

REVIEW



# A Bibliometric Analysis of the Most Cited Articles in Neurocritical Care Research

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## Abstract

Bibliometric analyses may indicate the most active journals, authors, countries, institutions and specialties by evaluating the most cited articles in a given research field. To the authors' knowledge, there is no bibliometric analysis regarding neurocritical care research. Thus, the aim of this study is to analyze and to provide a scope of the current scientific production in this area. The 100 most cited articles in the neurocritical care research were retrieved from the research "(neurocritical) AND (care)" in the Scopus database. The variables collected and included in this analysis were: number of citations, article title, first author's name, year and journal of publication and its impact factor (IF), specialty, affiliation and country of the corresponding author at the time of publication, and category of the article. Also, these variables were assessed for primary research only. The articles were published in 34 different journals from 1995 to 2017, with a mean citation number of 109.36, ranging from 44 to 540. *Neurocritical Care* (23 articles in top 100 and 2190 citations, IF = 3.163) and *Critical Care Medicine* (20 articles and 2896 citations in top 100, IF = 6.630) were the journals with the greatest number of articles and citations, respectively. *Neurocritical Care* also had the highest number of primary research papers (15 articles, accounting for 850 citations). Excepting one article from Asia (Singapore) and one from Oceania (Australia), all the other 98 papers were from North America (67) or Europe (31). United States was the country with most articles (60, 35 primary research) and citations (6115) among the top 100. *Columbia University* (11 articles, being 7 primary research, and 915 citations) was the institution with the highest number of articles and primary research articles in top 100, whereas *University of Heidelberg* (6 articles and 1220 citations) was the most cited institution. Neurology was the specialty with the greatest number of publications in top 100 and the most cited one (57 articles and 5983 citations). The first author with the greatest number of publications as well as primary research articles was A. I. Qureshi (5 articles, being 4 primary research, and 660 citations), while the most cited was K. H. Polderman (2 articles and 749 citations). Fifty-nine publications were primary and 41 secondary research. Among primary research, treatment/management was the most frequent and most cited topics (33 articles and 4172 citations). To the authors' knowledge, this is the first bibliometric analysis regarding neurocritical care research. Our findings suggest that the neurocritical care research field is more prominent in North America and Europe, more frequently published in specific critical care journals and after 1994. The most discussed topic was related to treatment and/or management within neurocritical care.

**Keywords:** Critical care, Neurology, Neurosurgery, Anesthesiology, Bibliometric analysis, Intensive care units

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## Introduction

Neurocritical care is relatively recent as a specialty. Indeed, the *Neurocritical Care Society* was founded in 2004, as was the *Neurocritical Care Journal* [1]. This field links neurosurgery, neurology, and critical care medicine, in order to provide a comprehensive management of difficult and life-threatening neurological conditions [2]. Many studies support that the implementation of a specialized neurocritical care team in intensive care units is related to lower mortality and shorter hospital length of stay [3–7]. In addition, this implementation was also related to a greater patient and family satisfaction [7].

The citation count of articles may be used to estimate the impact of a given research in a specific field. Moreover, many individual author's and journal's metrics are affected by the number of citations. Examples include the *h* index, the journal impact factor (IF), the eigenfactor score, SCImago journal rank, among others [8]. Assessing the most cited articles in a specific research area is important in terms of determining the most active journals, authors, countries, institutions, and specialties, providing a scope of the research field in question. Bibliometric analyses regarding various medical research fields assessed these variables [9–12].

Several specialties, including neurosurgery [9, 13], anesthesiology [11], radiology [12], trauma [14], and critical care medicine [10] underwent comprehensive bibliometric analyses. Moreover, many recent studies performed more specific bibliometric analyses inside the neurological and neurosurgical subspecialties. Examples include aneurysmal subarachnoid hemorrhage [15], severe traumatic brain injury [16], spinal disorders [17], Parkinson's disease [18], and epilepsy [19]. To the authors' knowledge, there are no bibliometric analyses regarding neurocritical care research. Therefore, this study aims to make an analysis in this field, providing a scrutiny of the current research.

## Methodology

### Search Protocol

The 100 most cited articles in neurocritical care were identified through a search in Elsevier's *Scopus* in October 2018. The exact search was "(neurocritical) AND (care)." The articles were arranged from higher to lower citation count and the 100 most cited were exported and analyzed. No other restrictions were adopted. The 2017 IF and the 5-year IF of the most cited journals were retrieved from the *InCites Journal Citation Reports (JCR)* website (<https://jcr.incites.thomsonreuters.com/>) in December 2018. The *h* index of the ten most cited authors was retrieved from authors' details in *Scopus* database.

### Bibliometric Analysis

From the 100 most cited papers, the variables collected and included in this analysis were: number of citations, article title, first author's name, year and journal of publication and its IF, specialty and country of the corresponding author at the time of publication, and category of the article. When multiple affiliations for the corresponding author were found, we preferred the educational institution. In a secondary analysis, these variables were assessed for primary research articles only, excluding secondary research (guidelines, consensus, and reviews). We obtained the mean citation number of the 100 most cited papers using Microsoft Excel. We classified the articles in primary research and secondary research. Primary research articles were subdivided based on their primary outcomes.

## Results

### General Information

Our search resulted in 1561 articles in the *Scopus* database. The mean number of citations was 109.36, ranging from 44 to 540. The ten most cited publications ranged from 251 to 540 citations (mean = 356.70) and are detailed in Table 1. The most cited article was a guideline published in 2012 in the *Neurocritical Care* journal by Brophy et al [20], from United States, with 540 citations. When excluding secondary research, the mean number of citations was 105, ranging from 44 to 461. The most cited article within primary research was a randomized controlled trial, published by Jüttler et al. in *Stroke* in 2007, accounting for 461 citations.

### Journal and IF Analysis

A total of 34 different journals comprised the publication of all of the 100 most cited articles. A list with number of articles in top 100, number of citations and IF for the ten most cited journals is provided in Table 2. Among the 100 most cited articles, 73 were from the ten most cited journals, accounting for 3567 of the total 10,936 citations. *Neurocritical Care* was the journal with the greatest number of articles (23) in the top 100, followed by *Critical Care Medicine* (20). Within primary research, *Neurocritical Care* was also the journal with the highest number of articles in the top 100. However, regarding the number of citations, *Critical Care Medicine* headed, with 2896 citations. Right after, *Neurocritical Care* appears with 2190 citations. When excluding secondary research, *Critical Care Medicine* and *Stroke* were the most cited journals, accounting for 1983 and 1605 citations, respectively. The number of citations according to the 5-year IF is shown in Fig. 1.

**Table 1 Top ten cited publications in neurocritical care research**

First author	Title	Year	Journal	Country	Citations
G. M. Brophy	Guidelines for the evaluation and management of status epilepticus	2012	Neurocritical Care	United States	540
E. Jüttler	Decompressive surgery for the treatment of malignant infarction of the middle cerebral artery (DESTINY): a randomized, controlled trial	2007	Stroke	Germany	461
M. N. Diringer	Critical care management of patients following aneurysmal subarachnoid hemorrhage: recommendations from the neurocritical care society's multidisciplinary consensus conference	2011	Neurocritical Care	United States	391
K. H. Polderman	Therapeutic hypothermia and controlled normothermia in the intensive care unit: Practical considerations, side effects, and cooling methods	2009	Critical Care Medicine	Netherlands	375
K. H. Polderman	Induced hypothermia and fever control for prevention and treatment of neurological injuries	2008	The Lancet	Netherlands	374
K. Rieke	Decompressive surgery in space-occupying hemispheric infarction: results of an open, prospective trial	1995	Critical Care Medicine	Germany	324
D. W. Krieger	Cooling for acute ischemic brain damage (COOL AID): an open pilot study of induced hypothermia in acute ischemic stroke	2001	Stroke	United States	318
G. Ling	Explosive blast neurotrauma	2009	Journal of Neurotrauma	United States	279
H. C. Patel	Specialist neurocritical care and outcome from head injury	2002	Intensive Care Medicine	United Kingdom	254
A. I. Qureshi	Use of hypertonic saline solutions in treatment of cerebral edema and intracranial hypertension	2000	Critical Care Medicine	United States	251

**Table 2 Ten most cited journals in neurocritical care research**

Journal	No of articles in top 100 (primary research)	No of citations (primary research)	2017 IF	5-Year IF
Critical Care Medicine	20 (14)	2896 (1983)	6.630	7.153
Neurocritical Care	23 (15)	2190 (850)	3.163	3.263
Stroke	9 (9)	1605 (1605)	6.239	6.610
Intensive Care Medicine	6 (3)	735 (465)	15.008	10.837
The Lancet	1 (0)	374 (0)	53.254	52.665
Neurosurgery	3 (1)	351 (117)	4.475	4.248
Journal of Neurotrauma	2 (1)	333 (54)	5.002	5.063
British Journal of Anesthesia	2 (0)	217 (0)	6.499	6.371
Current Opinion in Critical Care	4 (1)	189 (45)	3.120	2.970
Critical Care	3 (1)	188 (48)	6.425	6.547

IF impact factor

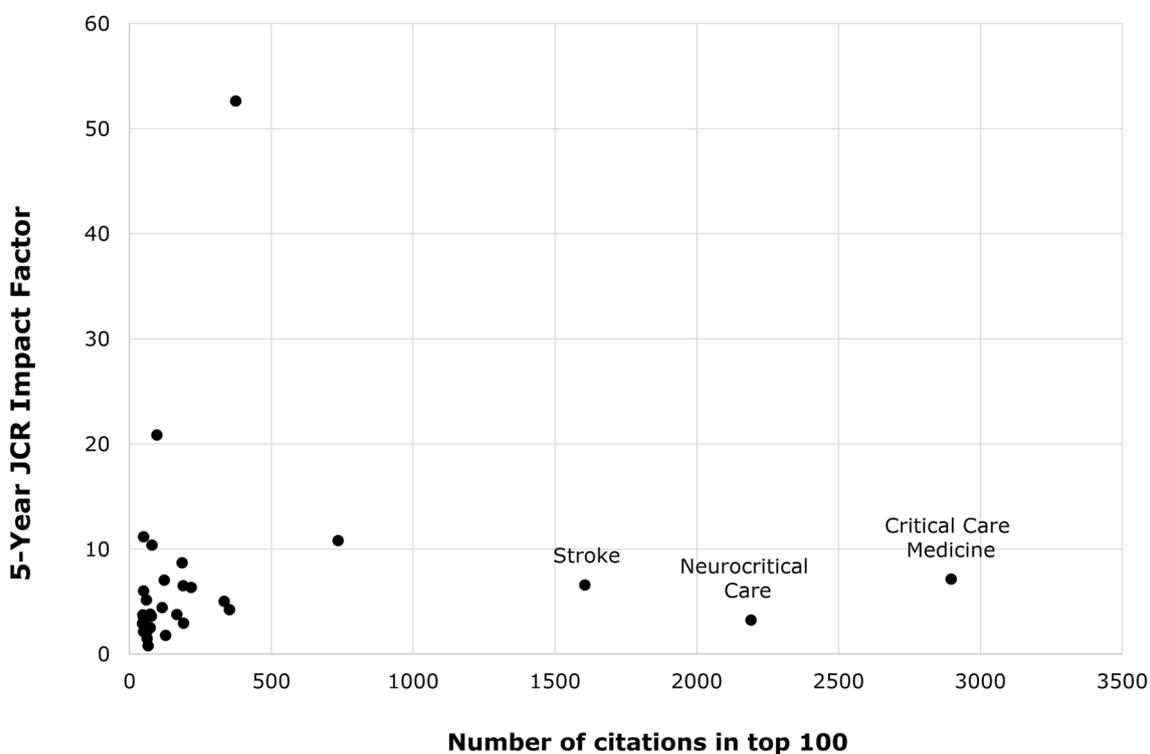
### Country and Affiliation Analysis

The 100 most cited papers were published by institutions from 12 different countries. Except for one article from Asia (Singapore) and one from Oceania (Australia), all other 98 articles were from North America (67 publications) and Europe (31 publications). By far, United States was the country with most papers (60) in top 100 and with the greatest number of citations (6115). After excluding secondary research, the country remained the most prolific (35 articles in top 100) as well as the most cited one (3219 citations). The second country in number of articles was United Kingdom (11) and the second in number of citations was Germany (1393). Germany, in turn, was the second country with the highest number of

articles (8) and citations (1393) within primary research. The complete list of the publications and citations by country is provided in Table 3. The articles were published by 47 different affiliations. United States also had the institution with the greatest number of articles in the top 100 as well as the one with the highest number of primary research articles (*Columbia University*), whereas Germany had the most cited institution in general and within primary research (*University of Heidelberg*) (Table 4).

### Year and Department Analysis

The articles were published from 1995 to 2017 and, excepting 1996, these publications occurred every year.



**Fig. 1** Scatter-plot showing the number of citations among the 100 most cited articles in neurocritical care research according to the 5-year IF of the journal of publication

**Table 3** Most cited countries in neurocritical care research

Region	No of articles in top 100 (primary research)	No of citations (primary research)
North America	67 (37)	6522 (3328)
United States	60 (35)	6115 (3219)
Canada	7 (2)	407 (109)
Europe	31 (21)	4198 (2867)
Germany	8 (8)	1393 (1393)
United Kingdom	11 (7)	1291 (928)
Netherlands	2 (0)	749 (0)
Austria	3 (2)	232 (115)
Spain	2 (1)	178 (56)
France	1 (1)	155 (155)
Switzerland	2 (1)	107 (59)
Portugal	2 (1)	93 (44)
Asia	1 (1)	117 (117)
Singapore	1 (1)	117 (117)
Oceania	1 (0)	99 (0)
Australia	1 (0)	99 (0)

The 2008 year encompassed the greatest number of citations (1408) and articles (14) in the top 100, followed by 2009 and 2007 (Table 5). The papers were published by 8 different departments. Neurology was the department that most frequently published (57 publications, being 40 from primary research) and cited (5983 citations, being 4127 from primary research) in the top 100, followed by Neurosurgery (Table 6).

#### First Author and Article Category Analysis

The first authors with most citations and number of articles in the top 100 were K. H. Polderman (2 articles and 749 citations) and A. I. Qureshi (5 articles and 660 citations), respectively. A. I. Qureshi was also the author with the highest number of primary research articles (4) in top 100. The h index among the ten most cited first authors varied from 11 (K. Rieke) to 78 (S. A. Mayer) (Table 7). Most papers and citations were from primary research (59 publications and 6195 citations) (Table 8). Among primary research, the topic “treatment/management” was the most frequently published and cited (33 publications and 4172 citations), as did “reviews” among secondary research (33 publications and 3358 citations). There were no laboratory studies in the top 100.

**Table 4 Most cited affiliations (with 2 or more articles in top 100) in neurocritical care research**

Affiliation	Country	No of articles in top 100 (primary research)	No of citations (primary research)
University of Heidelberg	Germany	6 (6)	1220 (1220)
University of Cambridge	United Kingdom	8 (6)	1026 (880)
Columbia University	United States	11 (7)	915 (611)
University Medical Center Utrecht	Netherlands	2 (0)	749 (0)
University of California	United States	8 (4)	535 (350)
The Cleveland Clinic Foundation	United States	3 (1)	514 (318)
University Hospitals of Cleveland	United States	3 (1)	498 (189)
University of Pennsylvania	United States	4 (4)	486 (486)
The Johns Hopkins Medical Institutions	United States	4 (4)	409 (409)
University of Calgary	Canada	5 (1)	295 (48)
Northwestern University	United States	2 (2)	243 (243)
Innsbruck Medical University	Austria	3 (2)	232 (115)
New York University	United States	2 (1)	191 (49)
University of Pittsburgh	United States	3 (2)	174 (102)
Lankenau Medical Center	United States	2 (0)	148 (0)
University of Washington	United States	2 (2)	101 (101)
San Francisco General Hospital	United States	2 (1)	95 (45)

**Table 5 Number of articles and citations among the top 100 cited articles in neurocritical care research**

Year	No of articles in top 100 (primary research)	No of citations (primary research)
1995	1 (1)	324 (324)
1996	0 (0)	0 (0)
1997	1 (1)	76 (76)
1998	1 (1)	184 (184)
1999	3 (3)	311 (311)
2000	4 (3)	472 (221)
2001	2 (2)	390 (390)
2002	2 (2)	448 (448)
2003	1 (1)	48 (48)
2004	4 (4)	652 (652)
2005	6 (3)	531 (278)
2006	5 (3)	556 (399)
2007	11 (5)	1197 (751)
2008	14 (8)	1408 (695)
2009	11 (5)	1391 (397)
2010	7 (6)	518 (465)
2011	9 (5)	770 (238)
2012	4 (1)	703 (55)
2013	3 (3)	171 (171)
2014	4 (0)	315 (0)
2015	4 (2)	247 (92)
2016	2 (0)	176 (0)
2017	1 (0)	48 (0)

## Discussion

Bibliometric analyses are useful to assess the most active journals, authors, countries, institutions, and specialties of a research field. Studies of this kind have been performed within several specialties [9–14]. In the current study, we presented a bibliometric analysis regarding the neurocritical care research. We found that this field is more prominent in North America and Europe, more frequently published in specific critical care journals and after 1994. The majority of the articles were clinical and from primary research. The most discussed topics within primary research were related to treatment and/or management within neurocritical care. However, secondary research (i.e., reviews and guidelines) represented almost half of the most cited studies.

According to the *InCites JCR* website (<https://jcr.incites.thomsonreuters.com/>), 239 (less than 2%) journals indexed in the *Web of Science* database have a 2017 IF higher than 10. In general, bibliometrics that included all journals when analyzing the most cited articles of a given specialty showed that they are more often published in journals with an IF lower than ten [10, 12, 21, 22]. As an example, *Radiology* (2017 IF=7.469) and *Critical Care Medicine* (2017 IF=6.630) were the journals that most frequently published among the most cited articles in radiology [12] and critical care [10], respectively. The same apply to the majority of bibliometrics regarding specific neurological conditions, such as aneurysmal subarachnoid hemorrhage [15], severe traumatic brain injury

**Table 6 Most cited specialties in neurocritical care research**

Specialty	No of articles in top 100 (primary research)	No of citations (primary research)
Neurology	57 (40)	5983 (4127)
Neurosurgery	14 (8)	1393 (948)
Anesthesiology	13 (6)	1358 (768)
Intensive Care	10 (2)	1243 (100)
Pharmacy	1 (0)	540 (0)
Physics	2 (1)	272 (150)
Pediatrics	2 (1)	90 (45)
Nursing	1 (1)	57 (57)

**Table 7 Ten most cited first authors in neurocritical care research**

First author	No of articles in top 100 (primary research)	No of citations (primary research)	<i>h</i> index
K. H. Polderman	2 (0)	749 (0)	34
A. I. Qureshi	5 (4)	660 (409)	71
G. M. Brophy	1 (0)	540 (0)	26
E. Jüttler	1 (1)	461 (461)	26
M. N. Diringer	1 (0)	391 (0)	61
K. Rieke	1 (1)	324 (324)	11
J. P. Coles	2 (2)	322 (322)	33
D. W. Krieger	1 (1)	318 (318)	37
G. Ling	1 (0)	279 (0)	33
S. A. Mayer	2 (2)	264 (264)	78

**Table 8 Most cited article categories in neurocritical care research**

Article category	No of articles in Top 100	No of citations
Primary research	59	6195
Treatment/Management	33	4172
Monitoring	11	1008
Outcome	13	777
Pathophysiology	2	238
Secondary research	41	4741
Reviews	33	3358
Guidelines	8	1383

[16], spinal disorders [17], and epilepsy [19]. For neurocritical care research, we demonstrated that the majority of the articles were published in journals with a 2017 IF and a 5-year IF lower than ten (Table 2 and Fig. 1). Yet, three of them (*Neurocritical Care*, *Critical Care Medicine*

and *Stroke*) were the three journals with most articles and citations in the top 100 (Table 2).

By far, United States comprises the greatest number of publications in the top cited neurological and neurosurgical research, as shown by prior bibliometric analyses [15–17, 19]. In addition, the majority of the most cited papers are from North American or European institutions, with very few being published by institutions from other continents. However, this pattern is far from being restricted to neurological and neurosurgical research. The United States published much more medical articles and its medical research was cited many more times than any other country in the world, as shown by the *Scimago Journal & Country Rank* (<https://www.scimagojr.com/countryrank.php>). As expected, we demonstrated that the United States was the country that most frequently published (primary and secondary research) and the most cited one with respect to the 100 most cited papers in the neurocritical care research (Table 3). When analyzing the affiliations of the corresponding author, *University of Heidelberg* (Germany) was the most cited, whereas *Columbia University* (United States) was the responsible for the greatest number of articles (Table 4).

Neurocritical care is a relatively recent specialty, as demonstrated by the foundation of the *Neurocritical Care Society* and the *Neurocritical Care Journal* in 2004 [1]. As expected, we demonstrated that the majority of the most cited articles in this field were published after 2004 (85 of the 100 articles), accounting for 8683 of the total 10,936 citations from the 100 most cited papers, showing an increasing interest in the neurocritical care research (Table 5). However, after 2013, the number of articles and citations was much lower. This occurred possibly because there was not enough time for these papers to be cited in larger scale rather than represent its lower impact [23]. We also presented in the current study that neurology, neurosurgery, anesthesiology, and intensive care were the most cited specialties and those that most frequently published within neurocritical care research (Table 6), pointing to the characteristic multidisciplinary nature of this field—although neurology was, by far, the most cited specialty and the one that most often published [2].

The initial metric of a specific author was his or her number of citations. However, an author could have a high citation number with just a few papers, with no citations in many other articles. The *h* index, in turn, is a metric which combines both the author's number of publications and its number of citations, considering, theoretically, the quantity and quality of the research produced by an author [8, 24]. Among the ten most cited authors in neurocritical care, two authors had an *h* index higher than 70 (Table 7): A. I. Qureshi (*h* index=71, 5

articles, and 660 citations) and S. A. Mayer ( $h$  index = 78, 2 articles, and 264 citations). Nevertheless, the  $h$  index—as well as other scientometric indexes—is not an exact indicator of the research quality of one author [24].

With respect to neurological conditions, prior bibliometric analyses vary regarding the most common primary research article category. For epilepsy [19] and Parkinson's disease [18] analyses, the most common were laboratory studies. For severe traumatic brain injury [16] was epidemiology/etiology studies, whereas for aneurysmal subarachnoid hemorrhage [15] and for neurosurgery in general [9] was treatment/management focused papers. Within neurocritical care primary research, we showed that the most common addressed topic was treatment/management (Table 8). There were no laboratory studies, acknowledging that the prevalence of a primary research study type depends strongly on the nature of the topic analyzed. A recent study evaluated 200 highly and lowly cited papers in the field of medicine and showed that primary and secondary research articles represented, respectively, 51% and 45% of the highly cited articles as well as 52% and 42% of the lowly cited articles, without statistically significant difference [25]. Similarly—and consistent with the neurological literature—secondary research represented a great part (41 articles and 4741 citations) of the neurocritical care research [9, 15, 16, 18, 19].

### Strengths and Limitations

In the current study, we assessed various information regarding the 100 most cited articles in the neurocritical care research. These included the number of citations, first author's name, year and journal of publication, specialty, country, and affiliation of the corresponding author at the time of publication, and category of the article. For each variable, we assessed the number of articles in the top 100 as well as the number of citations. For instance, 60 articles of the top 100 were from the United States, accounting for 6115 citations.

However, this study presents some limitations. Since the information was retrieved from a single database (Scopus), some articles may have been missed and the number of citations underestimated—although the authors believe that this is unlikely to occur. Indeed, Scopus covers more than 36,000 journals (data retrieved from <https://www.scopus.com/sources> in April 16 of 2019), including Medline and Embase-indexed journals [26]. This is a significantly higher coverage than the approximately 21,000 journals covered by the Web of Science Core Collection (WoS), for instance (data retrieved from <https://clarivate.libguides.com/webofscienceplatform/coverage> in April 16 of 2019). Additionally, Scopus found approximately 93% of the citations that WoS

found in Health & Medical Sciences [27]. Google Scholar (GS), however, covers more journals than these two databases. Yet, a systematic comparison of Scopus, WoS, and GS published in 2018 showed that the scientific impact for unique GS citations is, in average, much lower than the impact of citations that are also found in Scopus and WoS [27]. For these reasons, the authors chose Scopus for this analysis.

Moreover, while evaluating citation number by the year of publication, more recent articles presented, in general, a lower number of publications. This occurred probably because these papers will be cited in larger scale in the next years. Another limitation is that corresponding authors may belong to multiple affiliations and have multiple specialties, which may contribute to overestimations as well as underestimations within these variables.

### Conclusions

To the authors knowledge, this is the first study to assess the 100 most cited articles in neurocritical care research. Our analysis showed that the research in the neurocritical care field significantly increased recently and, as expected, involved various specialties. North American and European institutions are, by far, the most impactful regions of the world regarding the research in this field, with a spotlight to United States. As medical research in general, this points to the centralization of research, also demonstrated by zero studies from South America and Africa and only one study from Oceania and Asia. The most cited papers were more often published in specific and lower IF journals rather than very high IF ones. The most addressed issue in the neurocritical care primary research was treatment/management and secondary research was also largely represented. The neurological bibliometric analyses vary widely regarding the most common primary study type, which certainly depends on the topic analyzed.

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MBR—Data Collection, Data Analysis, Manuscript writing; EK—Data Analysis, Manuscript writing; JRJ—Data Analysis, Manuscript writing; MJT—Project development, Data Analysis; EGF—Project development, Data Analysis, Manuscript writing.

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#### Conflict of interest

The authors declare that they have no conflict of interest.

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This article does not contain any studies with human participants or animals performed by any of the authors.

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