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Bibliometric Analysis of 6 Major European Neurosurgical Publications from 2011-2020 (part 3): a Comparative Metrics Review

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ABSTRACT

Background: We previously conducted bibliometric analysis of 6 North American neurosurgical journals. **Objective:** To perform a bibliometric analysis of 6 European neurosurgical journals to build on our previous studies. **Methods:** We searched Web of Science for articles published in *Acta Neurochirurgica*, *British Journal of Neurosurgery*, *Child's Nervous System*, *Journal of Neurological Surgery Part A: Central European Neurosurgery*, *Journal of Neurosurgical Sciences*, and *Neurosurgical Review* between 2011 and 2020. We analyzed bibliometric parameters related to total annual document distribution, author metrics, journal metrics, country and continental distribution, institution, keywords, and journal impact. **Results:** European countries provided the greatest contributions. *Acta Neurochirurgica* followed by *Child's Nervous System* published the greatest number of articles and had the highest h-index and number of citations. From 2018 to 2020, total documents increased 79.6%, original articles increased 86.5%, review articles increased 103.6%, citations increased 79.6%, number of publishing authors increased 72.1%, number of authors in multi-author documents increased 72.4%, and author's keywords and keywords plus increased 72.4% and 27.0%, respectively. The collaboration index decreased 5.3% from 4.49 to 4.25. Annual published documents and citations were lower for European journals versus North American journals. **Conclusion:** Several parameters of the European journals increased by 2020. One interesting finding is that growth for the 6 journals dramatically increased in the 2 years prior to the COVID-19 pandemic. While neurosurgeon free time during lockdowns may account for much of the increase in 2020, the trend began before this. Our analysis did not identify a cause for the pre-COVID increases.

Keywords: Bibliometrics, Scientometrics, Neurosurgical journals, Publication trends, Article types.

1. BACKGROUND

Bibliometrics and its statistical methods are frequently used in library and information science to analyze books, articles, and other publications (1, 2). Since the late 2000s, it has become a principal review study methodology to examine parameters that have significantly influenced the medical literature, such as articles, authors, journals, countries, and continents. For example, a search for the keyword bibliometrics in the National Library of Medicine's PubMed database returned over 16,500 articles, and the annual number of articles published has steadily increased. Almost 2100 bibliometric articles were published in 2021 alone, representing an astounding 676% increase from the mere 270 articles published in 2005.

Scientometric studies are essential for understanding the various author and article-based parameters as the amount of scientific literature available in all the specialties has increased tremendously. According to De Bellis, scientometrics "encompasses all quantitative aspects and models related to the production and dissemination of scientific and technological knowledge" (1). Using scientometric parameters to perform longitudinal medical literature studies can uncover publication trends

Description	Total	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Documents	12,682	1,009	1,125	1,227	1,075	1,161	1,184	1,152	1,177	1,458	2,114
Citations											
Average citations per document	7.433	12.7	12.23	10.74	9.988	8.486	7.382	6.757	5.406	3.77	2.622
Average citations per year per document	1.072	1.058	1.112	1.074	1.11	1.061	1.055	1.126	1.081	1.018	1.054
Citations	180,620	20,793	22,796	23,073	21,876	22,537	23,769	24,579	26,732	31,222	48,015
Document Types[a]											
Original Article	8,626	655	804	863	789	789	741	763	773	1,007	1,442
Article; proceedings paper	43	6	5	4	3	2	6	3	4	7	3
Article; retracted publication	3	1	-	1	-	-	-	-	-	-	1
Biographical item	65	3	4	5	3	6	6	6	10	7	15
Book review	17	-	-	-	-	-	1	1	-	1	14
Correction	115	5	2	3	7	11	12	26	13	19	17
Editorial material	831	100	91	101	93	103	129	59	44	57	54
Letter	1,293	138	108	130	93	141	127	134	137	116	169
News item	1	-	-	-	-	-	-	1	-	-	-
Retraction	2	-	-	-	-	-	1	-	-	1	-
Review	1,685	101	111	120	86	109	161	159	196	243	399
Keywords											
Author's keywords (DE)	17,345	2,085	2,434	2,780	2,563	2,652	2,635	2,763	2,868	3,414	4,945
Keywords plus (ID)	12,764	2,385	2,595	2,686	2,550	2,501	2,749	2,733	2,881	2,795	3,658
Authors											
Authors	31,421	3,646	4,114	4,601	4,197	4,598	4,552	4,704	5,048	6,773	8,690
Author appearances	66,320	4,666	5,354	6,067	5,383	5,741	5,719	5,982	6,296	8,894	12,218
Authors of single-authored documents	516	77	70	58	62	85	97	66	51	62	73
Authors of multi-authored documents	30,905	3,569	4,044	4,543	4,135	4,513	4,455	4,638	4,997	6,711	8,617
Author collaborations											
Single-authored documents	878	97	87	73	81	108	120	88	65	74	85
Documents per author	0.404	0.277	0.273	0.267	0.256	0.253	0.26	0.245	0.233	0.215	0.243
Authors per document	2.48	3.61	3.66	3.75	3.9	3.96	3.84	4.08	4.29	4.65	4.11
Co-authors per document	5.23	4.62	4.76	4.94	5.01	4.94	4.83	5.19	5.35	6.1	5.78
Collaboration index	2.62	3.91	3.9	3.94	4.16	4.29	4.19	4.36	4.49	4.85	4.25

Table 1. Characteristics of European neurosurgical publications (2011–2020). [a]Document types determined by Web of Science.

within a specialty.

In our previous scientometric studies (3, 4), we studied the parameters of the six major North American neurosurgical journals from 2011 to 2020 (3). In this third article of our series, we examined 6 European medical journals that are either the official journals of the neurosurgical societies of European countries or edited by European editors. The aim of part 3 is to study the various geographic (country and continent), author, and citation-related metrics of the 6 European journals, to analyze the annual changes in trends over the same period we examined as our previous studies, and to compare these new results with our North American findings.

2. OBJECTIVE

The aim of this article was to perform a bibliometric analysis of 6 European neurosurgical journals to build on our previous studies.

3. MATERIAL AND METHODS

Data collection

We searched the Web of Science (Clarivate Analytics, Philadelphia, PA) database on 16th May 2022 for all documents published between 2011 to 2020 in 6 European journals, which were either the official journals of the neurosurgical societies of European countries or major journals edited by European editors. These journals include the following: *Acta Neurochirurgica (ANC), Neurosurgical Review (NRev), British Journal of Neurosurgery (BJNS), Journal of Neurological Surgery, Part A: Central European Neurosurgery (JNLS-A), Journal of Neurosurgical Sciences (JNSS)*, and *Child's Nervous System (CNS)*. These journals have a focus on general neurosurgery.

We excluded journals that involve cooperation with other specialties (spinal surgery, for example, includes both neurosurgery and orthopedics), which we labeled *combined journals* in our previous analyses. Our rationale for excluding combined journals is that the citation metrics will differ from general neurosurgical journals due to the effect of non-neurosurgical participation. Likewise, we excluded topic-based journals because of the narrow focus and possible cross-specialty effects seen with combined journals.

Publication data for several parameters were collected. We examined document metrics, such as the number of published documents over time per journal, the number of citations journals received over time, and the distribution of published document types over time. Document types were defined by Web of Science as the following: *Original Article,*

Document	DOI	Total Citations	Total Citations per Year	Normalized Total Citations
Peeters W, 2015, Acta Neurochir	10.1007/s00701-015-2512-7	347	43.3750	40.8919
Bush Nao, 2017, Neurosurg Rev	10.1007/s10143-016-0709-8	267	44.5000	39.5149
Ducruet AF, 2012, Neurosurg Rev	10.1007/s10143-011-0349-y	219	19.9091	17.9117
Zanin L, 2020, Acta Neurochir	10.1007/s00701-020-04374-x	191	63.6667	58.5418
Chua NHL, 2011, Acta Neurochir	10.1007/s00701-010-0881-5	174	14.5000	13.6990
Coenen VA, 2011, Acta Neurochir	10.1007/s00701-011-1036-z	139	11.5833	10.9434
Pang D, 2011, Child Nerv Syst	10.1007/s00381-010-1358-9	137	11.4167	10.7860
Thelin EP, 2017, Acta Neurochir	10.1007/s00701-016-3046-3	136	22.6667	20.1274
Meola A, 2017, Neurosurg Rev	10.1007/s10143-016-0732-9	122	20.3333	18.0555
Duffau H, 2016, Acta Neurochir	10.1007/s00701-015-2621-3	121	17.2857	16.3918
Stummer W, 2011, Acta Neurochir	10.1007/s00701-011-1001-x	120	10.0000	9.4476
Schebesch KM, 2013, Acta Neurochir	10.1007/s00701-013-1643-y	119	11.9000	11.0817
Toma AK, 2013, Acta Neurochir	10.1007/s00701-013-1835-5	118	11.8000	10.9886
Pollack IF, 2011, Child Nerv Syst	10.1007/s00381-010-1264-1	107	8.9167	8.4241
Duffau H, 2013, Acta Neurochir	10.1007/s00701-013-1653-9	106	10.6000	9.8711
Chon KH, 2012, Acta Neurochir	10.1007/s00701-012-1399-9	105	9.5455	8.5878
Selbekk T, 2013, Acta Neurochir	10.1007/s00701-013-1647-7	103	10.3000	9.5918
Tovar-Spinoza Z, 2013, Child Nerv Syst	10.1007/s00381-013-2169-6	98	9.8000	9.1261
Acerbi F, 2013, Acta Neurochir	10.1007/s00701-013-1734-9	95	9.5000	8.8468
Miller LE, 2012, Brit J Neurosurg	10.3109/02688697.2011.641613	95	8.6364	7.7699
Abubaker K, 2011, Brit J Neurosurg	10.3109/02688697.2010.544781	95	7.9167	7.4793
Duffau H, 2012, Acta Neurochir	10.1007/s00701-012-1275-7	91	8.2727	7.4427
Siu A, 2012, Acta Neurochir	10.1007/s00701-011-1228-6	91	8.2727	7.4427
Jean WC, 2020, Acta Neurochir	10.1007/s00701-020-04342-5	90	30.0000	27.5851
Kamp MA, 2012, Acta Neurochir-A-B	10.1007/s00701-011-1200-5	90	8.1818	7.3610
Puget S, 2015, Child Nerv Syst-A	10.1007/s00381-015-2832-1	88	11.0000	10.3703
Phan K, 2015, Brit J Neurosurg	10.3109/02688697.2015.1036838	88	11.0000	10.3703
Zoia C, 2020, Acta Neurochir-A	10.1007/s00701-020-04305-w	87	29.0000	26.6656
Iaccarino C, 2018, J Neurosurg Sci-A	10.23736/S0390-5616.18.04532-0	86	17.2000	15.9079
Krieg SM, 2017, Acta Neurochir	10.1007/s00701-017-3187-z	86	14.3333	12.7276
Van Der Meulen J, 2012, Child Nerv Syst	10.1007/s00381-012-1803-z	86	7.8182	7.0338
Zurek J, 2012, Acta Neurochir	10.1007/s00701-011-1175-2	86	7.8182	7.0338
Arthurs BJ, 2011, Neurosurg Rev	10.1007/s10143-011-0307-8	86	7.1667	6.7708
Martin KD, 2014, Acta Neurochir	10.1007/s00701-014-2021-0	85	9.4444	8.5103
De Almeida EA, 2011, Child Nerv Syst	10.1007/s00381-010-1278-8	85	7.0833	6.6920
Englot DJ, 2014, Neurosurg Rev	10.1007/s10143-014-0527-9	84	9.3333	8.4102
Hammouche S, 2014, Acta Neurochir	10.1007/s00701-014-2156-z	83	9.2222	8.3100
Schramm J, 2012, Acta Neurochir	10.1007/s00701-012-1481-3	81	7.3636	6.6249
Zahl SM, 2011, Neurosurg Rev	10.1007/s10143-011-0327-4	81	6.7500	6.3771
Gudrunardottir T, 2011, Child Nerv Syst	10.1007/s00381-010-1328-2	80	6.6667	6.2984
Pascual JM, 2011, Acta Neurochir	10.1007/s00701-011-1149-4	78	6.5000	6.1409
Duffau H, 2012, Acta Neurochir-A	10.1007/s00701-011-1216-x	76	6.9091	6.2159
Schucht P, 2014, Acta Neurochir	10.1007/s00701-013-1906-7	75	8.3333	7.5091
Kulcsar Z, 2012, Acta Neurochir	10.1007/s00701-012-1482-2	75	6.8182	6.1341
Archavlis E, 2012, Acta Neurochir	10.1007/s00701-012-1333-1	74	6.7273	6.0523
Dimou S, 2013, Neurosurg Rev	10.1007/s10143-012-0436-8	73	7.3000	6.7980
Ohba S, 2013, Neurosurg Rev	10.1007/s10143-012-0396-z	73	7.3000	6.7980
Adeeb N, 2012, Child Nerv Syst-A	10.1007/s00381-012-1744-6	72	6.5455	5.8888
Gudrunardottir T, 2016, Child Nerv Syst	10.1007/s00381-016-3093-3	71	10.1429	9.6183
Rehder R, 2016, Child Nerv Syst	10.1007/s00381-015-2923-z	70	10.0000	9.4828

Supplemental Table 1. Most cited articles from the 6 European journals from 2011–2020

Proceedings paper, Biographical item, Book review, Correction, Editorial material, Letter, News item, Retraction, and *Review Article*. Author parameters included the distribution of authors per document, levels of author collaboration with a collaboration index(5) - first proposed by Lawani (6) - which we used in our previous papers (3, 4), and Lotka's law of scientific productivity (7).

Journal metrics included examining journals via the h-index (which measures the largest number of published documents that have been cited an equivalent number of times) (8), g-index (a modified h-index in which the largest number of documents has been cited a squared equal number of times) (9), and Bradford's Law (a model that illustrates the distribution of citations into zones with the following ratio:

Journal	Total Documents	Total Citations	h-Index	g-Index
Acta Neurochirurgica	3,781	36,450	55	77
Childs Nervous System	3,660	25,281	44	56
Neurosurgical Review	2,154	12,612	40	56
British Journal of Neurosurgery	1,530	12,149	37	47
Journal of Neurological Surgery Part A: Central European Neurosurgery	832	3,957	22	29
Journal of Neurosurgical Sciences	725	3,813	23	29

Table 2. Cumulative journal impact from 2011–2020

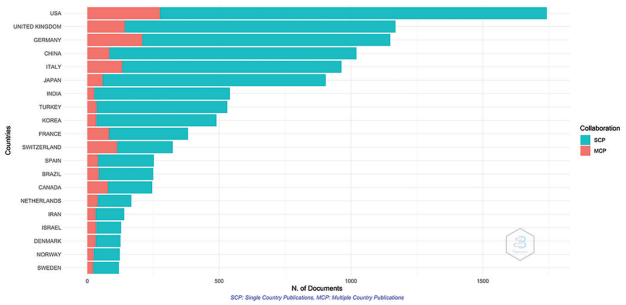


Figure 1. Country of origin for authors showing documents with single and multiple country co-authors.

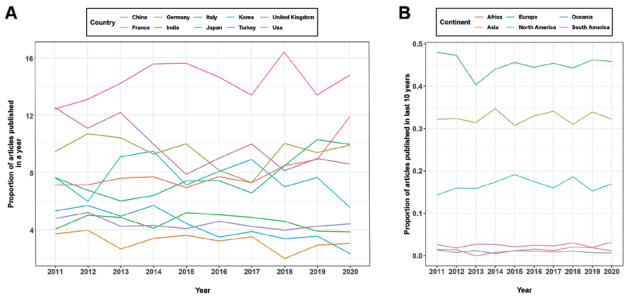
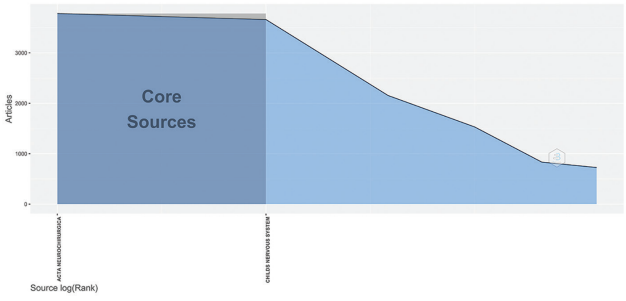


Figure 2. (A) Annual proportion of published documents from the top 10 countries of origin with the highest number of published documents. (B) Annual change in the proportion of published documents by the author's continent of origin.



Supplemental Figure 1. Application of Bradford's Law to the European journal citation data from 2011–2020.

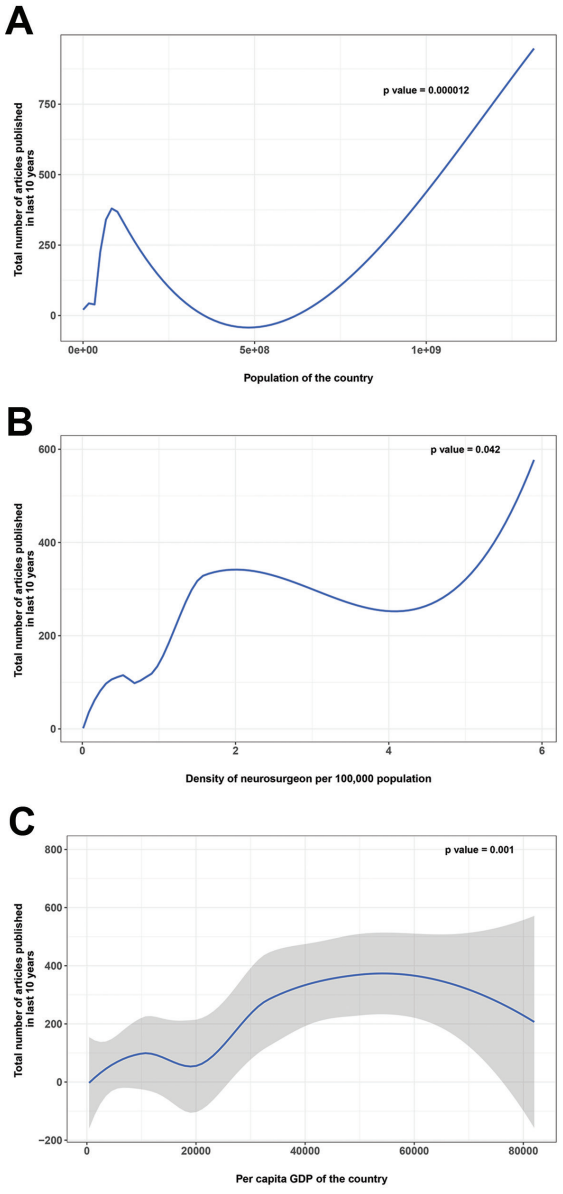
1:n:n2; the most significant number of citations will be found in zone 1) (10).

Distribution of published documents by country (as determined by the corresponding author's country of origin) and the levels of single-country and multi-country collaborations were examined. Continental parameters included population density, per capita GDP, and literacy rate, which were taken from the World Bank and United Nations databases. Data concerning the density of neurosurgeons per 100,000 people were taken from The World Federation of Neurosurgical Societies (WFNS) (https://www.wfns.org/menu/61/global-neurosurgical-workforce-map).

We determined institutions with the highest numbers of documents and authors and examined the distribution of keywords. Finally, we examined the journal impact factors of the 6 European journals.

Statistical analysis

Statistical analysis was performed using R version 4.0.3 (R Foundation for Statistical Computing, Vienna, Austria) employing the "bibliometrix" package (11). Various plots were drawn using the "ggplot" package (Tidyverse, https://ggplot2.tidyverse.org). Statistical significance was set at $\alpha=0.05$. Parametric data with normal distribution of data were analyzed using t-test or ANOVA, depending on the number of variables.



Supplemental Figure 2. (A) Relationship between country population and total number of articles published from 2011–2020. (B) Relationship between the country GDP (in USD) and the total number of articles published from 2011–2020. (C) Relationship between the density of neurosurgeons per 100,000 population and the total number of articles published from 2011-2020. 87

Documents written, n	Authors, n	Authors, %
1	20,750	66.0
2	4860	15.5
3	2119	6.7
4	1066	3.4
5	651	2.1
6	451	1.4
7	334	1.1
8	243	0.8
9	175	0.6
10	133	0.4
11	109	0.3
12	78	0.2
13	68	0.2
14	54	0.2
15	45	0.1
16	23	0.1
17	24	0.1
18	31	0.1
19	17	0.1
20	22	0.1
21	21	0.1
22	9	0
23	19	0.1
24	11	0
25	8	0
26	6	0
27	9	0
28	5	0
29	7	0
30	6	0
31	3	0
32	4	0
33	2	0
34	2	0
35	6	0
36	5	0
37	4	0
38	3	0
39	5	0
40	2	0
41	2	0
42	3	0
43	2	0
44	2	0
45	2	0
47	2	0
48	1	0
50	3	0
51	2	0
52	1	0
53	1	0
58	1	0
59	1	0
63	1	0
64	1	0
65	1	0
69	1	0
72	1	0
75	1	0
106	1	0
188	1	0

Supplemental Table 2. Breakdown of dataset with Lotka's law

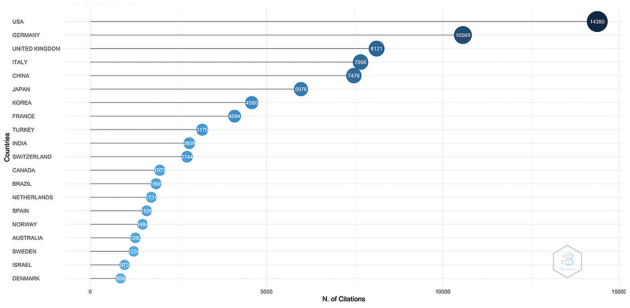
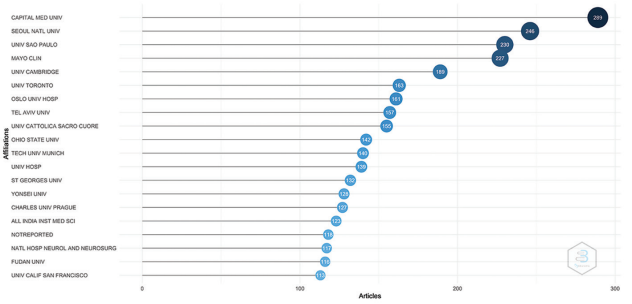


Figure 3. Total citations for articles per the country of origin of authors.



Supplemental Figure 3. Top 20 institutional affiliations of corresponding authors with the greatest number of published documents.

4. RESULTS

Document metrics

Characteristics of the 6 European journals can be found in Table 1. A total of 12,682 documents were published over the study time period (2011 to 2020). A few papers were written by single authors (n=878; 6.9%), while the remaining documents were written by more than one author (n=11,804; 93.1%).

The number of articles published per year remained steady, with the annual number of published documents ranging between 1009 and 1227; however, there was an uptick in published papers to 2114 in 2020. Original articles represented 68.0% of the documents published, with review articles representing 13.3% and letters representing 10.2%. Another 6.6% of published papers were categorized as editorial material. The remaining 1.9% of article types comprised biographical items, book reviews, corrections, letters, abstracts, news items, and retractions. The proportion of original articles published per year peaked in 2014, with 73.5% of the total documents published that year, but then declined to 62.6% in 2016, the year with the lowest proportion of original articles. The ratio of review articles increased late in the study time period. The lowest percentages occurred between 2011 (13.3%) and 2015 (9.4%) and then increased between 2016 (13.6%) and 2020 (18.9%). The lowest per-year proportion occurred in 2014, with 8.0%, which more than doubled to 18.9% by 2020.

The average number of citations per document for the 2011–2020 time period was 7.43. The average number of citations per year and per document was 1.07. The mean citations per year and per document varied from 1.05 to 1.1 during the ten years. Supplemental Table 1 shows the top 20 most cited articles from the 6 journals.

Author metrics

A total of 31,421 authors contributed to the documents in our analysis, making 66,320 appearances (Table 1). There was an average of 2.48 authors per document (31,421 authors/12,682 total documents) for the total number of au-

Figure 4. Combined bar and line graphs showing the per journal annual distribution of published articles (bars) and annual changes in journal impact factor (lines).

thors contributing to an article. There was an average of 5.23 authors per document for the entire time period for the total number of author appearances (ie, the number of times authors show up as first, corresponding, or co-authors; 66,320 appearances/12,682 total documents). The average number of authors per document rose steadily from 3.61 in 2011 to 4.11 in 2020. The average number of co-authors per document ranged from a low of 4.62 in 2011 and peaked at 6.1 in 2019; the average then lowered slightly to 5.78 by 2020. The collaboration index for the cumulative time period was 2.62. The per-year collaboration index mirrored the distribution of average co-authors per document, with the average index

Supplemental Figure 4. Treemap chart showing the numbers and proportions of the 50 most used document keywords.

values starting near 4.0 in the first four years of the study period, peaking in 2019 at 4.85, and then lowering slightly to 4.25 in 2020.

Analysis using Lotka's law showed that most authors (66.0%) contributed to only 1 document, while 15.5% of authors contributed to 2 documents each, and 6.7% of the authors contributed to 3 documents. Only 14 authors contributed to more than 50 documents and just 2 authors contributed to more 100 documents (Supplemental Table 2).

Journal metrics

The journal with the most published documents between 2011 to 2020 was Acta Neurochirurgica (ANC) (n=3,781), followed closely by Child's Nervous System (CNS) (n=3,660) (Table 2). The British Journal of Neurosurgery (BJNS) was third (n=2,154), followed by Neurosurgical Review (NRev) (n=1,530), Journal of Neurological Surgery: Part A (JNLS-A) (n=832), and Journal of Neurosurgical Sciences (JNSS) (n=725). ANC had the most significant number of citations (n=36,450), followed by CNS (n=25,281). JNLS-A and JNSS had the least number of citations (n=3,957 and n=3,813, respectively). ANC had the highest h-index (55) and g-index (77), meaning that 55 documents had been cited 55 times, and 77 had been cited 77 times. JNLS-A and JNSS had the lowest h-index (22 and 23, respectively) and g-index (29 for both).

Using analysis with Bradford's Law, we found that *ANC* and *CNS* were in Bradford Zone 1, while *BJNS* was in Bradford's Zone 2 (Supplemental Figure 1).

Countries

There were 88 countries of origin for the corresponding authors of the 12,682 documents (Figure 1). The greatest number of corresponding authors came from the United States (USA) (n=1,743), followed by the United Kingdom (UK) (n=1,169) and Germany (n=1,149). The greatest number of co-authors came from the USA (n=5,342), followed by Germany (n=3,309) and the UK (n=3,173). The variable number of authors per article and the variable rates of multi-country collaboration among different countries can explain the change in the sequence with Germany and the UK.

Among the top 10 countries that contributed to the highest number of articles, the multi-country to single-country ratio was highest for France (21.5%), followed by Germany

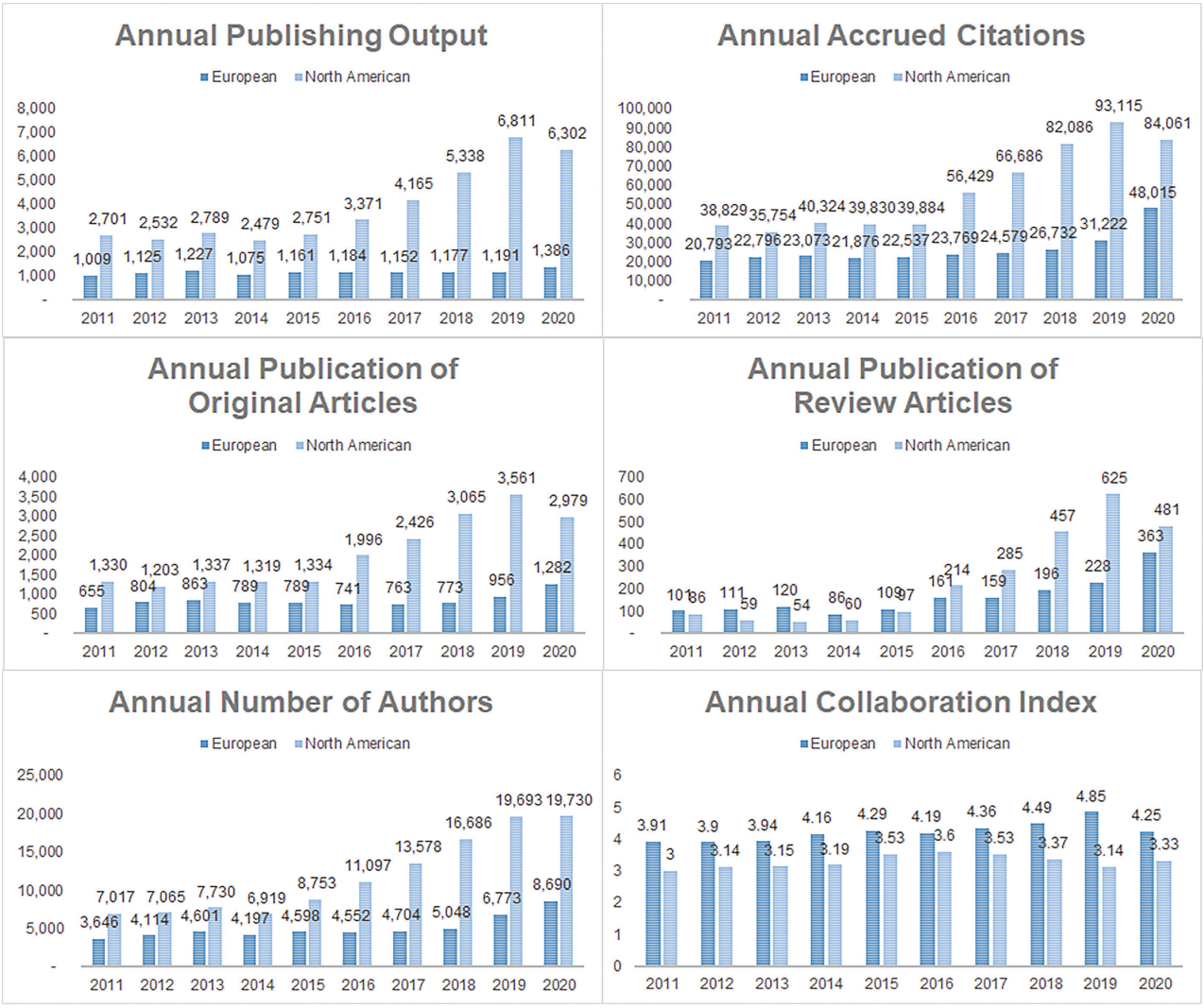


Figure 5. Bar graphs showing comparisons between the European journals from this study and the North American journals from our previous studies.

(18.1%) and the USA (15.8%) (Figure 1). India (4.8%) and Japan (6.4%) had the lowest multi-country to single-country ratio. Among the countries of origin for authors who contributed more than 20 articles, the ratio of multi-country to single-country collaboration was highest for Singapore (41.86%), followed by Switzerland (34.9%) and Austria (34.8%).

The number of documents published by authors from the USA increased from 12.4% of the total published documents in 2011 to 14.8% of the total published documents in 2020, while documents from the UK decreased gradually from 12.5% in 2011 to 8.6% in 2020 (Figure 2A). The country with the biggest increase in publishing output was China, which rose from 7.1% in 2011 to 11.9% in 2020. Authors from Italy and Germany also experienced increases in publication output, while authors from Japan, India, Turkey, Korea, and France experienced decreases.

Documents authored by the authors from the USA received the highest number of citations (n=14,380), followed by authors from Germany (n=10,569) and the UK (n=8,121) (Figure 3). Among countries with authors that published at least 20 articles, the greatest number of citations per document were published in Belgium (14.1%), followed by Australia (13.2%) and Norway (12.07%).

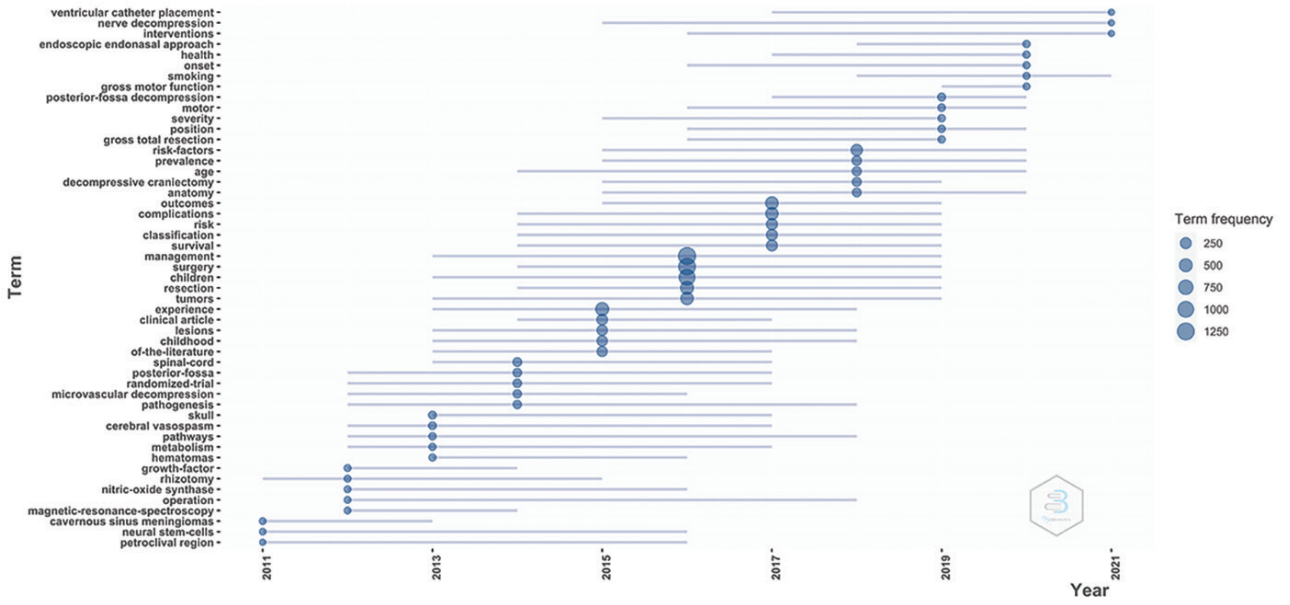
Continental distributions

A review of continental distribution showed that the greatest number of documents were published by the authors from Europe, followed by Asia (Figure 2B). The proportion of documents published by authors from Europe gradually decreased from 48.0% in 2011 to 45.8% in 2020, while the same increase was observed for authors from North America, from 14.3% in 2011 to 17.0% in 2020. The remaining continents did not experience any major change.

The relationship between country population and total number of documents was found to be statistically significant (P=0.00001) (Supplemental Figure 2A). The relationship between the density of neurosurgeons per 100,000 population and the total number of documental was also statistically significant (P=0.042) (Supplemental Figure 2B). The relationship between country GDP (in USD) and the total number of published documents was positive and linear between $20,000 and $40,000 per year, after which the curve flattened. Nevertheless, the relationship was statistically significant (P=0.001) (Supplemental Figure 2C).

Institutional affiliations

The institutional affiliation for corresponding authors with the greatest number of published documents was Capital Medical University, Beijing, China (n=289), followed by Seoul National University, Seoul, South Korea (n=246), and the University of Sao Paulo, Sao Paulo, Brazil (n=230) (Supplemental Figure 3). The highest ranked North Amer-



Supplemental Figure 5. Frequency and changes of keywords over time.

ican and European affiliations were Mayo Clinic, Rochester, USA (n=227) and University of Cambridge, Cambridge, UK (n=189). Seven of the affiliations in the top 20 were European.

Keywords

A total of 17,345 keywords were used in the documents. The 3 most used keywords were *management* (n=1,323), *surgery* (1,241), and *children* (1,044), representing approximately 27% of the 50 most used keywords (Supplemental Figure 4). The frequency of the most used keywords per year has shifted from rhizotomy, cavernous sinus meningiomas, neural stem cells, and the petroclival region as the most used in 2011 to endoscopic endonasal approaches, health, onset, smoking, and gross motor function in 2020 (Supplemental Figure 5).

Journal Impact factors

ANC experienced little change with its journal impact factor and the number of published documents per year, with the exception of a slight uptick of both in 2020 (Figure 4). The journal impact factors of BJNS, JNLS-A, and NRev increased dramatically despite not significantly increasing their publishing output. CNS experienced a slight uptick in published documents by 2020, similar to ANC, but the journal saw little growth in journal impact factor. JNSS experienced a significant increase in the number of papers the journal published starting in 2014, with a moderate increase in its journal impact factor by 2020.

5. DISCUSSION

Findings

Our overall findings for these 6 European journals showed that annual publishing output mostly plateaued between 2014 and 2018, except for a brief spike of 1,227 documents in 2013 (mean, 1,144.56; median, 1,161; range, 1,009–1,458) and then experienced a sudden rise in 2020 (n=2,114) (Table 1). This rise represented a 45.0% increase from 2019. Original articles were the most published document type, followed by review articles. Both article types experienced a similar plateauing with a sudden rise in 2019 and 2020. Original articles increased by 30.3% between 2018 (n=773) and 2019 (n=1,007), and 43.2% between 2019 (n=1,007) and 2020 (n=1,442); review articles increased by 24.0% between 2018 (n=196) and 2019 (n=243), and 64.2% between 2019 (n=243) and 2020 (n=399). Annual citation numbers experienced the same kind of sudden increase: a 16.8% increase between 2018 (n=26,732) and 2019 (n=31,222), and an astounding 53.8% increase between 2019 (n=31,222) and 2020 (n=48,015).

Overall author data showed similar increases late in the study period. The annual number of authors plateaued between 2011 and 2017 (mean, 4344.58; median, 4552; range, 3,646–4,704) but then experienced a dramatic rise of 7.3% to 5,048 in 2018, 34.2% to 6,773 in 2019, and 28.3% to 8,690 in 2020. Interestingly, the collaboration index did not mirror the other statistics exactly, which remained stable from 2011 to 2017 (mean, 4.16; median, 4.18; range, 3.9–4.49), then moderately peaked in 2019 at 4.85. It then decreased to 4.25 in 2020.

Our analysis of journal data placed the 6 journals into a clearly delineated order in 4 parameters each: total documents, total citations, *h*-index, and *g*-index. *ANC* ranked first in all 4 parameters, followed closely by *CNS*. The remaining journals can be ranked with *NRev* third, followed by *BJNS* fourth, *JNLS-A* fifth, and *JNSS* sixth. Bradford's law confirmed that the core journals for zone 1 came from both *ANC* and *CNS*.

Analysis of country data showed that the country of origin for most corresponding authors was first the USA, then the UK and Germany, while the country of origin for any author was the USA, then Germany and the UK. The most published documents originated from authors in France, Germany, and the USA. The countries with the highest ratio of multicountry collaborations were France, followed by Germany and the USA. Documents published in the USA increased from 2011 to 2020 as did China, which had the largest increase.

Most documents were published by European authors, although the proportion of European authors slightly declined between 2011 and 2020. Documents published by Asian authors were next, followed by documents published by North American authors. The proportion of both Asian and North American authors increased between 2011 and 2020. Popu-

lation, GDP, and national density of neurosurgeons were all significantly associated with published documents as mentioned above.

The institutional affiliations of most corresponding authors were Asian (Beijing, China and Seoul, South Korea) and South American (Sao Paulo, Brazil). Mayo Clinic in Rochester, USA and the University of Cambridge in Cambridge, UK were the institutional affiliations of the most North American and European corresponding authors, although they were still lower than the Asian and South American institutions.

The number of keywords increased in a manner like that noted above. The number of citations remained mostly stable from 2011 to 2018 (mean, 23.26; range, 20,793–26,732). After that, the number of citations increased from 26,732 in 2018 to 31,222 in 2019 (an increase of 16.8%) and from 31,222 in 2019 to 48,015 in 2020 (an increase of 53.8%).

Both the journal impact factors, and the annual number of published documents were plateaued for *ANC* and *CNS* between 2011 and 2019, with an uptick in both parameters for both journals in 2020 (Figure 4). *JNSS's* impact factor also remained mostly plateaued with a slight increase between 2011 and 2020 even though the annual number of published documents dramatically increased starting in 2014 and peaking in 2019, meaning that the increased volume of documents was not cited more than the previous smaller volume. *BJNS* experienced a decline in the number of annually published documents with a converse rise in impact factor, meaning that the lesser number of documents had been cited more. Except for a peak in 2013, *JNLS-A's* output was mostly flat. The journal nonetheless experienced a dramatic rise in impact factor, illustrating that the same volume of documents per year was being cited more. Finally, *NRev's* output was similarly flat, with lower volumes in 2017, 2018, and 2019. *NRev* also saw a dramatic increase in impact factor despite the flat—and for 3 years, smaller - publication output.

Annual trends

The overall rise of several parameters in the 6 European journals between 2018 and 2020 was substantial. Total documents increased by 17.8%; original articles increased by 65.8%; review articles increased by 85.2%; citations increased by 79.7%. The number of publishing authors increased by 72.1%, the number of authors in multi-author documents increased by 72.4%, and the author's keywords and keywords plus increased by 72.4% and 94.1%, respectively. However, the collaboration index decreased by 5.34% from 4.49 to 4.25. While some of the rise in author activity and publication output - primarily in 2020 - could be explained by academic neurosurgeons with extra free time during pandemic-related lockdowns to focus on writing, there is something else we could not detect that initiated the increase between 2018 and 2019. The increases we have documented occurred right before the onset of the COVID pandemic. Further investigation will be needed to determine the cause.

Comparison to North American journals

There are striking differences between the data from the 6 European journals when compared to the data from our previous two articles that analyzed North American journals (Neurosurgery, Journal of Neurosurgery, Journal of Neurosurgery: Spine, Journal of Neurosurgery: Pediatrics, Operative Neurosurgery, and World Neurosurgery) (3, 4). The annual publishing output for the North American journals is substantially greater than that of the European journals (Figure 5). The North American journals publish a far greater volume of documents. The total number of papers published from 2011 to 2020 was 39,239 versus the 12,682 documents published by European journals (North American journal output was over three times greater). North American journals published 20,550 original articles versus 8,415 for the European journals (4 times more) and 2,418 review articles versus 1,634 for European journals. The 6 North American journals also have higher impact factors. For example, the h-index was highest for JNS (90), while it was much less for ANC (55), the top-ranked European journal from the current analysis.

Starting around 2015, the trends for most parameters used to analyze the North American journals experienced an increase in annual output, which peaked in 2019 and then decreased slightly in 2020. These parameters include accrued citations and publication of original and review articles. This trend did not completely match the 6 European journals for which most parameters began their rise closer to 2016 and 2017 and then continued to peak in 2020.

One final interesting difference involves levels of author collaboration. Even though the North American journals have much greater numbers across most parameters compared with the European journals, authors submitting to European journals had higher levels of collaboration than those submitting to the North American journals.

Limitations of the study

Limitations to our study include our reliance on a single database - Web of Science. Since our analyses are based on the data derived from this single source, there may be some bias in our interpretation of the results. The number of articles published in the last year of our analysis (2020) might also vary between different sources due to different practices of journals with respect to the time interval between the date of online publication of an accepted article and its assignment to an issue. Finally, we limited our data to just 6 European journals, which could introduce bias by excluding other journals from the region.

6. CONCLUSIONS

Our analysis showed that European countries provided the most significant contributions to the six journals: more than two-fifths of all the articles published in the journals of European neurosurgical societies. However, the authors from the USA were top contributors to European journals. Acta Neurochirurgica published the most significant number of articles and had the highest h-index and number of citations among the journals included in the analysis, followed closely by Child's Nervous System. Annual published documents and citations were much lower for the European journals when compared to the North American journals we analyzed in our previous studies. Authors submitting to European journals were involved in greater levels of multi-author collaborations than authors submitting to North American journals.

Analyses of trends in the 6 European journals found increases across most parameters, which mainly started around 2017 and continued to increase in 2019 and 2020 at greater rates than seen in the years before 2017. Therefore, most pa-

rameters peaked in the final year of our analysis (2020), suggesting the possibility that the increase could have continued into later years. This steeper increase in annual trends could be attributable to more neurosurgeons having time to work on writing and publishing during the start of the COVID-19 outbreak when COVID-19 restrictions were first implemented; however, the climb started between 2018 and 2019 before COVID-19 became known to the world. With this upward bend occurring pre-COVID, there is undoubtedly another variable at work that we did not see in our data analysis. Further study will be needed to determine a potential cause.

- **Patient Consent Form:** n/a.
- **Authors contribution:** KG, BC, AJG, BS, and KIA provided substantial contributions to the conception and design of the work; data acquisition, analysis, and interpretation; and drafting and critically revising the work for important intellectual content. All authors gave final approval of the version to be published and agreed to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.
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