Predictors of Citations in Neurosurgical Research

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■ OBJECTIVE: **The number of citations an article receives is an important measure of impact for published research. There are limited published data on predictors of citations in neurosurgery research. We aimed to analyze predictors of citations for neurosurgical articles.**

■ METHODS: **All articles published in 14 neurosurgical journals in the year 2015 were examined and data collected about their features. The number of citations for each article was tallied using both Web of Science (WoS) and Google Scholar (GS) 2.5 years after their publication in print. Negative binomial regression was then performed to determine the relationship between article features and citation counts for scientific articles.**

■ RESULTS: **A total of 3923 articles were analyzed, comprising 2867 scientific articles (72.6%) and 1056 nonscientific (editorial, commentary, etc.) articles (27.4%). At 2.5 years, scientific articles had a median [interquartile range] number of citations per article of 3.0 [6.0] and 7.0 [9.0] found in WoS and GS, respectively; nonscientific articles had accumulated median 0.0 [2.0] in both WOS and GS. Articles with the study topic "Spine" had the highest citation count at 4.0 [5.0] and 8.0 [10.0] in WoS and GS, respectively. Significant predictors of citation count in scientific articles were level of evidence, number of centers, number of authors, and impact factor.**

■ CONCLUSIONS: **This is the largest investigation analyzing predictors of citations in the neurosurgical literature. Factors found to be most influential on citation rates in scientific articles included the study's level of evidence, number of participating centers, number of authors, and the publishing journal's impact factor.**

INTRODUCTION

In recent years there has been an increase in the volume of research, along with multiple efforts to quantify the productivity of researchers and the influence of study results. One long-standing measure of research impact is the journal impact factor, which is calculated based on the number of citations received by an article published in a given journal. Though somewhat controversial for the ways in which this calculation can be skewed, the impact factor is a well-recognized measure of the significance of scientific research. Given the limitations of this one calculation, however, the field of bibliometrics has emerged with many measures and indices developed to analyze research productivity and quality.[1] The number of citations an article receives, also referred to as the *citation rate*, is arguably the most important measure of impact for published research. The citation rate has important bibliometric implications not only for the article itself, but also for that of the authors, the institutions, and the journal.

Researchers have previously investigated features that may predict citation rates in published medical research in many specialties including cardiovascular, emergency medicine, plastic surgery, orthopedic surgery, transplant, and urology.[2-10] In the field of neurosurgery, however, there has yet to be any rigorous published analysis evaluating predictors of citations within neurosurgical publications or the effect of article study design, subject, level of evidence (LOE), or collaboration in obtaining future citations. With the expanding emphasis on bibliometrics, journal impact factor, and research

Key words
- Bibliometrics
- Citation rate
- Collaboration
- Level of evidence
- Neurosurgery
- Publications

Abbreviations and Acronyms
GS: Google Scholar
LOE: Level of evidence
NB: Negative binomial regression
WoS: Web of Science

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

Table 1. Number of Articles and Citations by Journal

	Number of Articles		Median Citations [IQR]			
			WoS		GS	
Journal	Scientific	Editorial	Scientific	Editorial	Scientific	Editorial
Acta Neuro	238	126	3.0 [4.0]	1.0 [2.0]	4.0 [7.0]	0.0 [1.8]
BJN	167	17	1.0 [2.0]	0.0 [1.0]	3.0 [5.0]	0.0 [1.0]
Euro Spine	444	70	3.0 [4.25]	0.0 [1.0]	7.0 [9.0]	0.0 [1.0]
JNS	350	88	5.0 [6.0]	0.0 [0.0]	10.5 [13.0]	0.0 [1.0]
JNSNF	86	106	5.0 [4.0]	3.0 [10.8]	9.0 [6.8]	2.0 [6.8]
JNSP	197	32	3.0 [6.0]	0.0 [0.0]	6.0 [10.0]	0.0 [1.0]
JNSS	199	24	4.0 [7.0]	0.0 [1.0]	8.0 [12.0]	0.0 [1.3]
JNSSci	14	29	1.0 [2.5]	3.5 [3.3]	2.5 [5.5]	2.0 [2.0]
Neurosurg Rev	77	5	3.0 [5.0]	1.0 [1.0]	5.0 [7.0]	2.0 [2.0]
Neurosurgery	203	147	5.0 [6.0]	0.0 [1.0]	9.0 [11.5]	0.0 [1.0]
Operative N	71	15	2.0 [2.0]	1.0 [1.0]	5.0 [6.0]	0.0 [0.5]
Spine	432	53	4.0 [5.0]	0.0 [0.0]	7.0 [9.0]	0.0 [0.0]
World N	389	281	3.0 [5.0]	0.0 [1.0]	6.0 [8.0]	0.0 [2.0]
NCNA		63		3.0 [4.5]		4.0 [4.5]
TOTAL	2867	1056	3.0 [6.0]	0.0 [2.0]	7.0 [9.0]	0.0 [2.0]

IQR, interquartile range; WoS, World of Science; GS, Google Scholar; Acta Neuro, Acta Neurochirurgica; BJN, British Journal of Neurosurgery; Euro Spine, European Spine; JNS, Journal of Neurosurgery; JNSNF, Journal of Neurosurgery Neurosurgical Focus; JNSP, Journal of Neurosurgery Pediatrics; JNSS, Journal of Neurosurgery Spine; JNSSci, Journal of Neurosurgical Sciences; Neurosurg Rev, Neurosurgical Rev; Operative N, Operative Neurosurgery; World N, World Neurosurgery; NCNA, Neurosurgical Clinics of North America.

productivity within academic neurosurgery, it is important to establish factors that may influence research impact within our specialty. We therefore sought to examine characteristics of neurosurgical articles, and identify predictive factors for future citations using a previously established database of nearly 4000 neurosurgical publications.

METHODS

All articles published in print between January 2015 and December 2015 in 14 English-language neurosurgical journals were reviewed as part of a prior pilot study to capture the LOE and international collaboration present within published neurosurgical literature.

Table 2. Negative Binomial Regression Model

Dependent: Web of Science Citations	IRR	SE	*P* Value
Level of evidence	0.86	0.01	<0.001
Number of centers	1.05	0.01	0.002
Number of authors	1.04	0.01	<0.001
Impact factor	1.42	0.04	<0.001
Dependent: Google Citations	**IRR**	**SE**	***P* Value**
Level of evidence	0.85	0.01	<0.001
Number of centers	1.06	0.01	<0.001
Number of authors	1.02	0.01	<0.001
Impact factor	1.35	0.01	<0.001

IRR, incidence rate ratio; SE, standard error.

Table 3. Number of Citations by General Article Subject

Subject Group	Number of Articles	Median Citations [IQR] WoS	GS
Functional	253	3.0 [5.0]	6.0 [8.0]
General neurosurgery	260	3.0 [6.0]	6.5 [9.0]
Vascular	446	3.0 [5.0]	5.0 [8.0]
Pediatric	147	3.0 [5.0]	5.0 [8.0]
Spine	943	4.0 [5.0]	8.0 [10.0]
Trauma	170	3.0 [6.0]	7.0 [10.0]
Tumor	468	3.0 [5.0]	7.0 [9.0]
Other	180	3.0 [6.0]	7.0 [9.0]

Detailed methodology regarding the data collection methods and results can be found elsewhere.[11] In brief, data were collected regarding authorship, number of contributing centers, study design, study subject, and LOE for all scientific and nonscientific papers published in 14 journals, including: *Acta Neurochirurgica*, *British Journal of Neurosurgery*, *European Spine Journal*, *Journal of Neurosurgery*, *Journal of Neurosurgery Neurosurgical Focus*, *Journal of Neurosurgery Pediatrics*, *Journal of Neurosurgery Spine*, *Journal of Neurosurgical Sciences*, *Neurosurgical Review*, *Neurosurgery*, *Operative Neurosurgery*, *Spine*, *Neurosurgical Clinics of North America*, and *World Neurosurgery*. Scientific articles were defined as studies that presented results of a clearly defined method in order to address a stated hypothesis (including meta-analyses and reviews), and/or studies that presented the results of 1 or more clinical cases. Nonscientific articles were defined as those that did not meet this criteria and included editorials, commentaries, historical articles, and science updates, among others. Criteria used to discriminate scientific versus nonscientific articles can be found elsewhere.[11]

Each study was assigned a LOE based on the modified LOE scale for neurointerventional and neurosurgical research, which consists of a score of I-V.[12] For the purposes of this study, "higher" LOE refers not to numerically higher but instead to LOE closer to level I (e.g., LOE of II is higher than LOE of III). Each study was also placed in a broad subject category including pediatric, trauma, vascular, tumor, spine, functional, general neurosurgery, or other. A subject subclassification within the given subject category was then selected.

To collect the number of citations, each article was searched on Web of Science (WoS; apps.webofknowledge.com) and Google Scholar (GS; scholar.google.com/) for the number of citations 2.5 years (30 months) after publication in print. For example, citation data were collected at the end of July 2017 for articles published in print versions of the journal in January 2015; similarly, citation data were collected at the end of June 2018 for articles published in print in December 2015. Therefore each article received an equal time consideration (2.5 years after print) for citation rates.

Impact factor for the 14 journals was recorded based on the January 2015 publicly reported journal impact factor in WoS Journal Citation Reports.[13]

Table 4. Number of Citations by Individual Subject Subclassification

Individual Subject Sub-Group	# Articles	Median Citations [IQR] WoS	GS
Pediatric brain tumor	39	2.0 [4.0]	4.0 [6.0]
Pediatric spine surgery	24	2.0 [4.5]	4.0 [4.0]
Pediatric traumatic injury/TBI	23	7.0 [8.5]	14.0 [15.0]
Other Pediatric	61	2.0 [3.0]	5.0 [7.0]
Adult traumatic brain injury	57	4.0 [5.0]	8.0 [11.0]
Adult traumatic spine	92	3.0 [6.3]	7.0 [10.3]
Other Trauma	21	3.0 [4.0]	6.0 [8.0]
Aneurysm	194	4.0 [5.8]	7.0 [10.0]
Arteriovenous malformation/fistula	96	4.0 [6.3]	7.5 [9.0]
Ischemic stroke	19	2.0 [5.0]	4.0 [8.0]
Hemorrhagic stroke	38	4.0 [4.0]	6.5 [8.0]
Other vascular	99	3.0 [4.0]	6.0 [8.0]
Intrinsic brain tumor	75	5.0 [7.0]	9.0 [11.5]
Meningioma	60	4.0 [5.3]	8.0 [9.0]
Brain metastases	79	3.0 [5.0]	6.0 [8.0]
Other Brain tumor	174	3.0 [4.8]	5.5 [8.8]
Spinal cord tumor	57	4.0 [4.0]	7.0 [6.0]
Spinal column tumor	23	3.0 [5.0]	8.0 [7.0]
Cervical myelopathy/surgery	243	4.0 [6.0]	7.0 [11.0]
Artificial disk	13	5.0 [5.0]	10.0 [6.0]
Fusion of thoracic or lumbar spine	152	4.0 [6.0]	10.0 [11.0]
Spinal deformity and scoliosis	277	3.0 [6.0]	7.0 [9.0]
Spinal infection	32	3.0 [4.5]	6.0 [9.5]
Other spine	226	4.0 [5.0]	8.0 [9.0]
Deep brain stimulation	44	3.0 [4.3]	7.0 [6.3]
Epilepsy/seizure	45	4.0 [6.0]	7.0 [10.0]
Pain/spasticity	149	3.0 [4.0]	6.0 [8.0]
Other functional	15	2.0 [2.0]	4.0 [4.0]
Hydrocephalus/CSF disorders	117	3.0 [5.0]	6.0 [9.0]
Other infection	30	3.5 [5.8]	7.0 [7.8]
Operating room	4	1.0 [0.5]	1.5 [1.3]
Residency training	17	3.0 [9.0]	8.0 [10.0]
Socioeconomic	19	5.0 [4.5]	9.0 [10.0]
Anatomy	73	4.0 [6.0]	6.0 [9.0]
Other	180	3.0 [5.0]	5.0 [8.0]

IQR, interquartile range; WoS, World of Science; GS, Google Scholar; TBI, traumatic brain injury; CSF, cerebrospinal fluid.

Table 5. Top 20 Represented Countries by First or Second Author and Citation Rates

First or Second Country	Number of Articles	Median Citations [IQR] WoS	GS
USA	1189	4.0 [6.0]	8.0 [10.0]
China	295	3.0 [5.0]	6.0 [8.0]
Japan	253	3.0 [4.0]	6.0 [7.0]
Germany	181	3.0 [6.0]	7.0 [9.0]
Canada	161	5.0 [6.0]	9.0 [11.0]
United Kingdom	144	2.0 [4.0]	5.0 [8.0]
Italy	138	2.0 [4.0]	5.0 [6.8]
Korea	120	3.0 [5.0]	6.0 [9.0]
France	81	4.0 [8.0]	9.0 [11.0]
Switzerland	68	3.0 [4.3]	6.0 [8.3]
India	60	2.0 [4.3]	4.0 [7.5]
The Netherlands	57	5.0 [5.0]	8.0 [8.0]
Australia	50	4.0 [6.8]	8.0 [9.8]
Turkey	47	2.0 [3.0]	6.0 [6.5]
Spain	39	3.0 [4.0]	7.0 [5.0]
Sweden	34	3.5 [5.8]	8.5 [10.5]
Brazil	32	3.0 [5.0]	7.0 [8.0]
Finland	28	5.0 [5.3]	8.0 [8.8]
Norway	28	5.0 [5.0]	10.0 [10.5]
Taiwan	28	3.5 [4.0]	8.0 [9.3]

IQR, interquartile range; WoS, World of Science; GS, Google Scholar.

Statistical Methods

Descriptive statistics were calculated such that median [interquartile range] were used for the skewed count data. Difference in distributions of citation rate between scientific and nonscientific articles was analyzed by Mann-Whitney U test. Difference in number of citations per article between WoS and GS were examined by Wilcoxon signed rank tests. WoS and GS citation counts for scientific articles were modeled by negative binomial regression (NB) using the predictors of LOE, number of centers, number of authors, and impact factor. Other predictors of study design, subject group, month of publication, and number of countries were considered separately and eliminated after comparison of model fit (Akaike information criterion). Prior to analysis, correlations between the predictors and response variables were examined. Because citation count is a non-negative integer, its distribution was remarkably skewed, and the conditional variance was larger than the conditional mean (overdispersion). A number of nonlinear models were compared in order to determine best fit. They included Poisson and quasi-Poisson regression, NB, hurdle NB, and zero-inflated Poisson/NB regressions.[14] Poisson and quasi-Poisson models were eliminated because of poor model fit. NB was chosen over hurdle NB and zero-inflated NB based upon results of the Vuong likelihood ratio test for model selection, examination of rootograms and comparison of estimates/standard errors.[15] Beta coefficients were converted to incidence rate ratios with standard error. Comparison in medians of WoS and GS citation counts between subject groups among scientific articles was tested using Kruskal-Wallis H test with *P*-values for pairwise comparisons adjusted by the Dunn method with Bonferroni correction. All analyses were conducted using R (R: A language and environment for statistical computing, R Foundation for Statistical Computing, Version 3.4.3, Vienna Austria) and RStudio (Integrated Development for R, Version 1.1.383, RStudio, Inc., Boston, MA). Two-tailed hypothesis testing was used with $P < 0.05$ interpreted for statistical significance.

RESULTS

A total of 3981 articles were published in the 14 journals in 2015 and were initially reviewed. There were 22 scientific articles and 36 editorial articles with either missing data or that were not traceable in either WoS or GS and were excluded from further analysis. Thus, a total of 3923 articles were analyzed comprising 2867 scientific articles (72.6%) and 1056 editorial articles (27.4%). Descriptive statistics for the articles and citations are shown in Table 1. LOE, study design, contributing centers and countries, and other data for scientific articles may be found elsewhere.[11]

Two and one half years after publication, the 3923 articles had generated a total of 16,355 citations in WoS and 28,542 in GS. Scientific articles were disproportionately responsible for the majority of these citations in both WoS (87%) and GS (93%), with a significantly higher citation rate for scientific than nonscientific articles ($P < 0.001$). The median number of citations per scientific article was 3.0 [6.0] and 7.0 [9.0] in WoS and GS respectively, whereas nonscientific articles had a median of 0.0 [2.0] for both WoS and GS. A sizable proportion of articles received zero citations during the 2.5 year period. There were 928 articles with zero citations in WoS (24%) and 668 with zero citations in GS (17%).

Scientific articles published in the *Journal of Neurosurgery* ($n = 350$) were the most highly cited on both WoS and GS. Nonscientific articles published in *Neurosurgical Focus* had the highest citation count in WoS; nonscientific articles published in *Neurosurgical Clinics of North America* had the highest citations in GS.

Citation Search Engine

The number of citations recorded for each article was significantly higher when using the GS search engine compared with WoS ($P < 0.001$), with the GS citation rate being 1.75 times higher than WoS.

Predictors of Citations

Several factors significantly and independently contributed to the prediction of both WoS and GS citation counts in scientific articles on regression analysis (Table 2). A 1-level increase in LOE (towards higher quality evidence) was associated with a 14% and 15% increase in citation counts for WoS and GS, respectively. For each additional contributing institution, citations increased by 5% and 6% for WoS and GS, respectively. For each additional contributing author, citations increased by 4% and 2% for WoS and GS,

Table 6. Top 10 Web of Science Cited Articles at 2.5 Years

Order	Title	Number of Citations: WoS	Number of Citations: GS	Journal	Subject	LOE	Number of Centers	Number of Authors	Inter-national?
1	The Barrow Ruptured Aneurysm Trial: 6-year results	72	134	JNS	Vascular	1	2	9	No
2	Effect of exosomes derived from multipluripotent mesenchymal stromal cells on functional recovery and neurovascular plasticity in rats after traumatic brain injury	71	102	JNS	Trauma	5	2	7	No
3	2015 updated Method Guideline for Systematic Reviews in the Cochrane Back and Neck Group	54	85	Spine	Functional	5	6	8	Yes
4	Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis	46	102	Spine	Spine	5	1	5	No
5	Awake craniotomy to maximize glioma resection: methods and technical nuances over a 27-year period	42	89	JNS	Tumor	4	1	7	No
6	Predictors of postconcussion syndrome after sports-related concussion in young athletes: a matched case-control study	37	70	JNSP	Pediatric	3	1	7	No
7	Long-term quality of life in patients with vestibular schwannoma: an international multicenter cross-sectional study comparing microsurgery, stereotactic radiosurgery, observation, and nontumor controls	37	56	JNS	Tumor	4	2	13	Yes
8	Validation of the supplemented Spetzler-Martin Grading System for brain arteriovenous malformations in a multicenter cohort of 1009 surgical patients	37	47	Neurosurgery	Vascular	4	4	11	Yes
9	Safety and efficacy of the Pipeline Embolization Device in 100 small intracranial aneurysms	36	50	JNS	Vascular	4	3	12	No
10	Two-level total disc replacement with Mobi-C cervical artificial disc versus anterior discectomy and fusion: a prospective, randomized, controlled multicenter clinical trial with 4-year follow-up results	35	58	JNSS	Spine	1	9	11	No

WoS, World of Science; GS, Google Scholar; JNS, Journal of Neurosurgery; JNSP, Journal of Neurosurgery Pediatrics; JNSS, Journal of Neurosurgery Spine; Euro Spine, European Spine; World, World Neurosurgery.

respectively. For each additional publishing journal impact factor point, citations increased by 42% and 35% for WoS and GS, respectively.

Study Subject

Table 3 demonstrates scientific article citation rates by article topic within neurosurgery. Spine articles ($n = 943$) were the most frequently cited on WoS, with a median of 4.0 [5.0] citations per article in WoS. Spine articles were also the highest cited on GS with 8.0 [10.0] per article.

Median WoS and GS citation counts were significantly different overall between subject groups, $\chi^2(7) = 19.3$, $P = 0.007$ and $\chi^2(7) = 38.8$, $P < 0.001$, respectively (Table 3). The post hoc analysis revealed a statistically significant difference in median WoS citation counts between spine and other subject groups ($P = 0.018$). There were also differences in median GS citation counts in the spine and other ($P < 0.001$), spine and pediatric ($P < 0.001$), and spine and tumor subject groups ($P = 0.018$).

Table 4 shows the individual subject subclassification and median citation rates. Pediatric traumatic injury/traumatic brain injury ($n = 23$) had the highest median citations with 7.0 [8.5] per article in WoS and 14.0 [15.0] in GS.

Collaboration

Table 5 presents the top 20 countries represented by either the first or second author and the number of articles and median citations per article. The US was represented the greatest number of times in 1189 articles published in 2015, with 4.0 [6.0] citations in WoS, and 8.0 [10.0] in GS. The second most represented country was China.

Top 10 Cited Articles

The top 10 most cited articles in both WoS and GS are presented in Tables 6 and 7, respectively. Key features of the articles are presented along with predictors of citation rate. The top 5 cited articles in both WoS and GS were varied in these features, although they shared the fact they were published in either *Journal of Neurosurgery* or *Spine*.

Table 7. Top 10 Google Scholar Cited Articles at 2.5 Years

Order	Title	# Citations GS	# Citations WoS	Journal	Subject	LOE	# Centers	# Authors	Inter-national?
1	The Barrow Ruptured Aneurysm Trial: 6-year results	134	72	JNS	Vascular	1	2	9	No
2	Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis	102	46	Spine	Spine	5	1	5	No
3	Effect of exosomes derived from multipluripotent mesenchymal stromal cells on functional recovery and neurovascular plasticity in rats after traumatic brain injury	102	71	JNS	Trauma	5	2	7	No
4	Awake craniotomy to maximize glioma resection: methods and technical nuances over a 27-year period	89	42	JNS	Tumor	4	1	7	No
5	2015 updated Method Guideline for Systematic Reviews in the Cochrane Back and Neck Group	85	54	Spine	Functional	5	6	8	Yes
6	Predictors of postconcussion syndrome after sports-related concussion in young athletes: a matched case-control study	70	37	JNSP	Pediatric	3	1	7	No
7	Development of three-dimensional hollow elastic model for cerebral aneurysm clipping simulation enabling rapid and low cost prototyping	67	30	World	Vascular	5	1	7	No
8	Incidence of traumatic spinal cord injury worldwide: a systematic review	63	26	Euro Spine	Trauma	3	4	5	Yes
9	Complications following cranioplasty: incidence and predictors in 348 cases	61	23	JNS	Other	4	2	13	No
10	Core outcome domains for clinical trials in non-specific low back pain	60	30	Euro Spine	Functional	5	13	19	Yes

WoS, World of Science; GS, Google Scholar.

DISCUSSION

The present study is the largest and most comprehensive review of neurosurgical literature citation rates, with nearly 4000 published articles reviewed across 14 journals, and 2.5 years' worth of citation data collected for each article from 2 independent citation search engines. This analysis demonstrates that certain tangible factors are highly predictive of citation rate and include higher levels of evidence, institutional and international collaboration, and publication in a journal with a higher impact factor. There was also a significant difference in citation rate, an important factor in bibliometric indices such as an author's *h*-index,[1,16,17] depending on the search engine used (WoS vs. GS). The difference may be due to Google Scholar's inclusion of additional documents considered scholarly such as theses, academic publishers and professional societies, and other Web sites.[18] In contrast, journal articles are included in WoS via a committee-based process driven by selection criteria; they then appear in search results based on catalogued features. Google Scholar search results appear based on word recognition driven by search engine.

Predictors of citation rates in other specialties have been reported previously and are highlighted in Table 8. The most frequently found predictors included study design[2,4,9,10,23] and number of authors.[5,7,20,22] In the present study, an article's LOE and the publishing journal's impact factor were found to be significant predictors of citation rate; each has previously been demonstrated as a predictor in the orthopedic, emergency medicine, and oral and maxillofacial surgery literature.[3,6,20] Impact factor as a predictor is somewhat intuitive because it is calculated with citation rates, although this metric is calculated from citations of articles published during the 2 prior years. We also found that the number of centers represented in the article and the number of authors were significant predictors of citation rate, which is consistent with other studies that also found collaboration to be predictive.[6-8,22] Although study subject was found to have a significant predictive relationship in the urology literature[9] and sample size was predictive in orthopedic literature,[6] these features were not significantly associated with citation rate in the present study.

Limitations of this study include the relatively short time period (1 year) of articles collected, although this was augmented by the number of journals reviewed (14) and the total number of articles included (3923) from that single year. Including more journals would have improved the article count but inclusion of articles

Table 8. Statistically Significant Features Predictive of Citation Rates Published in Non-neurosurgical Fields

Predictive Factor	Field, Reference
All authors radiologists	Radiology[8]
Article selected for press release	Public Health[19]
Collaborators	Radiology[7]
Country of origin	Radiology[8]
Countries (multiple)	Radiology[7]
Disclosed conflict of interest	Orthopedics,[6] Plastics[5]
Fewer pages	Transplantology[4]
First author's *h*-index: increasing	OMFS[20]
Human participants	Transplantology[4]
Journal impact factor: increasing	Emergency Medicine[3]
Journal	OMFS,[20] Plastics[5]
Level of evidence	OMFS,[20] Orthopedics[6]
More characters or words in abstract	Radiology[8]
More words in manuscript	Radiology[8]
More words in title	Radiology[21]
Newsworthiness score	Emergency Medicine[3]
Number of articles published by same author	Public Health[19]
Number of authors	OMFS,[20] Pharmacy,[22] Plastics,[5] Radiology[7]
Number of institutions	Orthopedics,[6] Pharmacy[22]
Publication time frame	Orthognathic,[23] Transplantology[4]
Sample size: 100 or more	Orthopedics[6]
Study content	OMFS,[20] Orthognathic,[23] Plastics,[5] Urology[9]
Study design	Cardiovascular,[10] Orthognathic,[23] Orthopedics,[2] Transplantology,[4] Urology[9]
Subjective quality score	Emergency Medicine[3]
Title contains acronym	Radiology[21]
Title contains colon	Radiology[21]
Title contains study findings	Radiology[8]

OMFS, oral and maxillofacial surgery.

from high-impact journals with content from multiple specialties may have also introduced confounders in the course of determining which articles are "neurosurgical" in nature, or relevant to our aim of characterizing the neurosurgical literature. The 2.5-year time period for citation analysis was chosen so as to include both modern, relevant neurosurgical publications yet still allow for a substantial enough follow-up period to accrue citations. Nonetheless, 1 potential confounder for citation rates was different lead times to publication for articles published online ahead of print. Future analysis of this database with citation counts performed at delayed intervals may help understand how neurosurgical literature is cited over time.

Additional limitations include the potential for errors in classifying the study's subject, study design, and level of evidence during the process of reviewing nearly 4000 articles. It is also possible that small variations in the way author affiliations were published lead to inaccurate categorization of collaboration status. The level of evidence scale utilized in this study is relatively new and yet to be repeatedly validated, therefore there may still be a way to further optimize study classification in this regard. An additional feature that would have improved the present analysis would be to include data on the rates of self-citations.

CONCLUSIONS

This is the largest and most in-depth investigation analyzing predictors of citations for neurosurgical published literature. Factors found to be most influential on citation rates included the study's level of evidence, number of participating centers, number of authors, and the publishing journal's impact factor.

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