe stenosis. North American Symptomatic Carotid Endarterectomy Trial Collaborators. **N Engl J Med 339:**1415–1425, 1998	1110
11.	Bracken MB, Shepard MJ, Collins WF, Holford TR, Young W, Baskin DS, Eisenberg HM, Flamm E, Leo-Summers L, Maroon J, Marshall LF, Perot PL, Piepmeier J, Sonntag VKH, Wagner FC, Wilberger JE, Winn HR: A randomized, controlled trial of methylprednisolone or naloxone in the treatment of acute spinal-cord injury. Results of the Second National Acute Spinal Cord Injury Study. **N Engl J Med 322:**1405–1411, 1990	1092
12.	European Carotid Surgery Trialists' Collaborative Group: Randomised trial of endarterectomy for recently symptomatic carotid stenosis: final results of the MRC European Carotid Surgery Trial (ECST). **Lancet 351:**1379–1387, 1998	1027
13.	Furlan A, Higashida R, Wechsler L, Gent M, Rowley H, Kase C, Pessin M, Ahuja A, Callahan F, Clark WM, Silver F, Rivera F: Intra-arterial prourokinase for acute ischemic stroke. The PROACT II study: a randomized controlled trial. Prolyse in Acute Cerebral Thromboembolism. **JAMA 282:**2003–2011, 1999	1016
14.	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
15.	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	994
16.	Kleihues P, Burger PC, Scheithauer BW: The new WHO classification of brain tumours. **Brain Pathol 3:**255–268, 1993	938
17.	Walker MD, Green SB, Byar DP, Alexander E Jr, Batzdorf U, Brooks WH, Hunt WE, MacCarty CS, Mahaley MS Jr, Mealey J Jr, Owens G, Ransohoff J II, Robertson JT, Shapiro WR, Smith KR Jr, Wilson CB, Strike TA: Randomized comparisons of radiotherapy and nitrosoureas for the treatment of malignant glioma after surgery. **N Engl J Med 303:**1323–1329, 1980	932
18.	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	925
19.	Patchell RA, Tibbs PA, Walsh JW, Dempsey RJ, Maruyama Y, Kryscio RJ, Markesbery WR, MacDonald JS, Young B: A randomized trial of surgery in the treatment of single metastases to the brain. **N Engl J Med 322:**494–500, 1990	903
20.	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
21.	Freed CR, Greene PE, Breeze RE, Tsai WY, DuMouchel W, Kao R, Dillon S, Winfield H, Culver S, Trojanowski JQ, Eidelberg D, Fahn S: Transplantation of embryonic dopamine neurons for severe Parkinson's disease. **N Engl J Med 344:**710–719, 2001	797
22.	Limousin P, Krack P, Pollak P, Benazzouz A, Ardouin C, Hoffmann D, Benabid AL: Electrical stimulation of the subthalamic nucleus in advanced Parkinson's disease. **N Engl J Med 339:**1105–1111, 1998	772

(continued)

TABLE 2: Articles with more than 400 citations, ranked in order of citations received *(continued)*

Rank	Article	No. of Times Cited
23.	Molyneux A, Kerr R, Stratton I, Sandercock P, Clarke M, Shrimpton J, Holman R; International Subarachnoid Aneurysm Trial (ISAT) Collaborative Group: International Subarachnoid Aneurysm Trial (ISAT) of neurosurgical clipping versus endovascular coiling in 2143 patients with ruptured intracranial aneurysms: a randomised trial. **Lancet 360:**1267–1274, 2002	771
24.	Cloward RB: The anterior approach for removal of ruptured cervical disks. **J Neurosurg 15:**602–617, 1958	728
25.	Adams RD, Fisher CM, Hakim S, Ojemann RG, Sweet WH: Symptomatic occult hydrocephalus with "normal" cerebrospinal-fluid pressure. A treatable syndrome. **N Engl J Med 273:**117–126, 1965	721
26.	Hobson RW II, Weiss DG, Fields WS, Goldstone J, Moore WS, Towne JB, Wright CB: Efficacy of carotid endarterectomy for asymptomatic carotid stenosis. The Veterans Affairs Cooperative Study Group. **N Engl J Med 328:**221–227, 1993	709
27.	Yadav JS, Wholey MH, Kuntz RE, Fayad P, Katzen BT, Mishkel GJ, Bajwa TK, Whitlow P, Strickman NE, Jaff MR, Popma JJ, Snead DB, Cutlip DE, Firth BG, Ouriel K, Stenting and Angioplasty with Protection in Patients at High Risk for Endarterectomy Investigators: Protected carotid-artery stenting versus endarterectomy in high-risk patients. **N Engl J Med 351:**1493–1501, 200	702
28.	Laitinen LV, Bergenheim AT, Hariz MI: Leksell's posteroventral pallidotomy in the treatment of Parkinson's disease. **J Neurosurg 76:**53–61, 1992	668
29.	Siesjo BK: Pathophysiology and treatment of focal cerebral ischemia. Part II: mechanisms of damage and treatment. **J Neurosurg 77:**337–354, 1992	667
30.	Guglielmi G, Viñuela F, Dion J, Duckwiler G: Electrothrombosis of saccular aneurysms via endovascular approach. Part 2: preliminary clinical experience. **J Neurosurg 75:**8–14, 1991	663
31.	Spetzler RF, Martin NA: A proposed grading system for arteriovenous malformations. **J Neurosurg 65:**476–483, 1986	657
32a.	Chesnut RM, Marshall LF, Klauber MR, Blunt BA, Baldwin N, Eisenberg HM, Jane JA, Marmarou A, Foulkes MA: The role of secondary brain injury in determining outcome from severe head injury. **J Trauma 34:**216–222, 1993	655
32b.	Jensen MC, Brant-Zawadzki MN, Obuchowski N, Modic MT, Malkasian D, Ross JS: Magnetic resonance imaging of the lumbar spine in people without back pain. **N Engl J Med 331:**69–73, 1994	655
34.	Marion DW, Penrod LE, Kelsey SF, Obrist WD, Kochanek PM, Palmer AM, Wisniewski SR, DeKosky ST: Treatment of traumatic brain injury with moderate hypothermia. **N Engl J Med 336:**540–546, 1997	648
35.	Kleihues P, Louis DN, Scheithauer BW, Rorke LB, Reifenberger G, Burger PC, Cavenee WK: The WHO classification of tumors of the nervous system. **J Neuropathol Exp Neurol 61:**215–229, 2002	644
36.	Simpson D: The recurrence of intracranial meningiomas after surgical treatment. **J Neurol Neurosurg Psychiatry 20:**22–39, 1957	643
37.	Allen GS, Ahn HS, Preziosi TJ, Battye R, Boone SC, Chou SN, Kelly DL, Weir BK, Crabbe RA, Lavik PJ, Rosenbloom SB, Dorsey FC, Ingram CR, Mellits DE, Bertsch LA, Boisvert DP, Hundley MB, Johnson RK, Strom JA, Transou CR: Cerebral arterial spasm—a controlled trial of nimodipine in patients with subarachnoid hemorrhage. **N Engl J Med 308:**619–624, 1983	638
38.	Limousin P, Pollak P, Benazzouz A, Hoffmann D, Le Bas JF, Broussolle E, Perret JE, Benabid AL: Effect of parkinsonian signs and symptoms of bilateral subthalamic nucleus stimulation. **Lancet 345:**91–95, 1995	636
39.	Locksley H: Natural history of subarachnoid hemorrhage, intracranial aneurysms and arteriovenous malformations. **J Neurosurg 25:**321–368, 1966	626
40.	Lindvall O, Brundin P, Widner H, Rehncrona S, Gustavii B, Frackowiak R, Leenders KL, Sawle G, Rothwell JC, Marsden CD, Bjorklund A: Grafts of fetal dopamine neurons survive and improve motor function in Parkinson's disease. **Science 247:** 574–577, 1990	611
41.	Cairncross JG, Ueki K, Zlatescu MC, Lisle DK, Finkelstein DM, Hammond RR, Silver JS, Stark PC, Macdonald DR, Ino Y, Ramsay DA, Louis DN: Specific genetic predictors of chemotherapeutic response and survival in patients with anaplastic oligodendrogliomas. **J Natl Cancer Inst 90:**1473–1479, 1998	592
42a.	Daumas-Duport C, Scheithauer B, O'Fallon J, Kelly P: Grading of astrocytomas. A simple and reproducible method. **Cancer 62:** 2152–2165, 1988	590
42b.	Leksell L: The stereotaxic method and radiosurgery of the brain. **Acta Chir Scand 102:**316–319, 1951	590
44.	Macdonald DR, Cascino TL, Schold SC Jr, Cairncross JG: Response criteria for phase II studies of supratentorial malignant glioma. **J Clin Oncol 8:**1277–1280, 1990	574
45.	International Study of Unruptured Intracranial Aneurysms Investigators: Unruptured intracranial aneurysms—risk of rupture and risks of surgical intervention. **N Engl J Med 339:**1725–1733, 1998	566
46.	Hegi ME, Diserens AC, Gorlia T, Hamou MF, de Tribolet N, Weller M, Kros JM, Hainfellner JA, Mason W, Mariani L, Bromberg JE, Hau P, Mirimanoff RO, Cairncross JG, Janzer RC, Stupp R: MGMT gene silencing and benefit from temozolomide in glioblastoma. **N Engl J Med 352:**997–1003, 2005	559

(continued)

TABLE 2: Articles with more than 400 citations, ranked in order of citations received *(continued)*

Rank	Article	No. of Times Cited
47.	Maynard FM Jr, Bracken MB, Creasey G, Ditunno JF Jr, Donovan WH, Ducker TB, Garber SL, Marino RJ, Stover SL, Tator CH, Waters RL, Wilberger JE, Young W: International Standards for Neurological and Functional Classification of Spinal Cord Injury. American Spinal Injury Association. **Spinal Cord 35:**266–274, 1997	554
48.	Rimel RW, Giordani B, Barth JT, Boll TJ, Jane JA: Disability caused by minor head injury. **Neurosurgery 9:**221–228, 1981	553
49.	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	552
50a.	Kassell NF, Sasaki T, Colohan A, Nazar G: Cerebral vasospasm following aneurysmal subarachnoid hemorrhage. **Stroke 16:** 562–572, 1985	551
50b.	Serbinenko FA: Balloon catheterization and occlusion of major cerebral vessels. **J Neurosurg 41:**125–145, 1974	551
52.	Denis F: The three column spine and its significance in the classification of acute thoracolumbar spinal injuries. **Spine (Phila Pa 1976) 8:**817–831, 1983	547
53.	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
54.	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
55.	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	537
56.	Brown MM, Rogers J, Bland JM, CAVATAS Investigators: Endovascular versus surgical treatment in patients with carotid stenosis in the Carotid and Vertebral Artery Transluminal Angioplasty Study (CAVATAS): a randomised trial. **Lancet 357:**1729–1737, 2001	536
57.	Benabid AL, Pollak P, Gao D, 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	534
58.	Fine HA, Dear KB, Loeffler JS, Black PM, Canellos GP: Meta-analysis of radiation therapy with and without adjuvant chemotherapy for malignant gliomas in adults. **Cancer 71:**2585–2597, 1993	533
59.	Siesjo BK: Pathophysiology and treatment of focal cerebral ischemia. Part I: pathophysiology. **J Neurosurg 77:**169–184, 1992	531
60.	Halliday A, Mansfield A, Marro J, Peto C, Peto R, Potter J, Thomas D; MRC Asymptomatic Carotid Surgery Trial (ACST) Collaborative Group: Prevention of disabling and fatal strokes by successful carotid endarterectomy in patients without recent neurological symptoms: randomised controlled trial. **Lancet 363:**1491–1502, 2004	530
61.	Deep-Brain Stimulation for Parkinson's Disease Study Group: Deep-brain stimulation of the subthalamic nucleus or the pars interna of the globus pallidus in Parkinson's disease. **N Engl J Med 345:**956–963, 2001	527
62.	Madrazo I, Drucker-Colin R, Diaz V, Martinez-Mata J, Torres C, Becerril JJ: Open microsurgical autograft of adrenal medulla to the right caudate nucleus in two patients with intractable Parkinson's disease. **N Engl J Med 316:**831–834, 1987	524
63.	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
64.	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
65.	EC/IC Bypass Study Group: Failure of extracranial-intracranial arterial bypass to reduce the risk of ischemic stroke. Results of an international randomized trial. **N Engl J Med 313:**1191–1200, 1985	509
66.	Brem H, Piantadosi S, Burger PC, Walker M, Selker R, Vick NA, Black K, Sisti M, Brem S, Mohr G, Muller P, Morawetz R, Schold SC: Placebo-controlled trial of safety and efficacy of intraoperative controlled delivery by biodegradable polymers of chemotherapy for recurrent gliomas. **Lancet 345:**1008–1012, 1995	500
67.	Burger PC, Vogel FS, Green SB, Strike TA: Glioblastoma multiforme and anaplastic astrocytoma. Pathologic criteria and prognostic implications. **Cancer 56:**1106–1111, 1985	486
68a.	Curran WJ Jr, Scott CB, Horton J, Nelson JS, Weinstein AS, Fischbach AJ, Chang CH, Rotman M, Asbell SO, Krisch RE, Nelson DF: Recursive partitioning analysis of prognostic factors in three Radiation Therapy Oncology Group malignant glioma trials. **J Natl Cancer Inst 85:**704–710, 1993	485
68b.	Mayberg MR, Wilson SE, Yatsu F, Weiss DG, Messina L, Hershey LA, Colling C, Eskridge J, Deykin D, Winn HR: Carotid endarterectomy and prevention of cerebral ischemia in symptomatic carotid stenosis. Veterans Affairs Cooperative Studies Program 309 Trialist Group. **JAMA 266:**3289–3294, 1991	485
70.	Mayer SA, Brun NC, Begtrup K, Broderick J, Davis S, Diringer MN, Skolnick BE, Steiner T; Recombinant Activated Factor VII Intracerebral Hemorrhage Trial Investigators: Recombinant activated factor VII for acute intracerebral hemorrhage. **N Engl J Med 352:**777–785, 2005	483

(continued)

TABLE 2: Articles with more than 400 citations, ranked in order of citations received *(continued)*

Rank	Article	No. of Times Cited
71.	Benabid AL, Benazzouz A, Hoffmann D, Limousin P, Krack P, Pollak P: Long-term electrical inhibition of deep brain targets in movement disorders. **Mov Disord 13 (Suppl 3):**119–125, 1998	481
72.	Wiebe S, Blume WT, Girvin JP, Eliasziw M: A randomized, controlled trial of surgery for temporal-lobe epilepsy. **N Engl J Med 345:**311–318, 2001	479
73.	Clifton GL, Miller ER, Choi SC, Levin HS, McCauley S, Smith KR Jr, Muizelaar JP, Wagner FC Jr, Marion DW, Luerssen TG, Chesnut RM, Schwartz M: Lack of effect of induction of hypothermia after acute brain injury. **N Engl J Med 344:**556–563, 2001	478
74.	Hochberg FH, Miller DC: Primary central nervous system lymphoma. **J Neurosurg 68:**835–853, 1988	472
75.	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	470
76.	Hochberg FH, Pruitt A: Assumptions in the radiotherapy of glioblastoma. **Neurology 30:**907–911, 1980	467
77.	Weber H: Lumbar disc herniation. A controlled, prospective study with ten years of observation. **Spine (Phila Pa 1976) 8:**131–140, 1983	465
78.	Kassell NF, Torner JC, Jane JA, Haley EC Jr, Adams HP: The International Cooperative Study on the Timing of Aneurysm Surgery. Part 2. Surgical results. **J Neurosurg 73:**37–47, 1990	460
79a.	Freed CR, Breeze RE, Rosenberg NL, Schneck SA, Kriek E, Qi JX, Lone T, Zhang YB, Snyder JA, Wells TH, Ramig LO, Thompson L, Mazziotta JC, Huang SC, Grafton ST, Brooks D, Sawle G, Schroter G, Ansari AA: Survival of implanted fetal dopamine cells and neurologic improvement 12 to 46 months after transplantation for Parkinson's disease. **N Engl J Med 327:**1549–1555, 1992	456
79b.	Sundt TM, Sharbrough FW, Piepgras DG, Kearns TP, Messick JM, O'Fallon WM: Correlation of cerebral blood flow and electroencephalographic changes during carotid endarterectomy: with results of surgery and hemodynamics of cerebral ischemia. **Mayo Clin Proc 56:**533–543, 1981	456
81a.	Perret G, Nishioka H: Report on the cooperative study of intracranial aneurysms and subarachnoid hemorrhage. Section VI. 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
81b.	Ram Z, Culver KW, Oshiro EM, Viola JJ, DeVroom HL, Otto E, Long Z, Chiang Y, McGarrity GJ, Muul LM, Katz D, Blaese RM, Oldfield EH: Therapy of malignant brain tumors by intratumoral implantation of retroviral vector-producing cells. **Nat Med 3:** 1354–1361, 1997	454
83.	Smith GW, Robinson RA: The treatment of certain cervical-spine disorders by anterior removal of the intervertebral disc and interbody fusion. **J Bone Joint Surg Am 40-A:**607–624, 1958	453
84.	Krack P, Batir A, Van Blercom N, Chabardes S, Fraix V, Ardouin C, Koudsie A, Limousin PD, Benazzouz A, LeBas JF, Benabid AL, Pollak P: Five-year follow-up of bilateral stimulation of the subthalamic nucleus in advanced Parkinson's disease. **N Engl J Med 349:**1925–1934, 2003	450
85.	Gardner WJ: Hydrodynamic mechanism of syringomyelia: its relationship to myelocele. **J Neurol Neurosurg Psychiatry 28:** 247–259, 1965	449
86.	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	448
87.	Yadav JS, Roubin GS, Iyer S, Vitek J, King P, Jordan WD, Fisher WS: Elective stenting of the extracranial carotid arteries. **Circulation 95:**376–381, 1997	446
88.	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	442
89.	Adams JH, Graham DI, Murray LS, Scott G: Diffuse axonal injury due to nonmissile head injury in humans: an analysis of 45 cases. **Ann Neurol 12:**557–563, 1982	439
90a.	Bracken MB, Shepard MJ, Holford TR, Leo-Summers L, Aldrich EF, Fazl M, Fehlings M, Herr DL, Hitchon PW, Marshall LF, Nockels RP, Pascale V, Perot PL Jr, Piepmeier J, Sonntag VKH, Wagner F, Wilberger JE, Winn HR, Young W: Administration of methylprednisolone for 24 or 48 hours or tirilazad mesylate for 48 hours in the treatment of acute spinal cord injury. Results of the Third National Acute Spinal Cord Injury Randomized Controlled Trial. National Acute Spinal Cord Injury Study. **JAMA 277:**1597–1604, 1997	437
90b.	Gaspar L, Scott C, Rotman M, Asbell S, Phillips T, Wasserman T, McKenna WG, Byhardt R: Recursive partitioning analysis (RPA) of prognostic factors in three Radiation Therapy Oncology Group (RTOG) brain metastases trials. **Int J Radiat Oncol Biol Phys 37:**745–751, 1997	437

(continued)

TABLE 2: Articles with more than 400 citations, ranked in order of citations received *(continued)*

Rank	Article	No. of Times Cited
92.	Rosner MJ, Rosner SD, Johnson AH: Cerebral perfusion pressure: management protocol and clinical results. **J Neurosurg 83:** 949–962, 1995	435
93.	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	433
94.	Pickard JD, Murray GD, Illingworth R, Shaw MD, Teasdale GM, Foy PM, Humphrey PR, Lang DA, Nelson R, Richards P, Sinar J, Bailey S, Skene A: Effect of oral nimodipine on cerebral infarction and outcome after subarachnoid haemorrhage: British aneurysm nimodipine trial. **BMJ 298:**636–642, 1989	426
95a.	del Zoppo GJ, Higashida RT, Furlan AJ, Pessin MS, Rowley HA, Gent M: PROACT: a phase II randomized trial of recombinant pro-urokinase by direct arterial delivery in acute middle cerebral artery stroke. PROACT Investigators. Prolyse in Acute Cerebral Thromboembolism. **Stroke 29:**4–11, 1998	424
95b.	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	424
97a.	Baron MS, Vitek JL, Bakay RA, Green J, Kaneoke Y, Hashimoto T, Turner RS, Woodard JL, Cole SA, McDonald WM, Delong MR: Treatment of advanced Parkinson's disease by posterior GPi pallidotomy: 1-year results of a pilot study. **Ann Neurol 40:**355–366, 1996	420
97b.	Hylek EM, Singer DE: Risk factors for intracranial hemorrhage in outpatients taking warfarin. **Ann Intern Med 120:**897–902, 1994	420
99.	Lozano AM, Lang AE, Galvez-Jimenez N, Miyasaki J, Duff J, Hutchinson WD, Dostrovsky JO: Effect of GPi pallidotomy on motor function in Parkinson's disease. **Lancet 346:**1383–1387, 1995	418
100.	West J, Fitzpatrick JM, Wang MY, Dawant BM, Maurer CR Jr, Kessler RM, Maciunas RJ, Barillot C, Lemoine D, Collignon A, Maes F, Suetens P, Vandermeulen D, van den Elsen PA, Napel S, Sumanaweera TS, Harkness B, Hemler PF, Hill DL, Hawkes DJ, Studholme C, Maintz JBA, Viergever MA, Malandain G, Pennec X, Noz ME, Maguire GQ, Pollack M, Pelizzari CA, Robb RA, Hanson D, Woods RP: Comparison and evaluation of retrospective intermodality brain image registration techniques. **J Comput Assist Tomogr 21:**554–566, 1997	416
101.	Walker MD, Strike TA, Sheline GE: An analysis of dose-effect relationship in the radiotherapy of malignant gliomas. **Int J Radiat Oncol Biol Phys 5:**1725–1731, 1979	415
102.	Drake CG: Report of World Federation of Neurological Surgeons committee on a universal subarachnoid hemorrhage grading scale. **J Neurosurg 68:**985–986, 1988	410
103.	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	406
104.	Rappaport M, Hall KM, Hopkins K, Belleza T, Cope DN: Disability rating scale for severe head trauma: coma to community. **Arch Phys Med Rehabil 63:**118–123, 1982	404
105.	Baron JC, Bousser MG, Rey A, Guillard A, Comar D, Castaigne P: Reversal of focal "misery-perfusion syndrome" by extra-intracranial arterial bypass in hemodynamic cerebral ischemia. A case study with 15O positron emission tomography. **Stroke 12:**454–459, 1981	403
106.	Racine R: Kindling: the first decade. **Neurosurgery 3:**234–252, 1978	402

series describing cortical dysplasia (No. 54), and a review of the "kindling" phenomenon (No. 106). The articles on stereotaxy included an early description of stereotactic radiosurgery with gamma rays (No. 42b) and a study comparing registration techniques for frameless stereotaxy (No. 100). The studies on functional localization both concerned language, included a study of language lateralization using endovascular administration of sodium amytal (No. 20), and a study of language localization using cortical mapping with electrical stimulation (No. 53).

Brain Tumors. Twenty-one articles concerned brain tumors. This included 13 articles on gliomas, 2 on meningioma, 2 on metastatic brain tumors, 1 on lymphoma, 1 on oligodendroglioma, and 2 that were nonspecific.

The articles on glioma included 11 on malignant glioma, of which 3 were specifically on glioblastoma multiforme and 1 was on anaplastic astrocytoma. Seven studies concerned radiotherapy (Nos. 68a, 76, 101), of which 4 assessed chemotherapy in conjunction with radiotherapy (Nos. 9, 15, 17, 58). One study identified a biochemical marker predictive of glioblastoma response to temozolomide (No. 46). There were 2 grading systems specifically for gliomas (Nos. 42a, 67), 1 trial of Gliadel (No. 66), 1 pilot study of intratumoral implantation of retroviral-producing cells (No. 81b), and 1 proposed set of criteria for Phase II studies of malignant gliomas (No. 44).

In addition, there were 2 classification systems of brain tumors by the WHO (Nos. 16, 35). Two studies were on the management of metastatic tumors to the brain, assessing radiotherapy in 1 (No. 90b) and resection in the other (No. 19). Two studies were on the recurrence of meningioma after surgery (No. 88), including 1 grading system for prediction of recurrence (No. 36). One study

TABLE 3: Journals in which citation classics were published*

Journal	No. of Articles	JIF (2008)
Journal of Neurosurgery	31	2.124
New England Journal of Medicine	24	50.17
Lancet	11	28.409
Journal of the American Medical Association	4	31.718
Journal of Neurology, Neurosurgery and Psychiatry	4	4.622
Stroke	3	6.499
Cancer	3	5.238
Neurosurgery	3	3.398
Journal of the National Cancer Institute	2	14.933
Annals of Neurology	2	9.935
International Journal of Radiation Oncology and Biophysics	2	4.369
Spine	2	2.793
Science	1	28.103
Nature Medicine	1	27.553
Annals of Internal Medicine	1	17.456
Journal of Clinical Oncology	1	17.157
Circulation	1	14.595
British Medical Journal	1	12.827
Neurology	1	7.043
Brain Pathology	1	5.576
Journal of Neuropathology and Experimental Neurology	1	5.14
Mayo Clinic Proceedings	1	4.811
Journal of Bone and Joint Surgery	1	3.313
Journal of Trauma	1	2.342
Archives of Physical Medicine and Rehabilitation	1	2.159
Spinal Cord	1	2.071
Journal of Computer Assisted Tomography	1	1.448
Acta Chirurgica Scandinavica	1	NA

* NA = not available.

was on the genetic predictors of response to chemotherapy of oligodendrogliomas (No. 41), and 1 was a review of primary CNS lymphoma (No. 74).

Trauma. The literature on trauma consisted of 14 articles on head trauma and 5 articles on spine trauma. With head trauma, 10 articles were on severe injury and 2 were on minor injury. Severe head injury topics included 2 trials evaluating the effects of hypothermia (1 showed no effect [No. 73] and the other showed hastened recovery and possible improved outcome [No. 34]) and 1 hyperventilation (adverse events associated with this practice, No. 93); 4 studies on the significance of ICP monitoring in severe head injury (Nos. 49, 55, 92, 95b); 1 prospective study evaluating the correlation between hypoxemia, hypotension, and poor outcomes (No. 32a); 3 studies classifying recovery after severe head injury (Nos. 1, 2, 104); and 1 case series on diffuse axonal injury (No. 89). The 2 articles on minor head injury concerned disability and neurobehavioral outcomes (Nos. 48, 86).

The articles on spine trauma included 4 on SCI and 1 on fractures. Studies on SCI included 2 randomized trials evaluating the effect of methylprednisolone (Nos. 11, 90a), 1 classification system (No. 47), and 1 review of the vascular mechanisms of secondary injury in SCI (No. 63). There was 1 classification system of thoracolumbar fractures (No. 52).

Other. Four articles regarding nontrauma-related spine disorders were included. Two were on the anterior cervical techniques for discectomy (Nos. 24, 83), and 2 were on MR imaging studies of the lumbar spine evaluating the significance of abnormal disc findings (Nos. 32b, 77). Two were studies of CSF pathology, including 1 on normal-pressure hydrocephalus (No. 25) and 1 on the hydrodynamic mechanism underlying syringomyelia (No. 85). One article was an analysis of CNS manifestations of AIDS (No. 14).

Types of Study

The studies were categorized as follows: 29 randomized trials, 15 grading systems or classifications, 16 prospective studies (including 5 cooperative studies), and 7 reviews. In addition, there were 39 case series. Table 4 breaks fields and types of study down by type of journal in which articles appeared, and Table 5 shows the distribution of types of study according to field of study.

Randomized Trials. Articles reporting on the results of randomized controlled trials made up 37% of the articles in this series (Table 4). Randomized trials were the highest cited papers in this collection, making up 8 of the 12 articles with more than 1000 citations. Eighty-six percent of the randomized trials appeared in *NEJM*, *Lancet*, or *JAMA*.

The 29 randomized trials included 17 trials on cerebrovascular disease, 5 on trauma, 6 on tumor, and 1 on epilepsy. Of the randomized cerebrovascular trials, 14 were studies of interventions for the prevention of stroke. These included 10 studies on CEA, comparing surgery to medicine in 8 and to stenting in 2; 8 of these were multicenter studies. There was 1 study of EC-IC bypass, concluding that the procedure failed to protect against ischemic stroke. There were 2 articles presenting the results from a randomized study of intraarterial thrombolysis for middle cerebral artery occlusion. Additional cerebrovascular randomized studies included 2 placebo-controlled trials of nimodipine for prevention of vasospasm, and 1 was a multicenter study comparing microsurgical clipping to endovascular coiling for ruptured aneurysms.

The 5 randomized studies on trauma included 2 on the results of the National Acute Spinal Cord Injury Randomized Trials, comparing methylprednisolone to naloxone in 1 and to tirilazad mesylate in the other, and 3 studies concerning hypothermia or hyperventilation.

The 6 tumor studies with a randomized trial design included a placebo-controlled trial of Gliadel wafers for recurrent gliomas, 3 studies evaluating the efficacy of radiotherapy and chemotherapy regimens (BCNU, nitrosoureas, and temozolomide) for high-grade gliomas, and 1 evaluat-

TABLE 4: Article citation count in relation to journal, year of publication, topic, and type of study

Variable	Citation Count								
	Total	400–500	501–600	601–700	701–800	801–900	901–1000	1001–2000	>2000
total	106	41	25	13	7	1	5	10	4
journal									
Journal of Neurosurgery	30	11	7	5	1	1	2	3	—
NEJM	24	5	5	3	5	—	2	3	1
Lancet	11	2	3	1	1	—	—	2	2
JAMA	4	2	—	—	—	—	—	1	1
JNNP	4	2	1	1	—	—	—	—	—
Neurosurgery	3	1	1	—	—	—	—	1	—
other	30	18	8	3	—	—	1	—	—
yr of publication									
1951–1955	1	—	1	—	—	—	—	—	—
1956–1960	4	1	—	1	1	1	—	—	—
1961–1965	3	1	—	—	1	—	—	1	—
1966–1970	2	1	—	1	—	—	—	—	—
1971–1975	4	—	2	—	—	—	—	—	2
1976–1980	8	4	1	—	—	—	2	1	—
1981–1985	16	8	5	1	—	—	—	2	—
1986–1990	15	6	4	2	—	—	2	1	—
1991–1995	23	8	4	6	1	—	1	1	2
1996–2000	17	8	4	1	1	—	—	3	—
2001–2005	13	4	4	1	3	—	—	1	—
field of study									
vascular	38	12	8	5	3	—	1	7	2
trauma	19	8	6	2	—	—	—	1	2
functional	21	9	6	3	2	1	—	—	—
tumor	21	9	5	2	—	—	4	1	—
spine	4	2	0	1	1	—	—	—	—
CSF	2	1	—	—	1	—	—	—	—
infection	1	—	—	—	—	—	—	1	—
type of study									
randomized	29	8	5	2	3	—	3	6	2
prospective	16	9	3	3	—	—	1	—	—
classification	15	3	4	3	—	—	1	2	2
case series/report	39	18	10	4	4	1	—	2	—
review	7	2	4	1	—	—	—	—	—

ing the efficacy of surgery for a single metastasis to the brain. The results of 1 of these trials were used to identify a genetic feature of glioblastoma that is predictive of response to temozolomide. The study on epilepsy randomized patients to surgery and prolonged medical therapy and found surgery to be superior in patients whose seizures are poorly controlled with medication.

Classification and Grading of Neurosurgical Disorders and Pathology. The 15 classification systems included 6 for tumor, 4 for vascular entities, and 5 for trauma. There were 2 general classifications for all brain tumors: the WHO and the updated WHO classification. There were 3 classification systems for astrocytomas, of which 2 were specific for malignant gliomas. The grading scale by Simpson is used to predict postoperative recurrence of meningiomas based on the extent of resection.

The 4 classification systems for cerebrovascular disease included 3 for ruptured aneurysms and 1 for AVM. These included the Hunt and Hess and the World Federation of Neurological Societies scores to predict outcome based on clinical grade, the Fisher score for assessing risk of vasospasm, and the Spetzler-Martin grading system for assessment of operative risk for AVM.

Among classifications for trauma, there were 2 for spine and 3 for head. The spine classifications included

TABLE 5: Breakdown by topics of types of study, 5-year epochs, and journal

Characteristic	Fields of Study						
	Vascular	Trauma	Functional	Tumor	Spine	CSF	Infection
study type							
randomized trial	17	5	1	6	—	—	—
case series/report	6	4	17	7	2	2	1
classification	4	5	—	6	—	—	—
prospective study	8	4	2	—	2	—	—
review	3	1	1	2	—	—	—
yr of publication							
1951–1955	—	—	1	—	—	—	—
1956–1960	—	—	1	1	2	—	—
1961–1965	—	—	—	—	—	2	—
1966–1970	3	—	—	—	—	—	—
1971–1975	1	2	1	—	—	—	—
1976–1980	1	2	1	4	—	—	—
1981–1985	6	5	1	2	1	—	1
1986–1990	6	2	3	4	—	—	—
1991–1995	9	4	5	4	1	—	—
1996–2000	7	3	4	3	—	—	—
2001–2005	5	1	4	3	—	—	—
2006–present	—	—	—	—	—	—	—
journal							
Journal of Neurosurgery	13	7	5	3	1	—	1
NEJM	8	3	7	4	1	1	—
Lancet	5	2	3	1	—	—	—
JAMA	3	1	—	—	—	—	—
JNNP	1	—	1	1	—	1	—
Neurosurgery	1	1	1	—	—	—	—
other	7	5	4	12	2	—	—

the International Standards for Neurological Classification in Spinal Cord Injury, and the Denis classification of thoracolumbar fractures. The head trauma classification systems included the prediction of disability after coma, the GOS, and the GCS.

Prospective Studies Defining Disease Course and Natural History. There were 15 prospective studies, of which 5 were cooperative studies. The latter included 2 on the timing of surgery for ruptured intracranial aneurysms, 1 on the natural history of unruptured aneurysms, 1 on the natural history of AVMs, and 1 characterizing the causes and demographics of SAH.

The prospective studies included 4 trauma studies, 3 vascular studies, 2 functional studies, and 2 spine studies. The trauma studies included 4 evaluating how outcomes after severe head injury correlate with various vital signs (blood pressure, oxygenation, and ICP), including the effect of aggressive ICP management on outcome. The vascular studies included 1 population-based cohort study on the incidences of stroke and hemorrhage, 1 study on the risk of hemorrhage in patients taking warfarin, and 1 study of elective carotid artery stenting. The 2 spine studies were on the significance of abnormal MR imaging findings in the lumbar spine. The 2 functional studies were both on DBS for PD.

Reports Detailing Pioneering and Early Experience With Procedures or Techniques. There were 39 articles that were case series, case reports, or pilot studies. There were 17 such articles on functional neurosurgery, 7 on tumor, 6 on vascular, 4 on trauma, 2 on spine, 2 on CSF, and 1 on infection.

There were 14 case series on movement disorders, including 11 on PD, 6 on DBS, 3 on pallidotomy, 5 on transplantation, 1 on tremor, and 1 including both PD and tremor. There were 2 on functional mapping, 2 on stereotaxy, and 1 on epilepsy. Pilot studies included adrenal medullary and embryonic neuron transplantation in PD, and globus pallidus internus pallidotomy for PD. One technical note described the stereotaxic method for radiosurgery of the brain.

There were 7 studies on tumors, including 2 statistical analyses of large databases to evaluate radiation therapy, and

TABLE 6: Impact factor, topics, and types of study in relation to categories of journals

Characteristic	Journal Category*			
	General (%)	Neurosurgery (%)	Other (%)	Total (%)
no. of journals	3	3	22	
total no. of articles	39 (37)	37 (35)	30 (28)	106 (100)
JIF (mean)	42.1	2.5	9.3	18.7
field of study				
vascular	16 (41)	15 (41)	7 (23)	38 (36)
functional	10 (26)	7 (19)	4 (13)	21 (20)
tumor	5 (13)	4 (11)	12 (40)	21 (20)
trauma	6 (15)	8 (22)	5 (17)	19 (18)
spine	1 (3)	1 (3)	2 (7)	4 (4)
CSF	1 (3)	1 (3)	—	2 (2)
infection	—	1 (3)	—	1 (1)
study type				
randomized trial	25 (64)	2 (5)	2 (7)	29 (27)
prospective study	4 (10)	8 (22)	4 (13)	16 (15)
case series/report	8 (21)	17 (46)	14 (47)	39 (37)
classification	2 (5)	5 (14)	8 (27)	15 (14)
review	—	5 (14)	2 (7)	7 (7)

* General = *NEJM*, *JAMA*, and *Lancet*; neurosurgery = *Journal of Neurosurgery*, *JNNP*, and *Neurosurgery*; other = remaining 22 journals. Percentages listed under field and type of study are in relation to the total articles in that category of journal.

1 on recurrences of meningioma after resection. One was a pilot study of retroviral vector–producing therapy of malignant brain tumors. Two additional articles were studies on radiation therapy of gliomas, and 1 study identified genetic predictors of chemotherapy for oligodendrogliomas.

The 4 vascular series included 2 early experiences with coiling, 1 on electroencephalographic findings during CEA, and 1 on endovascular occlusion of large vessels for various indications. There were 2 spine series on the anterior approaches for cervical discectomy. There was 1 series of CNS manifestation of AIDS.

There were 4 articles on trauma: 2 outcome studies on minor head trauma and 2 on severe head injury (case studies on diffuse axonal injury and the relationship between ICP and cerebral blood flow).

Reviews. There were 3 review articles on vascular topics, 2 concerning the pathophysiology of stroke, and 1 concerning vasospasm. Under tumor, 1 review article concerned CNS lymphoma, and another was a meta-analysis of radiotherapy and chemotherapy for malignant gliomas. There was a review on the role of "kindling" in epileptic seizures, and a review of the role of ischemia in secondary injury after SCI.

Citations and Impact Factors

There were a total of 75,410 citations to 106 articles, with a mean citation count of 711 (Table 7). As a topic, cerebrovascular surgery received the most total citations, and trauma averaged the most citations per paper (there was 1 study on infectious disease, and that study had 1007 citations). Randomized trials received the most citations, and the classification systems received the highest mean citations per paper. The GOS and the GCS largely accounted for the high mean citation count among trauma papers. While the 41 articles in journals with JIF > 25 (39 in *NEJM, JAMA,* and *Lancet*) averaged 916 citations, and the 47 articles in journals with a JIF < 5 (including the 37 neurosurgical journals) averaged 605 average, articles appearing in journals with a JIF of 5–25 averaged 523 citations. The citation count of an article did not correlate with the JIF of the journal in which the article appeared.

Discussion

Types of Studies That are Citation Classics

The most highly cited papers in our specialty are randomized trials evaluating surgical or medical treatments, followed by studies classifying or grading neurosurgical disease. Next in the ranking are studies that define the natural history of neurosurgical disorders and then studies outlining the first or early experience with a novel procedure or technique. Surprisingly, only 7% of the citation classics were review articles. Half of the randomized trials in this study concerned the prevention of stroke or the treatment of acute stroke. The highly cited randomized trials in neurosurgery appear preferentially (86%) in non-neurosurgical journals such as *NEJM, Lancet,* or *JAMA*.

Where are the Citation Classics Published?

While the 106 classic papers appeared in a total of 28 journals, they were heavily concentrated in a small number with half of the articles appearing in only 2 journals,

TABLE 7: Total and mean cites per article based on types of topic, study, and journal

Characteristic	Total Cites	Articles	Mean Cites/Article
total	75,410	106	711
field of study			
vascular	29,634	38	780
functional	11,545	21	550
tumor	13,234	21	630
trauma	16,519	19	869
spine	2301	4	575
CSF	1170	2	585
infection	1007	1	1007
study type			
randomized	24,293	29	838
case series/report	22,366	39	573
classification	16,542	15	1103
prospective study	8530	16	533
review	3679	7	526
JIF			
>25	37,561	41	916
5–25	8370	16	523
<5	28,422	47	605
category*			
general	36,496	39	936
neurosurgical	23,620	37	638
other	15,294	30	510

* Categories: general = *NEJM*, *JAMA*, and *Lancet*; neurosurgical = *Journal of Neurosurgery*, *JNNP*, and *Neurosurgery*; other = remaining 22 journals.

the *Journal of Neurosurgery* or *NEJM* (Table 3). The number of citations received was significantly higher for the 37 top-cited articles published in 3 high-impact journals, *NEJM, JAMA,* or *Lancet*, compared with the 37 top-cited articles published in neurosurgical journals (936 vs 638 mean citations per article). Overall, 45 articles (43%) appeared in journals with impact factors greater than 10, and 47 (44%) in journals with a JIF less than 5, the latter including all neurosurgical journals.

Topics

The citation classics papers were not equally distributed across neurosurgical subspecialties. Certain subspecialties in neurosurgery were more likely to have citation classics. The greatest number of citation classics was in the field of cerebrovascular diseases. Papers on cerebrovascular topics made up 38% of the articles, and 7 of the 10 top-cited articles were on cerebrovascular entities. This was followed by functional neurosurgery and tumor, and then trauma.

Of the 21 articles concerning stereotactic and functional neurosurgery, there was 1 randomized trial on epilepsy surgery and 2 formal prospective studies of DBS. Otherwise, functional articles were typically presented as case series. There were no classification systems, and no randomized studies of movement disorders, whereas such types of study were prominent among top-cited works in the other 3 major categories of vascular disease, trauma, and tumor.

While studies on tumors made up only 11% of articles in the neurosurgical journals and 13% of articles in the general medical journals *JAMA, NEJM,* and *Lancet*, such studies made up 40% of articles found in the remaining journals. This third group included journals on oncology and pathology, as well as *Nature Medicine* and *Science*. Thus, the type of publication in which highly cited tumor studies were published was different from those in which articles on other categories of studies were published ($p = 0.0017$, Fisher exact test).

Year of Publication

This analysis of citation rates allows for the recognition of seminal advances in neurosurgery and gives a historical perspective on the scientific progress of this specialty. It has been suggested that the true impact of an article often cannot be accurately assessed for at least 2 decades.[1,5,7,9,12] In this study, more than half of the articles were published since 1990 (Table 5), and 81% of articles were published since 1980. The absence of articles published after 2005 reflects insufficient amount of time having elapsed for such articles to amass 400 citations. The presence of only 22 articles from before 1980 may be related to limitations of the database source and to issues of immediacy, and may also reflect the relatively recent introduction of major technological advances such as microneurosurgery, spinal instrumentation, DBS, and endovascular techniques, which have played a major role in the growth of the specialty.

Highlights of High-Impact Work Over 6 Decades

The 1950s witnessed the introduction of stereotaxy and the anterior approach to the cervical spine, and the 1960s were characterized by cooperative studies on SAH and AVMs, as well as the Hunt and Hess grading system. The 2 studies on CSF pathologies (normal-pressure hydrocephalus and syringomyelia) were published during this period. During the 1970s, studies on head trauma emphasized the role of ICP management in improving survival, and the GCS and the GOS were introduced. Studies in neurooncology focused on radiotherapy and chemotherapy for gliomas.

In the 1980s, 3 pilot studies used cellular transplantation methods for the treatment of PD. Studies on cerebrovascular disease focused on vasospasm, including prediction using the Fisher grading system, diagnosis using transcranial Doppler ultrasonography, and prevention using nimodipine. Early in the decade, a study highlighted the use of EC-IC bypass for reversing misery perfusion, although a randomized study later failed to demonstrate any benefit from the surgery. The WHO classification system for brain tumors was introduced.

In the 1990s, trauma studies focused on the roles of cerebral perfusion pressure and effects of hypothermia and hyperventilation. Methylprednisolone for SCI was

evaluated in 2 trials. Cerebrovascular studies included the results of a large cooperative study on the timing of surgery for SAH. In addition, several studies focused on the benefits of CEA for the prevention of stroke and, later in the decade, endovascular thrombolysis for acute stroke. Glioma studies included the placebo-controlled randomized trial of Gliadel and a pilot study on the use of retroviral therapy. In addition, there were statistical and meta-analyses on the use of radiotherapy. The studies on surgery for movement disorders published during this decade included 4 on the early use of DBS and 3 studies on the use of pallidotomy.

Since 2000, there has been a prospective study comparing targets used for DBS and a pilot study on stem cell transplantation, both for PD. A randomized trial showed the beneficial effect of surgery for epilepsy. There have been large trials comparing endovascular techniques to microsurgical techniques for stroke prevention and aneurysmal SAH. The WHO classification of brain tumors was updated, the role of radiotherapy plus temozolomide for glioblastomas was established, and a biochemical marker to predict glioblastoma responsiveness to temozolomide was identified.

Limitations of the Study

Perhaps the greatest limitation to this work is the omission of highly cited articles that may not have been detected with the methods we used. Searches were derived based on topics found in the most cited articles in the neurosurgical journals in a companion study.[15] We included additional topics encountered in the course of conducting this assessment (for example, CEA). While articles may easily have been omitted by virtue of alterations in spelling (for example, stereotactic vs stereotaxic) or phrasing, the method presented is reproducible and allows for addition of topics that may reveal citation classics that we overlooked in the present study.

The present analysis was limited to articles describing clinical work in patients. The search produced 358 unique articles, of which 254 (71%) were omitted. Reasons for omitting papers included the following: 1) the paper was predominantly in the basic sciences; 2) it involved predominantly animal studies; and 3) the article belonged to other clinical fields. A large number of highly cited studies in neurooncology were omitted, perhaps somewhat arbitrarily, on the basis of their focus on basic science or molecular biology or molecular therapeutics. Such articles include the characterization of p53 mutations in human cancers, which was the highest cited work under "brain tumors" (5865 citations), initial trials of gene therapy, and the identification of mutations in neoplasms.[13,14,17] Articles identified in the present study were also limited to scientific and medical journals tracked by Web of Science and thus did not include classic textbooks on neurosurgery.[19]

The decision to omit papers before 1950 was in part due to limitations in the database. Indeed, our search found only 2 articles published before 1950: Kernohan's classification of tumors,[11] and an article by Dandy on hydrocephalus.[4] Several articles that appeared in *Neurosurgical Classics*[18] were not found on Web of Science, and others had relatively small citation counts. We believe this is an artifact of the database, and the limitations inherent in the database for tracking citations to older articles. Thus, the relative scarcity of articles from 1950–1980 may be related to limitations of Web of Science. Such limitations are acknowledged in other databases such as Google Scholar and Scopus.[2,6]

Future

The term "citation classics" was first used in 1977 to denote highly cited scientific articles identified by the Science Citation Index, the Social Sciences Citation Index, or the Arts and Humanities Citation Index. At that time, the journal *Current Contents* republished a series of highly cited papers, along with invited commentaries by the authors of these works. By 1984, more than 1800 authors had written invited commentaries on their highly cited papers for the journal. Four hundred citations was the cutoff for what was considered a "citation classic."

The informatics pertaining to the number of citations to a specific article has evolved and enables one to track trends in ideas and methods through time and include various indices by which to quantify the impact of a work, an individual, or a journal. Currently, bibliometric informatics provides such data as the citation index for an article, the *h* index for individuals, and the impact factor for journals. The *h* index was first proposed only 4 years ago[10] and is now widely used in academia for such processes as evaluation for grant allocation, making offers of employment, promotion, tenure, and fellowship in medical or scientific societies.[3] As bibliometrics continues to advance, indices will be developed to measure not only the impact of authors and journals but also of institutions and departments.

Conclusions

This study identifies 106 articles that have each amassed more than 400 citations in neurosurgery and are designated as citation classics. We would like to suggest certain implications of this work. First, neurosurgeons should be familiar with these classic articles. They are part of what is likely the most important and impactful body of work in our specialty. Second, neurosurgery training programs could consider studying these works in the neurosurgical curriculum to cover not only the historical aspects of our specialty but also identify its scientific foundations, the evolution of knowledge in our specialty, and its future direction. Third, both prospective authors and journal editors could use this list to evaluate the attributes of these works to gain insights into "what it takes" to have a classic publication and have major impact in our field. The collection of articles presented here is not intended to reflect a fixed list, but rather a dynamic list that will continue to change. No doubt, such a study as this will look very different in 5 or 10 years. We welcome letters from readers pointing out errors and omissions in our methods and analysis, as this will help track the highly impactful studies in our field.

Disclosure

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