A Correlation Between National Institutes of Health Funding and Bibliometrics in Neurosurgery

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■ OBJECTIVE: **The relationship between metrics, such as the h-index, and the ability of researchers to generate funding has not been previously investigated in neurosurgery. This study was performed to determine whether a correlation exists between bibliometrics and National Institutes of Health (NIH) funding data among academic neurosurgeons.**

■ METHODS: **The h-index, m-quotient, g-index, and contemporary h-index were determined for 1225 academic neurosurgeons from 99 (of 101) departments. Two databases were used to create the citation profiles, Google Scholar and Scopus. The NIH Research Portfolio Online Reporting Tools Expenditures and Reports tool was accessed to obtain career grant funding amount, grant number, year of first grant award, and calendar year of grant funding.**

■ RESULTS: **Of the 1225 academic neurosurgeons, 182 (15%) had at least 1 grant with a fully reported NIH award profile. Bibliometric indices were all significantly higher for those with NIH funding compared to those without NIH funding ($P < .001$). The contemporary h-index was found to be significantly predictive of NIH funding ($P < .001$). All bibliometric indices were significantly associated with the total number of grants, total award amount, year of first grant, and duration of grants in calendar years (bivariate correlation, $P < .001$) except for the association of m-quotient with year of first grant ($P = .184$).**

■ CONCLUSIONS: **Bibliometric indices are higher for those with NIH funding compared to those without, but only the contemporary h-index was shown to be predictive of NIH funding. Among neurosurgeons with NIH funding, higher bibliometric scores were associated with greater total amount of funding, number of grants, duration of grants, and earlier acquisition of their first grant.**

An academic physician's publication productivity and impact on his or her scientific community can by determined by quantitatively analyzing the number of publications and citations that appear in peer-reviewed journals, a process termed evaluative bibliometrics (25). Bibliometrics (or more broadly, infometrics or scientometrics) is rooted in citation analysis, or data on references cited in the footnotes and bibliographies of research publications (22). Although not perfect, it is generally believed that there is a correlation between the citation count of a publication and the impact or interest created within the academic community by the article. Some view citations as networks of trust (5): when researcher A cites researcher B, then A assumes B's claims are supported and true, and that publications cited by B (i.e., research done by other researchers C, D, E, etc.) were evaluated and influenced B's thinking and direction of research. Therefore, a successful publication record would consist of a number of publications (i.e., quantity), some of which are published in higher-impact journals or receive high citation counts (i.e., quality) (3).

Bibliometrics, such as the Hirsch index (16) and the impact factor of the publishing journal, allow one to portray the publication record of a researcher in quantitative detail. A bibliometric profile can be used to compare the research output of individual researchers, groups of individuals (e.g., male vs. female, young vs.

Key words
- Bibliometrics
- Citations
- Contemporary h-index
- Funding
- g-Index
- h-Index
- Neurosurgery
- NIH
- m-Quotient

Abbreviations and Acronyms
CIHR: Canadian Institutes of Health Research
GS: Google Scholar
NIH: National Institutes of Health
PoP: Publish or Perish
RePORTER: Research Portfolio Online Reporting Tools Expenditures and Reports

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old), and academic departments (18, 19). The use of bibliometrics in neurosurgery has been growing since the initial analysis by Lee et al. in 2009 (2, 8, 17-19, 21, 24, 28). Prior studies have investigated the relationship of bibliometrics to National Institutes of Health (NIH) funding within the fields of otolaryngology (29), radiology (25), and urology (10). Here we evaluate nearly all of academic neurosurgery—1225 neurosurgeons from 99 departments—to determine whether bibliometric indices, such as the h-index, m-quotient, g-index, and contemporary h-index (h_c)-index, are correlated to the number of research grants, total amount of funding, and duration and timing of funding.

METHODS

Study Population

A listing of the 2012 Accreditation Council for Graduate Medical Education neurosurgery residency training programs was obtained (https://www.acgme.org/ads/Public/Reports/ReportRun?ReportId=1&CurrentYear=2012&SpecialtyId=35). Departmental websites were consulted for names, academic ranks (i.e., assistant, associate, professor, and chairman), and subspecialties (i.e., spine, pediatrics, neurooncology/skull base, vascular, general, functional/epilepsy, peripheral nerve, and radiosurgery). Nonneurosurgical faculty (e.g., neurologists and basic science researchers) were excluded from this study. If there was insufficient information provided on a departmental website, we contacted the department via e-mail or telephone.

Definition of Bibliometrics

The h-index has a number of limitations that have prompted the development of innumerable other indices (1, 6). Here, we supplement the h-index with the m-quotient, h_c-index, and g-index.

h-Index. The h-index is defined as an individual having h papers with at least h citations. In other words, it corresponds to the point where the number of citations crosses the publications listed in decreasing order of citations.

m-Quotient. The m-quotient, also proposed by Hirsch (16), is the h-index divided by the number of years since the author's first publication. It allows a more accurate comparison of veteran to junior researchers, a bias inherent with the h-index.

h_c-Index. The contemporary h-index was developed by Sidiropoulos et al. (27). It corrects the original h-index by placing greater weight on newer publications than older ones. It is derived by multiplying the citation count of the article by 4, then dividing by the number of years since publication. Thus, the number of citations an article published in this year (2013) would be multiplied by 4; a paper from 4 years ago would have its citation count multiplied by 1; and a paper from 6 years ago would have its citation count multiple by 4/6.

g-Index. With articles ranked in decreasing order of the number of citations that they received, the g-index is the largest number such that the top g articles received (together) at least g^2 citations (12, 13). This gives credit to highly cited articles that would not have been recognized by the h-index.

Calculation of Bibliometrics

The h-index was calculated for individuals and departments using Elsevier's Scopus and Google Scholar (GS). The automated h-index from Scopus (http://www.scopus.com) was obtained using the Author Search function. Each individual then also had a manually calculated h-index determined by looking at each of the author's manuscripts (accounting for articles prior to 1996 in Scopus). The m-quotient was calculated by dividing Scopus's manually calculated h-index by the years since the first publication. Harzing's Publish or Perish (PoP; http://www.harzing.com/pop.htm) application was used to access GS for the g-index and contemporary h-index (h_c). PoP uses the Advanced Scholar Search capabilities of GS (14).

Authors' first and last names were used within search strings. Careful examination of the results from each search determined whether the author had a preference on how their initials were used for authorship. Further analysis was performed on each search result to determine whether it indeed represented the individual being searched for. This included looking at article titles, journals, and locations, as well as in some instances reading articles in their entirety for consistency.

NIH Funding Data

The funding status of each academic neurosurgeon was queried using the NIH's Research Portfolio Online Reporting Tools Expenditures and Reports (RePORTER) website (http://projectreporter.nih.gov/reporter.cfm), which provides data from 1989 to the present. The total amount of funding, total number of grants (including subprojects), total calendar years, and year of first grant awarded were recorded.

Statistical Analysis

We compared the median h-index, m-quotient, h_c-index, and g-index of academic neurosurgeons with and without NIH funding. A logistic regression model was used to determine whether any of the bibliometric indices under study were predictive in acquiring NIH funding. Among funded neurosurgeons, bivariate correlation was performed to determine whether the h-index, g-index, m-quotient, and h_c-index correlated with the total number of grants, total award amount, year of first grant, or duration of grants in calendar years. Correlation coefficients were calculated. Significance was determined as $P < .05$. Mean values $\pm$ standard deviations are presented. All statistics were calculated using SPSS version 21 (IBM, Aramonk, New York).

RESULTS

Study Population

A total of 233 (19%) academic neurosurgeons out of 1225 at 99 academic centers had obtained at least 1 NIH grant throughout their career. There were a total of 2369 NIH funding grants given to these 233 neurosurgeons (2 instructors, 38 assistants, 54 associates, 84 professors, and 54 chairmen). The total number of grants ranged from 1 to 87, with an average of 10 ± 13 and a median of 6 grants. The year of first grant ranged from 1989 to 2013, with an average of 1999 $\pm$ 7.5 years. The total calendar years of funding ranged from 1 to 25, with a mean of 5 ± 7 and a median of 5 years. Of the 233 academic neurosurgeons with at least 1 NIH grant, 182 had complete data—including total amount of funding (U.S. dollars)—and were

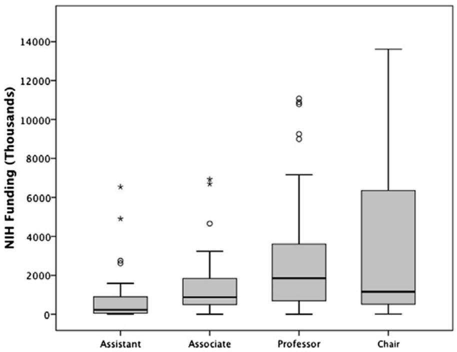

Figure 1. Box-and-whisker plot of the total NIH funding by academic rank (n = 182). The box extends from the 25th to 75th percentile, representing the interquartile range (IQR). The *dark horizontal line* is the median. The *lower whisker* extends to the lowest value within 1.5 IQR of the lower quartile, and the *upper whisker* extends to the highest value within 1.5 IQR of the upper quartile. More extreme values are represented by the *circles* and *asterisks*. NIH, National Institutes of Health.

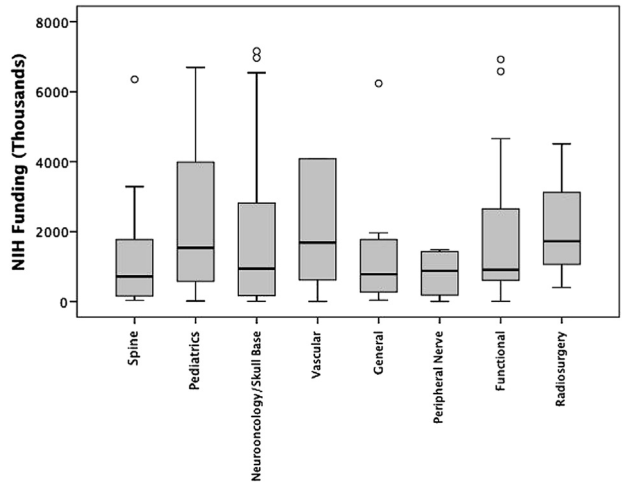

Figure 2. Box-and-whisker plot of the total NIH funding by specialty (n = 182). The box extends from the 25th to 75th percentile, representing the interquartile range (IQR). The *dark horizontal line* is the median. The *lower whisker* extends to lowest value within 1.5 IQR of the lower quartile, and the *upper whisker* extends to the highest value within 1.5 IQR of the upper quartile. More extreme values are represented by the *circles* and *asterisks*. NIH, National Institutes of Health.

included in the bibliometric analysis. The median total number of U.S. dollars of funding of the 182 with complete NIH grants data was $1,111,000.

The total amount of funding increased with each academic rank (Figure 1). The median amount of NIH funding was highest among pediatric and vascular neurosurgeons, whereas general and spine neurosurgeons had the lowest median NIH funding values (Figure 2). The top 10 departments with the highest total NIH funding dollars among neurosurgeons are shown in Table 1. The median total funding of U.S. dollars was $1,064,000 awarded to women and $1,869,000 awarded to men.

Bibliometric Analysis

Table 2 shows the median bibliometric indices for academic neurosurgeons with and without NIH funding. The h-index, m-quotient, g-index, and contemporary h-index all were significantly higher for those with NIH funding (N = 182) compared with those without NIH funding (N = 998) (Wilcoxon rank sum; $P < .001$). Logistic regression analysis demonstrated only the contemporary h-index to be predictive of NIH funding ($P < .001$). For those neurosurgeons with NIH funding, all bibliometric indices under study were positively significant when compared with the total number of grants, total award amount, and duration of grant in calendar years (bivariate correlation; $P < .001$) (Table 3). All bibliometric indices were significantly negatively correlated with the year of first grant except for the m-quotient ($P = .184$).

DISCUSSION

This is one of few published studies that evaluates the association between bibliometric measurement and NIH funding in a surgical subspecialty. We collected publishing and NIH funding data on nearly the entire specialty of academic neurosurgery. Our results show that academic or publishing output, as measured by the h-index, g-index, contemporary h-index, and m-quotient, are higher among neurosurgeons who have NIH funding compared with their nonfunded counterparts. Our use of bibliometrics other than the h-index as it relates to NIH funding is the first. We chose these bibliometrics because they corrected for some of the well-described deficiencies of the h-index. A somewhat surprising finding was that only the contemporary h-index was predictive of NIH funding. The contemporary h-index places greater weight on current publication productivity (within the last 4 years) and is considered by some to be a more robust version of the h-index and

Table 1. Top 10 Neurosurgery Departments with the Highest Total NIH Grant Funding Awards

Department	Total NIH Grant Funding (US $)
University of California, San Francisco	71,720,318
Brigham and Women's Hospital	42,216,605
University of Pittsburgh Medical Center	37,941,973
Yale University	29,766,969
Massachusetts General Hospital	27,126,711
The Ohio State University	27,061,601
University of California, Los Angeles	23,651,844
Stanford University	22,620,949
Oregon Health & Science University	20,723,666
Indiana University	17,110,758

NIH, National Institutes of Health.

Table 2. Median (with Range) Bibliometric Indices for Those with (N ≥1 Grants) Compared to Those without NIH Funding

	NIH Funding	
Bibliometric	**Yes**	**No**
h-Index	24 (0—74)	9 (1—76)
m-Quotient	1.0 (0.1—3.0)	0.5 (0—3.7)
hc- Index	12 (2—42)	3 (0—39)
g- Index	29 (2—131)	8 (0—129)

All bibliometrics were significantly higher in the NIH funding group compared to those without NIH funding (Wilcoxon Rank-Sum $P < .001$).
NIH, National Institutes of Health.

m-quotient, and thus is perhaps more predictive of academic success and ability to obtain funding (27). Among neurosurgeons with NIH funding, significant positive correlation was demonstrated between all bibliometric indices and all NIH data, except for the relationship of m-quotient and the year of first grant. The remaining bibliometric indices were negatively correlated with the year of first grant. This can be interpreted as those with higher academic output securing funding earlier in their careers.

All previous studies—urology, radiology, otolaryngology—have demonstrated that researchers with NIH funding have higher mean or median h-indices compared with those without NIH funding (10, 25, 29). However, consistent correlation between the h-index and other funding data has not been shown. In agreement with our results, Colaco et al. (10) and Svider et al. (29) both found a strong correlation between individual h-index and NIH funding awards. On the other hand, Rezek et. al. (25) found no significant correlation between h-index and number of grants, years of funding, or total funding amount among a randomly selected population of academic professors of radiology. There are several reasons that may explain this discrepancy. First, we analyzed over 5 times the number of researchers in our study. Second, we analyzed all records of funding, in contrast to the study by Rezek et al., which only analyzed the past 10 years. Lastly, Rezek et al. analyzed only professors and included those with PhD within the study population, whereas we limited our study to academic neurosurgeons.

The results of our study serve as benchmarks for individuals seeking NIH funding. One can compute their own bibliometrics and determine whether their numbers fall within the range of those who have achieved NIH funding. The natural question then arises: does the NIH use bibliometrics when determining who is to receive research grants? Interest, use, and evolution of bibliometric techniques is occurring within federal agency research, as reviewed by Hicks et al. (15). NIH grant reviewers are asked to "…provide an overall impact/priority score to reflect their assessment of the likelihood for the project to exert a sustained, powerful influence on the research field" (http://grants.nih.gov/grants/peer_review_process.htm). They also are asked to give individual scores based on the application's significance, principal investigator, innovation, approach, and environment. According to Dr. Karyl Swartz from the Center for Scientific Review at the NIH, each reviewer can use their own judgment when evaluating the investigator; there are no formal bibliometric criteria or checklists that are used (personal communication, July 2013). Reviewers are encouraged to focus solely on the contents of the application rather than on outside information such as the principal investigator's publication history.

The Canadian Institutes of Health Research (CIHR) has a similar approach (http://cihr-irsc.gc.ca/e/4656.html#s3_7_2). They too assess an application based on 5 criteria: 1) research approach, 2) originality of the proposal, 3) applicant(s), 4) environment for the research, and 5) impact of the research. Although there is no formal use of bibliometrics within its peer review process, they do provide the following statement:

> An important evaluation criterion in all grant programs is the excellence of the applicant(s). A key factor in assessing this criterion is the productivity of the applicant(s), as determined by the quality and impact of contributions to the field. When assessing the quality of publications, peer review committees should focus on the quality of a publication's content and not simply the number of publications nor the quality or impact factor of journals.

There is no doubt that other countries are using bibliometrics as part of a broader process to ensure that they get the highest-quality research for their money. In the United Kingdom, funding to universities from the Department for Education and Skills is mainly metrics based (7). In Australia, the government established the Research Quality Framework in order to determine the quality and impact of government-funded research, a portion of which was by the use of quantitative metrics. Some collectable quality indicators were the number of highly cited articles published, the number of articles in high-quality journals, and the number of citations of articles within articles published in high-quality journals (9). In 2004, the Institut National de la Santé et de la Recherche Médicale (French National Institute of Health and Medical Research) introduced bibliometrics as part of its research assessment procedures (26). In addition to the basic indicators

Table 3. Spearman Coefficient and Significance Values for Bibliometric Indices and NIH Grant Data

Bibliometric	Number of Grants	Years of Funding	Year of First Grant	Total NIH Funding (US $)
h-Index	0.538, $P < .001$	0.535, $P < .001$	−0.505, $P < .001$	0.420, $P < .001$
m-Quotient	0.409, $P < .001$	0.392, $P < .001$	−0.085, $P = .184$	0.384, $P < .001$
g-Index	0.490, $P < .001$	0.495, $P < .001$	−0.491, $P < .001$	0.387, $P < .001$
h_c-Index	0.538, $P < .001$	0.537, $P < .001$	−0.371, $P < .001$	0.475, $P < .001$

NIH, National Institutes of Health.

(citation numbers and journal impact factor), they also use the number of publications from an individual researcher that fall within the top 10% of articles within their specific discipline based on citations and within the top 10% impact-factor journals.

Study Limitations

The limitations of this study include the databases used (NIH RePORTER, Scopus, GS). Our results are only as accurate as provided by the online databases, which have several shortcomings (11). Scopus and GS have been shown to provide similar results, but occasionally vary from individual to individual (4, 11, 20, 23). The NIH RePORTER's tool for determining funding only dates back to 1989, thus spanning only a portion of the career of many of the researchers included in this study. Consequently, we found instances in which the number of grants to a scientist was published, but the total funding was not.

CONCLUSIONS

Although bibliometric analysis currently is not formally a part of the NIH peer-review process, it is part of the review process in other countries, and researchers should be aware of its potential use. We have demonstrated that bibliometric indices—h-index, m-quotient, h_c-index, and g-index—are all higher among neurosurgeons who have NIH funding compared with those who do not. However, only the contemporary h-index was shown to be predictive of NIH funding. Among those who have funding, higher bibliometric measures were associated with greater total amount of funding, number of grants, and duration of grants.

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