Five-Year Institutional Bibliometric Profiles for 119 North American Neurosurgical Residency Programs: An Update

Ryan P. Lee[1], Garrett T. Venable[2], Mallory L. Roberts[1], Kara A. Parikh[3], Douglas R. Taylor[2], Nickalus R. Khan[2], L. Madison Michael II[2,4], Paul Klimo Jr[2,4]

■ BACKGROUND: **We recently performed a comprehensive bibliometric analysis of 103 U.S. neurosurgical departments and found the ih(5)-index as meaningful and reproducible using public data. The present report expands this analysis by adding 14 Canadian and 2 additional U.S. programs.**

■ METHODS: **Departments were included if listed in the American Association of Neurological Surgeons Residency Directory. Each institution was considered a single entity, and original research articles with authors who were neurosurgeon faculty were counted only once per institution, although a single article may have been credited toward multiple institutions, if applicable. The following bibliometric indices were calculated and used to rank departments: ih(5), ig(5), ie(5), and i10(5). In addition, intradepartmental comparison of productivity among faculty members was analyzed by computing Gini coefficients for publications and citations.**

■ RESULTS: **The top 5 most academically productive North American neurosurgical programs based on ih(5)-index were found to be the University of Toronto, University of California at San Francisco, University of California at Los Angeles, University of Pittsburgh, and Brigham and Women's Hospital. The top 5 Canadian programs were the University of Toronto, University of Calgary, McGill University, University of Sherbrooke, and University of British Columbia. The median ih(5)-index for U.S. and Canadian programs was 12 and 10.5, respectively.**

■ CONCLUSIONS: **This is the most accurate comprehensive analysis to date of contemporary bibliometrics among North American neurosurgery departments. Using the ih(5)-index for institutional ranking allows for informative comparison of recent scholarly efforts.**

INTRODUCTION

Recently, there has been increasing interest in the objective quantification of academic productivity among neurosurgery departments.[1-20] Although each of these measures of publication output (or bibliometrics) captures only 1 aspect of a department's productivity, collectively they create a profile that can be used for intradepartmental and interdepartmental analysis, both at a single point in time and longitudinally. Such analysis may be of interest to funding bodies, prospective employees or trainees, and hospital or academic administration. It is therefore essential that appropriate statistics be used, allowing individuals and groups to make the most well-informed decisions.

Numerous metrics, including the h-index and its variations, have been applied to the publication data from neurosurgery departments.[1-20] Many of these publications have focused on the lifetime cumulative output of a department's faculty members. Such cumulative statistics can be biased toward early career achievements and do not adequately represent more recent activity, or a lack thereof. In response, we recently introduced several 5-year institutional bibliometric measures to more accurately gauge

Key words
- Bibliometrics
- Canada
- e-Index
- g-Index
- Gini coefficient
- h-Index
- i10-Index
- Institutional
- Neurosurgery
- Rank

Abbreviations and Acronyms
JIF: Journal impact factor

From the [1]College of Medicine, [2]Department of Neurosurgery, University of Tennessee Health Science Center, Memphis, Tennessee; [3]College of Medicine, Louisiana State University, New Orleans, Louisiana; and [4]Semmes-Murphey Neurologic & Spine Institute, Memphis, Tennessee, USA

To whom correspondence should be addressed: Paul Klimo Jr., M.D., M.P.H. [E-mail: pklimo@semmes-murphey.com]

Citation: World Neurosurg. (2016) 95:565-575.
http://dx.doi.org/10.1016/j.wneu.2016.07.006

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

contemporary academic activity.[15] These new benchmarks include the ih(5)-index, ig(5)-index, ie(5)-index, and i10(5)-index. We found the ih(5)-index particularly useful because it was predictive of intradepartmental publication equality yet relatively insensitive to factors that tend to distort other indices, such as outlier faculty who are either highly productive or no longer academically active.

Using these, as well as other measures of academic productivity, we analyzed the 5-year institutional bibliometric profiles for 103 U.S. neurosurgical departments with residency programs.[15] The data from that analysis yielded an informative and novel set of institutional rankings. In the current analysis, we extended these methods to include the 14 Canadian neurosurgery departments with residency programs and added analyses of the National Capital Consortium Neurosurgery Residency Program (Walter Reed National Military Medical Center, Bethesda, Maryland, USA)[2] and Cleveland Clinic Neurosurgery Residency Program, creating a novel bibliometric analysis and ranking of 119 North American academic neurosurgical departments.

METHODS

The following methodologies are identical to those outlined in our previous publication.[15]

Selection of Programs

A list of the 2014 Canadian neurological surgery residency programs was compiled according to the American Association of Neurological Surgeons Residency Directory (http://www.aans.org/Young%20Neurosurgeons/Medical%20Students/Residency%20Directory.aspx). Departmental Web sites were consulted for faculty names, excluding all nonneurosurgical faculty members. Attempts were made by email and telephone to obtain unclear or unavailable relevant information in the departmental Web sites. All new data collection and calculations were carried out during August and September 2015, with the exception of Cleveland Clinic, for which data were collected in July 2016.

Bibliometric Analysis

Each neurosurgical institution was converted into a single entity whereby each neurosurgical faculty member's 5-year academic yield (measured in publications and citations) was compiled to compute the various metrics as listed later. A protocol was defined (also detailed later) for acquiring publication and citation data and then rigorously followed to ensure the most accurate evaluation of an institution's 5-year scholarly contributions to neurosurgery.

After composing a list of faculty for each institution, Scopus (Elsevier, www.scopus.com) was queried to obtain publication and citation data. The Author Search function was used to uniquely identify a faculty member, and each search was limited to include only peer-reviewed original research articles published from 2009 to 2013. An author's contributions counted toward the total publication and citation number of their affiliated institution at the time of publication. We accomplished this search by scrutinizing article headings of individual publications to account for any change in institutional affiliation over the last 5 years. If multiple authors from the same institution were on the same article, the following authorship assignment algorithm was used to ensure that each publication was counted only once: the article was assigned in the order of first author, second author, last author, then third author, and so on. Conversely, if the publication was multi-institutional, each institution received credit for the academic product attributed by that institution's respective faculty.

Definition of Metrics

After identifying an institution's total publications and citations for 2009–2013 using Scopus, all data were entered into Microsoft Excel, where publications were listed in decreasing order by number of citations. The following bibliometric measurements were calculated for each institution (i). Each metric is noted as (5) to indicate that the metric was calculated for a finite 5-year period and not for each individual member's entire career.

1) ih(5)-index: ih(5) = h(publications) with $\geq$h(citations); an institution's number of publications (h) with at least h citations.[21] It is the point at which the number of citations intersects the number of publications listed in descending order by citation count. We also normalized the ih(5)-index for the 119 neurosurgical residency programs to account for each institution's respective faculty number (at the time of our analysis) by using a simple ratio: ih(5)-index:faculty number. This result can be viewed as the average, equal contribution that each neurosurgeon on faculty makes to the department's 5-year (2009–2013) h-index.
2) ig(5)-index: ig(5) = g(publications) with $\geq g^2$(citations); an institution's number of publications (g) that cumulatively have received at least g^2 citations.[22] The g-index is designed to complement the h-index to more accurately capture highly cited publications.
3) ie(5)-index: ie, (5) = $\sqrt{}$(total citations of h papers, h^2); calculated by determining the total number of citations from articles that make up the institution's ih(5)-index, then subtracting the minimum number of citations required to reach that ih(5)-index (h^2).[23] The square root of this excess citation count is the ie(5)-index.[23] Like the g-index, the e-index was designed for highly cited publications.
4) i10(5)-index: i10(5) = n(publications) with $\geq$10 citations. Initially created by Google Scholar (http://scholar.google.com), it tallies the number of articles produced by an institution within the allotted 5-year span, acquiring 10 or more citations.

Ranking of Programs

All American Association of Neurological Surgeons–listed Canadian (n = 14) neurosurgical training programs were ranked by the defined metrics, total number of publications and citations, as well as by Gini coefficients for publications and citations (see later discussion). In addition, all North American programs, which include the 14 Canadian programs, the Cleveland Clinic, and our recent analysis of the National Capital Consortium Neurosurgery Residency Program (Walter Reed National Military Medical Center),[2] were pooled to construct an overall ranking by the defined metrics.

Publication Equality

To assess academic equality within each department, Lorenz curves and Gini coefficients were generated for publications and citations by all programs. The Lorenz curve is constructed with cumulative percent authors and cumulative percent publications or citations.[24] Thus, equal contribution by each faculty member would construct a straight 45° line of equality. Each department's Lorenz curve was first calculated using publications from neurosurgeons who were part of a particular department during the specified period. The Gini coefficient is a mathematical summary of inequality for author contribution to the department publication total based on the Lorenz curve. A Gini coefficient of 0 indicates equal contribution of department members to the overall publication rate, with a value of 1 showing complete inequality.

Statistical Analysis

After the various institution-specific metrics and Gini coefficients were calculated, pooled descriptive statistics were calculated for all 15 programs. Bivariate correlation using the Spearman coefficient was performed to assess the relationship between the various indices. Two-tailed statistical tests were used, with a P value <0.05 denoting statistical significance. All statistical analyses were carried out using SPSS (IBM Corp, Armonk, New York, USA) and R (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Canadian Programs

The bibliometric characteristics of neurosurgical training programs in Canada ($n = 14$) are listed in Table 1. The median number of faculty was 13. The median number of total publications was 66.5, with a median of 438.5 total citations. Other median indices were: ih(5) of 10.5, ig(5) of 19.5, ie(5) of 12.5, and i10(5) of 13.5. The median Gini coefficients for publications and citations for the Canadian departments analyzed were 0.58 and 0.74, respectively. Three of 14 programs (21.4%) had a Gini coefficient for publications lower than 0.5, and none had a Gini coefficient for citations lower than 0.5.

Among Canadian programs, ih(5) was significantly and positively correlated in bivariate analysis with number of faculty, total publications, total citations, and Gini coefficient for citations, but not significantly correlated with Gini coefficient for publications (Table 2). Similarly, the i10(5) index was significantly and positively correlated with number of faculty, total publications, and total citations. The ig(5) and ie(5)-indices were positively correlated with total publications and total citations, but not statistically correlated with number of faculty. None of the indices was correlated with Gini coefficient for publications but all were significantly negatively correlated with Gini coefficient for citations.

Institutional Rankings

The top 5 most academically productive North American neurosurgical programs by ih(5)-index were the University of Toronto, University of California at San Francisco, University of California at Los Angeles, University of Pittsburgh, and Brigham and Women's Hospital (Appendix 1). Table 3 shows the institutional rankings of the 14 Canadian programs by ih(5)-index, total publications, and total citations. The top 4 Canadian programs after the University of Toronto were the University of Calgary, McGill University, University of Sherbrooke, and University of British Columbia.

Table 1. Bibliometrics of North American Neurosurgical Programs

Characteristic	Canadian (n = 14)	U.S. (n = 105)
Faculty	13 (10.0—18.0)	13 (9.0—18.0)
Total publications	66.5 (35.5—93.3)	77 (34.0—166.0)
Total citations	438.5 (201.5—651.0)	716.0 (278.0—1441.0)
ih(5)-index	10.5 (7.3—14.0)	12.0 (8.0—19.0)
ig(5)-index	19.5 (13.5—22.5)	22.0 (14.0—32.0)
ie(5)-index	12.5 (9.5—16.5)	16.0 (10.0—24.0)
i10(5)-index	13.5 (5.5—22.8)	16.0 (8.0—42.0)
Gini coefficient		
Publications	0.58 (0.53—0.66)	0.58 (0.50—0.69)
Citations	0.74 (0.64—0.79)	0.71 (0.63—0.78)

All data are presented as the median (25%—75% interquartile range).

DISCUSSION

In this report, we provide a comprehensive bibliometric evaluation of nearly all North American academic neurosurgery by adding 14 Canadian programs, The National Capital Consortium Neurosurgery Residency Program (Walter Reed National Military Medical Center),[2] and Cleveland Clinic Neurosurgery Residency Program to our previous analysis of 103 U.S. programs. Using the ih(5) index, the University of Toronto ranked first in North America but ranked 26th when correcting for number of faculty.

Our previous analysis of U.S. programs showed a significant correlation between each core contemporary index (ih(5), ie(5), ig(5), and i10(5)) and number of faculty, total publications, total citations, and Gini coefficients for publications and citations, which showed the usefulness of these indices in predicting traditional metrics among U.S. programs.[15] When looking at Canadian programs in isolation, ih(5) and i10(5) were both positively correlated with (and thus predictive of) number of faculty, total publications, and total citations. The ig(5)- and ie(5)-indices, designed to favor more highly cited publications, were positively correlated with total publications and total citations but not with number of faculty. An explanation for this finding would be that within a typical department, there may be an individual or small group of researchers whose publications garner a high number of citations because of a well-established research infrastructure or network. An example is Dr. Michael Taylor at the University of Toronto, whose tumor biology research is of cutting-edge interest to a large audience and is published in very high-impact journals.[25,26]

The Gini coefficient was used to assess academic output equality among departments, herein stratified by both publications and citations. None of the core metrics were correlated with

Table 2. Spearman's Coefficient and Significance Values for Bibliometric Indices of Canadian Programs

Metric	Number of Faculty (*P* Value)	Total Publications (*P* Value)	Total Citations (*P* Value)	Gini Coefficient for Publication (*P* Value)	Gini Coefficient for Citations (*P* Value)
ih(5)-index	0.60 (0.023)	0.96 (<0.001)	0.99 (<0.001)	0.002 (0.994)	−0.556 (0.039)
ig(5)-index	0.53 (0.050)	0.89 (<0.001)	0.99 (<0.001)	−0.088 (0.765)	−0.585 (0.028)
ie(5)-index	0.49 (0.074)	0.79 (0.001)	0.92 (<0.001)	−0.095 (0.750)	−0.534 (0.049)
i10(5)-index	0.56 (0.039)	0.95 (<0.001)	0.99 (<0.001)	−0.042 (0.887)	−0.583 (0.029)

Gini coefficient for publications in a Canada-only analysis. This, in addition to our finding that few programs ($n = 3$; 21.4%) had a Gini coefficient for publication less than 0.5, indicated that publishing is, in general, similarly disproportionate among faculty members in Canadian programs compared with American (29/103; 28%).[15] Although all of the indices were significantly and negatively correlated with Gini coefficient for citations, which meant that a higher calculated departmental ih(5), ig(5), ie(5), or i10(5) score correlated to an increased equality in citation number among faculty, overall distribution of citations among Canadian faculty members was still disproportionate because no program had a Gini citation coefficient less than 0.5. This too is similar to our previous analysis in which only 4 U.S. programs had a citation coefficient of less than 0.5. The lack of equitable distribution of publications and citations was not surprising because departments are commonly composed of faculty with varying degrees of interest in research and breadth of readership within their respective subspecialty journals (eg, spine surgery vs. pediatric neurosurgery).

Since the submission of our previous study, the use of bibliometrics in neurosurgery has continued to grow. Wilkes et al.,[20] Jamjoom et al.,[3] and Knight et al.[10] applied the h-index and its variants to the United Kingdom. In the United Kingdom, the h-index positively correlated with advanced academic position, higher degree, and greater consultant experience.[3,20] Also, there were no differences in the indices between genders. However, Tomei et al.[16] showed higher research productivity (h-index) among men in the U.S. overall, but this effect was lost when correcting for academic rank. Schoenfeld et al. provided the first comparison of academic productivity and contributions to the

Table 3. Comparison of Canadian Departmental Rankings Based on Institutional h-index, Total Publications, and Total Citations

	ih(5)-Index				Total Publications			Total Citations		
Department	Canada Rank*	NA Rank*	Number†	Number of Faculty	Canada Rank	NA Rank	Number	Canada Rank	NA Rank	Number
University of Toronto	1 (2)	1 (26)	44 (1.38)	32	1	1	852	1	1	9739
University of Calgary	2 (3)	27 (28)	19 (1.36)	14	2	29	164	2	26	1658
McGill University	3 (9)	34 (80)	17 (0.77)	22	3	47	100	3	39	1059
University of Sherbrooke	4 (1)	50 (23)	14 (1.40)	10	6	59	76	4	58	665
University of British Columbia	4 (12)	50 (104)	14 (0.48)	29	4	49	97	6	62	567
University of Alberta	6 (5)	54 (60)	13 (0.93)	14	7	63	71	5	59	609
University of Saskatchewan	7 (4)	65 (51)	11 (1.00)	11	9	81	41	7	71	449
University of Western Ontario	8 (7)	69 (73)	10 (0.83)	12	5	55	82	9	77	356
University of Montreal	8 (11)	69 (96)	10 (0.53)	19	8	69	62	8	73	428
University of Dalhousie	10 (6)	87 (68)	8 (0.89)	9	10	84	40	10	89	275
McMaster University	11 (8)	94 (78)	7 (0.78)	9	11	88	34	12	99	157
University of Ottawa	12 (10)	100 (93)	5 (0.63)	8	12	98	27	11	97	177
University of Manitoba	13 (13)	107 (110)	4 (0.40)	10	13	101	23	13	107	88
Laval University	13 (14)	107 (115)	4 (0.27)	15	14	111	13	14	111	71

Rank in the second column is calculated among Canadian programs only; rank in the third column is rank calculated among a comprehensive North American program list.
NA, North American.
*Number in parentheses indicates program rank based on ih(5) corrected by faculty number during the 5 year period from 2009 to 2013: ih(5)/number faculty.
†Number in parentheses indicates h-index corrected by faculty number during the 5 year period from 2009 to 2013: ih(5)/number of faculty.

literature among faculty members of spine fellowship programs. Among these faculty, academic affiliation and number of fellows in a program were significantly associated with total number of publications, h-tot (h-index, 1996 to present), and h-pres (h-index 2011 to present).[14]

Also, in the interim, several articles have entered the literature that reviewed the historical use of bibliometrics, the progression to more advanced metrics, and their individual and generalized usefulness.[4,12,27-29] Azer et al.[27] provided an argument that h- and g-indices, along with Article Impact Score, have many advantages over Journal Impact Factor (JIF) in assessing individual and group research performance. Choudhri et al.[28] also echoed flaws in JIF and provided an excellent and comprehensive review of bibliometrics for both journals and individual articles. Along with Choudhri et al., Jenkins[4] highlighted several of the pitfalls in current bibliometric practice, including citation results variability between search engine or database used,[30-32] h-index distortion by self-citation and courtesy authorship, and contemporary metrics (eg, 2-year JIF, 5-year h-index), that lack adequate time for recent publications to accumulate citations. Madhugiri et al.[12] recently reported that the mean ± standard deviation of articles cited in the neurosurgical literature was 11.6 ± 11.7 years (median, 8). The peak rate of citation was reached at 6.25 years, suggesting that a 10-year discrete period may be more appropriate than the 5-year period used in our approach, or that shorter analyses need to be repeated to fully capture citations generated by articles. This dilemma highlights the difficulty with designing a metric that both provides an up-to-date picture of the productivity of a program and adequately captures impact of articles published in that time frame.

Madhugiri et al.[12] also discussed differences in baseline citation rates among specialties (particularly lower impact factor and rates of citation for neurosurgery-specific articles and journals) and proposed the use of a new interfield citation metric, which is a normalized measure that compares the average article citation of a journal against the average article citation in a given field. This metric shows promise in leveling the field in favor of smaller and more self-contained specialties like neurosurgery and provides similar results to our previous work in that highly interdisciplinary journals have broader readership and higher citation rates.[18,19]

Limitations

Consistent with our previous report, this analysis is limited by the accuracy of the information available from public sources. Every effort was made to attribute only active neurosurgical faculty to each institution and to contact programs when Web site information was unclear. Also, as before, we followed a strict protocol for collection and tabulation of publication statistics from Scopus, with diligent attempts to account for publication annotation errors, such as duplications and name misspellings. Although these analyses are limited by our raw data collection method, the protocol in our methodology represents the most efficient and publicly reproducible way to query institution-level bibliometric information on national and international scales.

As is obvious, publication statistics have become increasingly popular for use in comparing and evaluating institutions, particularly in light of improving bibliometric indices, such as the ih(5) and its variants. However, they do not provide insight into crucial parallel departmental efforts, such as training residents and fellows both in and out of the operating theater, how to effectively communicate with patients and families, participation in conferences (local, national, or international), research funding, and involvement in 1 or more of the many neurosurgical professional societies.

Future Directions

Increased focus over the past decade on bibliometrics not only has provided top programs with vindication for their efforts but also has shed light on program characteristics that foster high productivity. Dissecting and identifying these characteristics among top programs will allow for other institutions to emulate their efforts, thus improving the productivity and furthering the advancement of the field as a whole. Included within a thorough bibliometric self-analysis paired with our previous report, the University of Toronto recently provided valuable insight into their program and institutional structure, noting several intrinsic and extrinsic advantages.[11,33] Each neurosurgical program would likely benefit from completing detailed in-house bibliometric profiles, but these are not likely to be externally reproducible because each institution will have known and complete internal bibliographies as opposed to querying publically maintained databases.

We continue to encourage the development of more precise metrics to improve accuracy in assessing particular questions about publication output because of its foundational and growing importance. For example, future analysis may involve evaluating publication of original research versus review articles and guidelines, both of which typically garner higher citation counts. It may also be beneficial to evaluate neurosurgery-specific research, the degree of a neurosurgeon's involvement in individual projects (eg, authorship value),[7] or resident-only and fellow-only analyses. Moreover, with recognition of the usefulness of contemporary over summed metrics, experienced groups should conduct institution-level analysis at regular intervals for the foreseeable future. Programs should also make a greater consistent effort to improving their public interface, particularly their Web site, to include up-to-date faculty listings with appropriate details of field of practice and active status. Similarly, there is increasing importance in the accurate and timely annotation and indexing of publications and citations on databases such as Scopus and Web of Science.

CONCLUSIONS

In this article, we provide an update of our previous report detailing and ranking contemporary publication statistics among 103 U.S. neurosurgical departments. The 14 Canadian neurosurgery departments with residency programs, along with the National Capital Consortium Neurosurgery Residency Program and Cleveland Clinic Neurosurgery Residency Programs, have been individually evaluated and subsequently compiled with our U.S. database to provide the most comprehensive and accurate analysis of academic productivity among North American neurosurgery to date. Our approach uses validated metrics of contemporary research output using publicly available information, with which we hope to promote the objective comparison of departments for use in advancing neurosurgery as a whole.

ACKNOWLEDGMENTS

The authors wish to thank Andrew J. Gienapp (Department of Medical Education, Methodist University Hospital, Memphis, Tennessee and Department of Neurosurgery, University of Tennessee Health Science Center, Memphis, Tennessee) for technical editing and copyediting, preparation of the manuscript for publishing, and publication assistance with the manuscript.

REFERENCES

1. Aoun SG, Bendok BR, Rahme RJ, Dacey RG Jr, Batjer HH. Standardizing the evaluation of scientific and academic performance in neurosurgery—critical review of the "h" index and its variants. *World Neurosurg*. 2013;80:e85-e90.
2. Bell RS, Neal CJ. Letter to the Editor: bibliometric profiles for US neurosurgical residency programs. *J Neurosurg*. 2016;124:1545-1546.
3. Jamjoom AA, Wiggins AN, Loan JJ, Emelifeoneu J, Fouyas IP, Brennan PM. Academic Productivity of neurosurgeons working in the United Kingdom. Insights from the h-index and its variants. *World Neurosurg*. 2016;86:287-293.
4. Jenkins NR. Variation in the h-index and its use in the assessment of academic output. *World Neurosurg*. 2016;87:619-620.
5. Kalra RR, Kestle JR. An assessment of academic productivity in pediatric neurosurgery. *J Neurosurg Pediatr*. 2013;12:262-265.
6. Khan N, Thompson CJ, Choudhri AF, Boop FA, Klimo P Jr. Part I: the application of the h-index to groups of individuals and departments in academic neurosurgery. *World Neurosurg*. 2013;80:759-765. e753.
7. Khan NR, Thompson CJ, Taylor DR, Gabrick KS, Choudhri AF, Boop FR, et al. Part II: Should the h-index be modified? An analysis of the m-quotient, contemporary h-index, authorship value, and impact factor. *World Neurosurg*. 2013;80:766-774.
8. Khan NR, Thompson CJ, Taylor DR, Venable GT, Wham RM, Michael LM 2nd, et al. An analysis of publication productivity for 1225 academic neurosurgeons and 99 departments in the United States. *J Neurosurg*. 2014;120:746-755.
9. Klimo P Jr, Venable GT, Khan NR, Taylor DR, Shepherd BA, Thompson CJ, et al. Bibliometric evaluation of pediatric neurosurgery in North America. *J Neurosurg Pediatr*. 2014;14:695-703.
10. Knight J. Academic impact rankings of neurosurgical units in the UK and Ireland, as assessed with the h-index. *Br J Neurosurg*. 2015;29:637-643.
11. Lozano CS, Tam J, Kulkarni AV, Lozano AM. The academic productivity and impact of the University of Toronto Neurosurgery Program as assessed by manuscripts published and their number of citations. *J Neurosurg*. 2015;123:561-570.
12. Madhugiri VS, Sasidharan GM, Subeikshanan V, Dutt A, Ambekar S, Strom SF. An analysis of the citation climate in neurosurgical literature and description of an interfield citation metric. *Neurosurgery*. 2015;76:505-512 [discussion: 513].
13. Ponce FA, Lozano AM. Academic impact and rankings of American and Canadian neurosurgical departments as assessed using the h index. *J Neurosurg*. 2010;113:447-457.
14. Schoenfeld AJ, Bhalla A, George J, Harris MB, Bono CM. Academic productivity and contributions to the literature among spine surgery fellowship faculty. *Spine J*. 2015;15:2126-2131.
15. Taylor DR, Venable GT, Jones GM, Lepard JR, Roberts ML, Saleh N, et al. Five-year institutional bibliometric profiles for 103 US neurosurgical residency programs. *J Neurosurg*. 2015;123:547-560.
16. Tomei KL, Nahass MM, Husain Q, Agarwal N, Patel SK, Svider PF, et al. A gender-based comparison of academic rank and scholarly productivity in academic neurological surgery. *J Clin Neurosci*. 2014;21:1102-1105.
17. Venable GT, Khan NR, Taylor DR, Thompson CJ, Michael LM, Klimo P Jr. A correlation between National Institutes of Health funding and bibliometrics in neurosurgery. *World Neurosurg*. 2014;81:468-472.
18. Venable GT, Shepherd BA, Loftis CM, McClatchy SG, Roberts ML, Fillinger ME, et al. Bradford's law: identification of the core journals for neurosurgery and its subspecialties. *J Neurosurg*. 2016;124:569-579.
19. Venable GT, Shepherd BA, Roberts ML, Taylor DR, Khan NR, Klimo P Jr. An application of Bradford's law: identification of the core journals of pediatric neurosurgery and a regional comparison of citation density. *Childs Nerv Syst*. 2014;30:1717-1727.
20. Wilkes FA, Akram H, Hyam JA, Kitchen ND, Hariz MI, Zrinzo L. Publication productivity of neurosurgeons in Great Britain and Ireland. *J Neurosurg*. 2015;122:948-954.
21. Hirsch JE. An index to quantify an individual's scientific research output. *Proc Natl Acad Sci U S A*. 2005;102:16569-16572.
22. Egghe L. An improvement of the h-index: The g-index. *ISSI Newsletter*. 2006;2:8-9.
23. Zhang CT. The e-index, complementing the h-index for excess citations. *PLoS One*. 2009;4:e5429.
24. Bornmann L, Mutz R, Neuhaus C, Daniel H. Citation counts for research evaluation: standards of good practice for analyzing bibliometric data and presenting and interpreting results. *Ethics Sci Environ Polit*. 2008;8:93-102.
25. Morrissy AS, Garzia L, Shih DJ, Zuyderduyn S, Huang X, Skowron P, et al. Divergent clonal selection dominates medulloblastoma at recurrence. *Nature*. 2016;529:351-357.
26. Northcott PA, Shih DJ, Peacock J, Garzia L, Morrissy AS, Zichner T, et al. Subgroup-specific structural variation across 1,000 medulloblastoma genomes. *Nature*. 2012;488:49-56.
27. Azer SA, Holen A, Wilson I, Skokauskas N. Impact factor of medical education journals and recently developed indices: can any of them support academic promotion criteria? *J Postgrad Med*. 2016;62:32-39.
28. Choudhri AF, Siddiqui A, Khan NR, Cohen HL. Understanding bibliometric parameters and analysis. *Radiographics*. 2015;35:736-746.
29. Thompson DF, Walker CK. A descriptive and historical review of bibliometrics with applications to medical sciences. *Pharmacotherapy*. 2015;35:551-559.
30. Bakkalbasi N, Bauer K, Glover J, Wang L. Three options for citation tracking: Google Scholar, Scopus and Web of Science. *Biomed Digit Libr*. 2006;3:7.
31. Kulkarni AV, Aziz B, Shams I, Busse JW. Comparisons of citations in Web of Science, Scopus, and Google Scholar for articles published in general medical journals. *JAMA*. 2009;302:1092-1096.
32. Winter JCF, Zadpoor AA, Dodou D. The expansion of Google Scholar versus Web of Science: a longitudinal study. *Scientometrics*. 2013;98:1547-1565.
33. Klimo P Jr, Michael LM 2nd, Venable GT, Taylor DR. Letter to the Editor: Bibliometrics. *J Neurosurg*. 2016;124:877-879.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 13 April 2016; accepted 2 July 2016

Citation: World Neurosurg. (2016) 95:565-575.
http://dx.doi.org/10.1016/j.wneu.2016.07.006

*Journal homepage: **www.WORLDNEUROSURGERY.org***

*Available online: **www.sciencedirect.com***

1878-8750/$ - see front matter

Appendix 1. North American Ranking of Departments by Each Bibliometric Index

	ih(5)-index		Faculty			Total Publications		Total Citations		ig(5)-index		ie(5)-index		i10(5)-Index		Publication Gini Coefficient		Citation Gini Coefficient	
Department	Rank	Number	Number	ih5/Faculty Rank	ih5/Faculty Number	Rank	Number	Rank	Number	Rank	Number	Rank	Number	Rank	Number	Rank	Number	Rank	Number
University of Toronto	1	44	32	26	1.38	1	852	1	9739	1	71	2	46	1	261	47	0.55	47	0.69
University of California, San Francisco	2	42	33	33	1.27	2	680	2	9048	3	66	3	43	2	243	35	0.52	25	0.62
University of California, Los Angeles	3	36	23	15	1.57	6	360	3	6038	2	69	1	52	6	104	56	0.57	66	0.74
Brigham & Women's Hospital	4	31	16	5	1.94	12	263	5	4250	4	58	3	43	9	84	28	0.5	16	0.59
University of Pittsburgh	4	31	34	64	0.91	4	388	6	4065	11	48	14	31	4	119	85	0.66	66	0.74
Johns Hopkins University	6	29	31	59	0.94	3	557	4	4795	6	50	11	34	3	135	23	0.48	18	0.60
University of Virginia	7	28	14	2	2.00	8	328	8	3552	14	44	17	28	5	107	37	0.53	3	0.42
Duke University	8	27	15	7	1.80	12	263	7	3783	5	54	5	41	10	83	6	0.41	50	0.70
Ohio State University	8	27	22	38	1.23	14	261	12	3013	13	46	13	32	12	76	82	0.65	66	0.74
Northwestern University	10	26	23	46	1.13	14	261	17	2468	19	39	28	24	15	62	59	0.58	18	0.60
Stanford University	10	26	26	51	1.00	10	279	10	3534	9	49	9	36	8	86	67	0.61	66	0.74
Barrow Neurological Institute	10	26	29	66	0.90	5	365	9	3547	9	49	8	37	12	76	67	0.61	36	0.65
University of Florida	13	25	18	25	1.39	16	246	11	3236	6	50	7	38	14	66	71	0.62	82	0.77
Columbia University	13	25	19	30	1.32	9	291	13	2843	17	40	21	26	7	87	56	0.57	55	0.71
Cornell University	15	24	12	2	2.00	22	204	21	2043	21	36	30	23	15	62	23	0.48	12	0.55
University of Pennsylvania	15	24	16	18	1.50	27	178	15	2757	12	47	10	35	15	62	8	0.42	32	0.64
Cleveland Clinic	15	24	28	71	0.86	7	340	16	2626	21	36	32	22	11	80	76	0.63	55	0.71
Massachusetts General Hospital	18	23	20	43	1.15	11	271	18	2401	17	40	17	28	15	62	28	0.5	39	0.66
University at Buffalo	19	22	13	12	1.69	35	146	14	2812	6	50	5	41	30	41	98	0.72	90	0.79
Emory University	19	22	19	42	1.16	21	207	20	2212	15	42	14	31	19	51	51	0.56	50	0.70
Cedars Sinai Medical Center	21	21	14	18	1.50	32	152	25	1692	21	36	25	25	20	50	17	0.45	39	0.66
Washington University in St. Louis	21	21	16	31	1.31	24	189	29	1441	43	26	69	13	27	45	47	0.55	25	0.62
University of Washington	21	21	18	40	1.17	25	187	22	1847	21	36	25	25	23	49	51	0.56	60	0.72
University of Miami	21	21	18	40	1.17	31	153	33	1338	35	29	53	16	25	47	23	0.48	28	0.63
Oregon Health & Science University	25	20	13	17	1.54	28	166	19	2264	15	42	12	33	20	50	11	0.43	36	0.65
Case Western Reserve University	25	20	14	22	1.43	34	147	32	1363	36	28	53	16	23	49	64	0.59	50	0.70
University of Calgary	27	19	14	28	1.36	29	164	26	1658	21	36	21	26	26	46	11	0.43	15	0.58

Modified with permission from Table 3 in Taylor DR, Venable GT, Jones GM, Lepard JR, Roberts ML, Saleh N, et al. Five-year institutional bibliometric profiles for 103 US neurosurgical residency programs. *J Neurosurg.* 2015;123:547—560.[15]

Appendix 1. Continued

Department	ih(5)-index		Faculty			Total Publications		Total Citations		ig(5)-index		ie(5)-index		i10(5)-Index		Publication Gini Coefficient		Citation Gini Coefficient	
	Rank	Number	Number	ih5/Faculty Rank	ih5/Faculty Number	Rank	Number	Rank	Number	Rank	Number	Rank	Number	Rank	Number	Rank	Number	Rank	Number
Yale University	27	19	14	28	1.36	42	127	24	1697	19	39	16	30	32	37	11	0.43	32	0.64
Baylor College of Medicine	27	19	15	34	1.27	26	182	31	1422	31	31	33	21	32	37	59	0.58	63	0.73
University of Utah	27	19	18	50	1.06	18	217	28	1568	29	32	33	21	28	42	23	0.48	9	0.54
Virginia Commonwealth University	31	18	11	14	1.64	65	69	34	1315	27	35	17	28	47	25	47	0.55	47	0.69
University of Alabama, Birmingham	31	18	14	32	1.29	23	202	29	1441	28	33	28	24	34	34	8	0.42	16	0.59
Thomas Jefferson University	31	18	22	75	0.82	19	216	27	1608	32	30	36	20	20	50	89	0.68	63	0.73
University of Chicago	34	17	10	11	1.70	53	87	43	925	39	27	40	18	45	26	67	0.61	102	0.81
New York University	34	17	14	39	1.21	38	134	37	1120	39	27	40	18	36	32	22	0.47	28	0.63
University of Colorado	34	17	19	67	0.89	33	151	35	1210	39	27	44	17	28	42	17	0.45	4	0.49
University of Michigan	34	17	20	72	0.85	17	241	23	1791	21	36	17	28	30	41	19	0.46	39	0.66
University of Texas Southwestern	34	17	21	77	0.81	65	69	52	759	47	25	53	16	50	22	64	0.59	102	0.81
McGill University	34	17	22	80	0.77	47	100	39	1059	32	30	33	21	38	31	71	0.62	63	0.73
Mayfield Clinic/University of Cincinnati	34	17	23	84	0.74	37	137	40	1046	43	26	44	17	36	32	71	0.62	32	0.64
University of South Florida	34	17	25	90	0.68	43	112	42	946	43	26	44	17	40	29	101	0.74	90	0.79
Henry Ford Hospital	42	16	9	8	1.78	55	82	44	921	43	26	44	17	35	33	33	0.51	25	0.62
University of Wisconsin	42	16	15	49	1.07	44	111	41	958	36	28	36	20	40	29	43	0.54	55	0.71
University of California, San Diego	42	16	18	68	0.89	40	129	47	843	48	24	59	15	52	21	14	0.44	14	0.57
Wayne State University	45	15	9	13	1.67	49	97	55	716	51	23	59	15	50	22	80	0.64	36	0.65
Medical University of South Carolina	45	15	10	18	1.50	45	110	49	832	48	24	53	16	42	28	4	0.37	1	0.31
University of Maryland	45	15	11	27	1.36	57	80	55	716	57	22	64	14	42	28	94	0.71	60	0.72
University of Southern California	45	15	15	51	1.00	30	159	38	1062	57	22	64	14	39	30	14	0.44	13	0.56
Methodist Houston	45	15	15	51	1.00	54	83	36	1157	29	32	25	25	45	26	90	0.69	102	0.81
University of Illinois, Peoria	50	14	8	9	1.75	63	71	60	571	74	17	100	8	42	28	28	0.5	21	0.61
University of Iowa	50	14	9	16	1.56	40	129	47	843	51	23	59	15	47	25	8	0.42	5	0.50
University of Sherbrooke	50	14	10	23	1.40	59	76	58	665	61	21	69	13	49	24	67	0.61	28	0.63
University of British Columbia	50	14	29	104	0.48	49	97	62	567	64	20	74	12	53	19	109	0.77	94	0.80
Walter Reed	54	13	14	60	0.93	58	77	51	770	51	23	44	17	58	16	51	0.56	50	0.70
University of Alberta	54	13	14	60	0.93	63	71	59	609	51	23	44	17	58	16	6	0.41	9	0.54

Vanderbilt University	54	13	17	82	0.76	36	138	54	726	57	22	53	16	56	17	76	0.63	82	0.77
National Institutes of Health	57	12	5	1	2.40	81	41	45	917	32	30	21	26	60	15	5	0.4	18	0.60
Dartmouth University	57	12	6	2	2.00	67	64	66	485	66	19	74	12	61	14	59	0.58	21	0.61
Tufts Medical Center	57	12	7	10	1.71	48	99	69	460	72	18	74	12	61	14	28	0.5	8	0.52
Mayo Clinic, Rochester	57	12	12	51	1.00	38	134	64	523	72	18	83	11	73	10	1	0.32	2	0.39
Medical College of Wisconsin	57	12	13	62	0.92	61	72	57	699	48	24	40	18	53	19	19	0.46	39	0.66
George Washington University	57	12	13	62	0.92	70	61	77	356	80	16	90	9	61	14	43	0.54	47	0.69
Semmes-Murphey Clinic/University of Tennessee, Memphis	57	12	16	83	0.75	59	76	46	846	36	28	30	23	56	17	71	0.62	105	0.83
Mount Sinai School of Medicine	57	12	26	106	0.46	73	55	68	468	66	19	74	12	55	18	86	0.67	82	0.77
University of Kentucky	65	11	6	6	1.83	97	29	76	361	66	19	69	13	61	14	28	0.5	44	0.67
University of Saskatchewan	65	11	11	51	1.00	81	41	71	449	64	20	64	14	61	14	94	0.71	94	0.80
Loma Linda University	65	11	11	51	1.00	87	37	79	336	74	17	74	12	68	11	102	0.75	114	0.88
NSLIJ/Hofstra University	65	11	16	89	0.69	78	45	86	292	84	15	86	10	68	11	37	0.53	72	0.75
University of Kansas	69	10	8	35	1.25	72	57	65	492	61	21	44	17	68	11	114	0.79	94	0.80
University of Minnesota	69	10	8	35	1.25	74	53	84	302	88	14	100	8	73	10	59	0.58	21	0.61
University of New Mexico	69	10	8	35	1.25	85	39	61	568	51	23	36	20	73	10	51	0.56	90	0.79
University of California, Davis	69	10	9	48	1.11	71	60	63	549	57	22	39	19	68	11	64	0.59	79	0.76
Wake Forest University	69	10	10	51	1.00	67	64	70	453	66	19	64	14	73	10	76	0.63	87	0.78
University of Western Ontario	69	10	12	73	0.83	55	82	77	356	84	15	90	9	66	13	14	0.44	9	0.54
University of Rochester	69	10	12	73	0.83	78	45	67	477	61	21	44	17	73	10	59	0.58	55	0.71
University of Illinois, Chicago	69	10	13	81	0.77	52	90	72	448	74	17	83	11	68	11	82	0.65	21	0.61
University of Montreal	69	10	19	96	0.53	69	62	73	428	66	19	59	15	73	10	86	0.67	66	0.74
Allegheny General Hospital	69	10	19	96	0.53	76	49	87	284	88	14	90	9	73	10	111	0.78	119	0.92
Indiana University	69	10	24	109	0.42	20	214	50	802	51	23	40	18	66	13	119	0.91	117	0.91
Louisiana State University, New Orleans	80	9	6	18	1.50	93	31	88	278	80	16	74	12	80	9	19	0.46	28	0.63
Mayo Clinic, Florida	80	9	8	47	1.13	61	72	84	302	88	14	90	9	83	8	3	0.36	6	0.51
Albany Medical Center	80	9	9	51	1.00	80	44	74	385	66	19	59	15	83	8	23	0.48	79	0.76
Georgia Regents University	80	9	10	65	0.90	86	38	94	218	92	13	90	9	83	8	92	0.7	72	0.75
Rush University Medical Center	80	9	11	75	0.82	46	104	75	379	74	17	74	12	80	9	43	0.54	32	0.64
University of Texas, Houston	80	9	19	105	0.47	88	34	82	306	74	17	69	13	80	9	108	0.76	117	0.91
New York Medical College	80	8	20	108	0.40	95	30	91	261	84	15	74	12	83	8	94	0.71	87	0.78

Modified with permission from Table 3 in Taylor DR, Venable GT, Jones GM, Lepard JR, Roberts ML, Saleh N, et al. Five-year institutional bibliometric profiles for 103 US neurosurgical residency programs. *J Neurosurg.* 2015;123:547—560.[15]

Appendix 1. Continued

Department	ih(5)-index Rank	ih(5)-index Number	Faculty Number	ih5/Faculty Rank	ih5/Faculty Number	Total Publications Rank	Total Publications Number	Total Citations Rank	Total Citations Number	ig(5)-index Rank	ig(5)-index Number	ie(5)-index Rank	ie(5)-index Number	i10(5)-Index Rank	i10(5)-Index Number	Publication Gini Coefficient Rank	Publication Gini Coefficient Number	Citation Gini Coefficient Rank	Citation Gini Coefficient Number
Louisiana State University, Shreveport	87	8	7	44	1.14	49	97	90	264	92	13	90	9	89	7	111	0.78	82	0.77
University of North Carolina	87	8	7	44	1.14	104	19	98	174	92	13	86	10	95	6	115	0.8	110	0.85
Dalhousie University	87	8	9	68	0.89	84	40	89	275	80	16	74	12	89	7	71	0.62	60	0.72
University of Texas, San Antonio	87	8	9	68	0.89	98	27	96	189	92	13	90	9	96	5	86	0.67	94	0.80
Brown University School of Medicine	87	8	11	85	0.73	75	52	80	325	80	16	69	13	83	8	43	0.54	46	0.68
Georgetown University	87	8	12	91	0.67	77	48	92	243	88	14	86	10	89	7	35	0.52	44	0.67
West Virginia University	87	8	14	94	0.57	92	32	95	207	92	13	90	9	83	8	116	0.84	110	0.85
University of Vermont	94	7	5	23	1.40	104	19	106	109	103	10	106	6	89	7	2	0.34	6	0.51
McMaster University	94	7	9	78	0.78	88	34	99	157	100	11	100	8	96	5	94	0.71	72	0.75
University of California, Irvine	94	7	9	78	0.78	101	23	99	157	99	12	100	8	89	7	109	0.77	113	0.87
SUNY/Upstate Medical University	94	7	11	92	0.64	81	41	105	114	104	9	109	5	100	4	56	0.57	39	0.66
University of Nebraska	94	7	14	98	0.50	93	31	53	754	39	27	21	26	89	7	37	0.53	116	0.89
Penn State University	99	6	16	111	0.38	88	34	104	115	104	9	106	6	96	5	80	0.64	90	0.79
University of Texas, Galveston	100	5	7	86	0.71	100	26	108	86	108	8	109	5	107	2	111	0.78	94	0.80
Saint Louis University	100	5	7	86	0.71	107	18	101	129	100	11	90	9	107	2	51	0.56	66	0.74
University of Arizona	100	5	7	86	0.71	109	14	109	85	104	9	100	8	100	4	99	0.73	105	0.83
University of Ottawa	100	5	8	93	0.63	98	27	97	177	92	13	83	11	96	5	37	0.53	94	0.80
Carolinas Medical Center	100	5	10	98	0.50	104	19	93	238	84	15	64	14	100	4	102	0.75	114	0.88
Loyola University	100	5	10	98	0.50	112	12	112	65	108	8	109	5	107	2	76	0.63	55	0.71
Albert Einstein College of Medicine	100	5	11	107	0.45	95	30	81	321	74	17	53	16	100	4	33	0.51	94	0.80
University of Medicine and Dentistry of New Jersey	107	4	7	94	0.57	88	34	110	77	112	7	109	5	105	3	99	0.73	72	0.75
University of Mississippi	107	4	8	98	0.50	107	18	114	32	113	5	115	3	115	0	82	0.65	50	0.70
Geisinger Health System	107	4	8	98	0.50	115	8	103	123	108	8	86	10	100	4	102	0.75	82	0.77
University of Manitoba	107	4	10	110	0.40	101	23	107	88	104	9	105	7	105	3	47	0.55	79	0.76
Laval University	107	4	15	115	0.27	111	13	111	71	108	8	106	6	107	2	37	0.53	112	0.86

University of Louisville	112	3	8	111	0.38	103	22	102	126	100	11	90	9	107	2	118	0.86	94	0.80
University of Oklahoma	112	3	8	111	0.38	109	14	83	303	92	13	44	17	107	2	92	0.7	105	0.83
University of Puerto Rico	112	3	8	111	0.38	117	6	116	18	116	4	117	2	115	0	102	0.75	87	0.78
Tulane University	112	3	12	116	0.25	114	9	115	31	113	5	114	4	113	1	116	0.84	105	0.83
University of Arkansas	112	3	13	119	0.23	112	12	113	34	113	5	109	5	113	1	37	0.53	105	0.83
Temple University	117	2	4	98	0.50	118	4	117	12	117	3	117	2	115	0	102	0.75	72	0.75
University of Missouri	118	1	4	116	0.25	115	8	118	9	117	3	115	3	115	0	90	0.69	72	0.75
Southern Illinois University	118	1	4	116	0.25	119	1	119	5	119	1	117	2	115	0	102	0.75	72	0.75

Modified with permission from Table 3 in Taylor DR, Venable GT, Jones GM, Lepard JR, Roberts ML, Saleh N, et al. Five-year institutional bibliometric profiles for 103 US neurosurgical residency programs. *J Neurosurg.* 2015;123:547—560.[15]