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Review Paper

Bibliometric Analysis of Neurosurgery Education From 1962 to 2023

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ABSTRACT

Background and Aim: Evaluating our scientific trend and patterns in the education of neurosurgery can benefit in determining the needs and the future of the research path, therefore we performed a bibliometric analysis in the Web of Science (WoS) dataset.

Methods and Materials/Patients: This was a bibliometric study of literature for studies on neurosurgery education. The WoS database was used for this study. The collected dataset was entered into the R shiny package of bibliometrics and was used for data analysis. Annual scientific production, citations, journals, and affiliation patterns were evaluated. Bradford's and Lotka's laws were used to interpret the patterns of contributions. Reference publication year spectroscopy (RPYS) was used to find source articles of literature.

Results: From 1962 to 2023, 1740 articles from 266 journals were included in this study. The annual growth rate of publishing neurosurgery education studies was 8.16%. "World neurosurgery" and "neurosurgery" journals with 441 articles (25.34%) were in zone 1 based on Bradford's law, showing inequality in publishers of neurosurgery education studies. Also, Lotka's law showed author productivity inequality, with most authors (approximately 75.5%) having only contributed a single article, while an Indian researcher has authored 28 articles as well as some other researchers with more than 20 articles. The USA led the way with 775 articles. Historical origins of research stemmed from studies about the virtual model of the temporal bone, the depiction of neurosurgery in cinematic genres, and a realistic neurosurgical simulator. Seminal neurosurgery education research has focused on anatomy education using imaging methods, informing later developments in simulated learning approaches. Based on the RPYS, seminal neurosurgery education research has focused on anatomy education like using imaging methods, which has contributed to later developments in simulated learning.

Conclusion: Bibliometric analysis of neurosurgery education literature reveals increasing annual production, inequality in publishing, and author productivity, identified with the USA's leading contributions and diverse research origins.

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Highlights

- Annual growth rate of neurosurgery education publications has been 8.16% from 1962 to 2023.
- Top-tier journals dominate the field: "World neurosurgery" and "neurosurgery" publish 25.34% of all articles.
- USA leads in contributions: 775 articles, followed by UK, Canada, Germany, and Italy.

Plain Language Summary

Neurosurgery education is a critical field that has been evolving over the years. To better understand this evolution, researchers conducted a comprehensive analysis of scientific publications on neurosurgery education from 1962 to 2023. This study aimed to identify trends, patterns, and influential factors in the field. The analysis revealed a significant increase in scientific publications on neurosurgery education over the years, with an annual growth rate of 8.16%. The United States led the way in contributing to this field, with the majority of publications coming from top-tier journals such as "world neurosurgery" and "neurosurgery". The study also found that a small number of authors contributed a disproportionate number of articles, with some authors publishing as many as 28 articles. The findings suggest that there is a need for more diverse and inclusive research, as well as a greater emphasis on collaboration and knowledge sharing. The study also shows the importance of top-tier journals in shaping the field of neurosurgery education. The study's findings have implications for the public, particularly in terms of understanding the advancements and challenges in neurosurgery education. As neurosurgery continues to evolve, it is essential to ensure that education and training programs keep pace with the latest developments. This study provides a foundation for future research and highlights the need for ongoing evaluation and improvement in neurosurgery education.

1. Introduction

Neurosurgery education has a rich history; the inception of the initial neurosurgical training program in the United States took place at the University of Chicago Medical Center. The program began in 1935 [1] directed by Adrien Ver Brugghen. In the United States alone, 1393 current neurosurgical residents exist across 99 programs in 39 states [2]. Japan leads with 1000 neurosurgical residents, followed by Taiwan (170), Indonesia (199), Malaysia (53), and the Philippines (51) [3]. Research in medical education aims to advance understanding of how medical education can be optimized to produce competent and compassionate healthcare professionals [4]. Significant contributions from research in medical education have deepened our comprehension of the learning process. Concurrently, the educational community increasingly recognizes the important role of evidence in guiding educational decisions. Key concepts of research in medical education include fundamental research on medical expertise's essence, problem-based learning methodologies, performance assessment techniques, and the ongoing education and evaluation of practicing physicians [5]. In neurosurgery, research is used to focus on designing and refining educational programs tailored to the needs of neurosurgical trainees [6, 7], emerging technologies in neurosurgical training, such as simulation and virtual reality [6, 7], and neurosurgical competency and performance assessment [8]. Bibliometrics is a field of science that employs statistical methods to analyze scholarly works by quantifying and assessing the impact of scientific research based on citation counts, patterns, and networks [9]. It helps identify emerging trends, assess research productivity, and facilitate decision-making in academic and scientific contexts [10]. In the case of neurosurgery, multiple bibliometric studies have been conducted on the evaluation of research quality in neurosurgery education [11], the identification of areas needing more research focus [12], and the recognition of contemporary leaders in neurosurgery [13]. However, in the field of neurosurgery education, no bibliometric analysis is available. Also, since science can develop and progress about almost any detail of human behaviors like education, and can sometimes lack direction, scientometry is needed to give purpose to our science and find paths that make the most important and usable knowledge. Analyzing the trends and patterns of neurosurgery education can prove instrumental in identifying the evolving needs and charting the future of research in this field. Therefore, in this study, we performed a bibliometric analysis in the Web of Science (WoS) dataset.

2. Methods and Materials

This was a bibliometric study of literature for studies on neurosurgery education. The WoS database was used for this study. While other datasets, such as Scopus and PubMed can be targeted by a bibliometric study, limitations in merging numerous records of these entities with each other may decrease the sensitivity of work regarding the selection of appropriate studies. Therefore, we only focused on the WoS that covers most large parts of the research. The search strategy was refined to achieve the most sensitive results. Finally, the query of neurosurgery keyword in WoS micro topics related to the educational studies was performed, as below:

ALL=(neurosurgery) and 1.14.849 surgical education or 1.14.363 nursing education or 1.14.1359 interprofessional education or 6.11.1094 medical education or 1.156.1502 indigenous education or 10.144.2452 history of education or 1.228.2421 veterinary education (citation topics micro)

The collected dataset was entered into the R shiny package of bibliometric and was used to analyze data [14]. The reason for selecting this package was that while VOSviewer is user-friendly with high-quality graphics, it has limited abilities in data integration, while Bibliometrix offers robust customization but requires programming skills. Also, it provides detailed bibliometric analyses, such as Bradford's and Lotka's law.

Bradford's law

Bradford's law, a principle in bibliometrics, describes the distribution of scientific contributions within a particular field. Named after Samuel C. Bradford, the law suggests that the literature of a subject can be divided into a core of key journals, a second zone containing a greater number of less-cited journals, and a third zone with even more journals, each of which has fewer citations. In essence, Bradford's law helps identify the core journals that contribute significantly to a specific field, allowing researchers and information professionals to focus their attention on those key sources [15].

Lotka's law

Lotka's law, formulated by Alfred Lotka, is a principle in bibliometrics that describes the distribution of productivity among authors in a given field. The law is particularly relevant in assessing the frequency of authors' contributions and the pattern of their productivity. Lotka's law states that a small percentage of authors in a specific field will contribute the majority of the published works, while most authors contribute only a few publications. Mathematically, Lotka's law can be expressed as an inverse square law [16]:

$n(a)=C/a^2$

where:

- n(a) is the number of authors with a publications,
- C is a constant,
- a is the number of publications by an author.

Reference publication year spectroscopy (RPYS)

By plotting the distribution of referenced publication years and RPYS, trends of the longevity of foundational works were evaluated [17].

3. Results

The bibliometric analysis of neurosurgery education spanning from 1962 to 2023, sourced from 266 journals and books, included 1740 documents with an annual growth rate of 8.16%. The average document age is 8.09 years, and each document garners an average of 12.98 citations. The extensive compilation involves 21441 references, with 1473 keywords plus (ID) and 2 514 author's keywords. A total of 5763 authors contributed to the corpus, with 169 authors exclusively producing single-authored documents. Collaboration is evident, as 196 documents involve multiple authors, averaging 5.2 co-authors per document, and international co-authorships constitute 15.46% of the collaborative efforts, reflecting a rich collaboration in neurosurgery education literature.

The annual scientific production in neurosurgery education has exhibited substantial growth over the decades. In the 1960s, only a few articles exist with a notable increase in the 1970s. The 1980s witnessed a gradual rise, with 6 articles. The 1990s marked a significant surge with 21 articles, and the early 2000s continued this upward trajectory with 40 articles. The subsequent decade, from 2010 to 2019, witnessed an exponential increase, reaching a peak in 2013 with 93 articles and maintaining a high level of productivity throughout. The 2020s began with a remarkable peak of 200 articles in 2020, and although there has been a slight decline, the field remains vibrant with 486 articles in the subsequent three years (2021-2023), showcasing a sustained and impactful scientific presence in neurosurgery education.

The mean total citation per article in neurosurgery education varied across the years, reflecting trends in the field's impact. In the early 1960s, a single article from 1962 had an average of 102 citations, setting a high standard. The following decades saw fluctuations, with occasional spikes, and a relative decrease in the mean total citation per article. The late 1990s and early 2000s stood out, demonstrating a substantial increase, reaching a peak in 2000 with an impressive 41.91 citations per article. The subsequent years maintained a high mean total citation per article, peaking in 2017 with 18.47 citations. However, the average citations per article experienced a decline in recent years, with 2023 showing a significant decrease to 1.07 citations per article. Despite these fluctuations, the overall pattern suggests a notable impact and recognition of neurosurgery education research, with varying citation trends over the decades.

The field of neurosurgery education is prominently represented by diverse journals, the most prolific of which is "world neurosurgery" with 441 articles published. Following closely is "neurosurgery" with 204 articles, and "journal of neurosurgery" with 168 articles, emphasizing their substantial contributions to the literature. "Operative neurosurgery" and the "British journal of neurosurgery" also play significant roles, each publishing 129 and 85 articles, respectively. "Acta neurochirurgica", "neurosurgical focus", and "journal of neurosurgery-spine" contribute to the scholarly landscape with 31, 30, and 28 articles, respectively. Additionally, "clinical neurology and neurosurgery" and the "journal of surgical education" round out the top ten with 27 and 25 articles, respectively.

The distribution of neurosurgery journals based on Bradford's law reveals a clear concentration of significant contributions in Zone 1, represented by the top two journals, "world neurosurgery" and "neurosurgery", which collectively account for 645 articles (Figure 1). The subsequent eight journals, including "journal of neurosurgery", "operative neurosurgery", and "British journal of neurosurgery", fall into zone 2, contributing to a cumulative total of 1168 articles. This emphasizes the existence of a core set of journals with substantial scholarly output. The remaining 265 journals, encompassing zone 3, have a comparatively smaller cumulative frequency, suggesting a wider dispersion of articles across numerous journals with lower individual contributions. The fact that only two journals fall into zone 1 indicates a strong concentration of scholarly impact in a select few publications. In contrast, the remaining 265 journals, falling into zone 2 and zone 3, contribute fewer articles individually but collectively represent a broader spectrum of sources. This distribution pattern is typical in many scientific disciplines, where a small number of top-tier journals publish the most influential research, while a larger number of journals contribute to the overall scholarly landscape.

The affiliation patterns of writers in neurosurgery education literature reveal a diverse array of academic and medical institutions. The University of California system emerges as the most prominent contributor, with 175 articles, followed closely by the University of California San Francisco with 79 articles. Harvard University and the University of Toronto also make significant contributions, publishing 76 and 63 articles, respectively. Singh R, from India, was the leading author with 28 articles

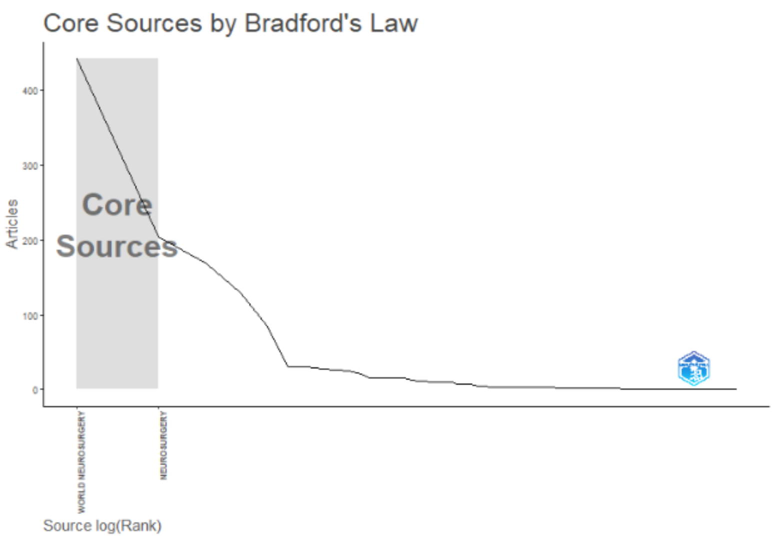

Figure 1. Core sources determined by Bradford's law

and had a substantial fractionalized impact with an impressive value of 6.40. Suri A, from India, closely follows with 27 articles and a fractionalized value of 6.60, indicating a significant and consistent contribution. Lawton MT, from the USA, with 25 articles, was next with a fractionalized value of 4.66. The results of Lotka's law for our dataset reveal a pattern consistent with the principle of author productivity inequality. The distribution indicates that a substantial majority of authors (approximately 75.5%) have only contributed a single article, reinforcing the idea that a large portion of researchers make limited contributions to the field of neurosurgery education. As the number of articles per author increases, the frequency of authors decreases, showcasing a sharp decline in the number of individuals contributing multiple articles. For instance, authors with two articles account for approximately 13.5% of the total, and this percentage progressively diminishes for authors with three or more publications. This distribution aligns with the expectations of Lotka's law, emphasizing the skewed nature of authorship in bibliometrics, where a few prolific authors contribute significantly more, while most contribute fewer articles (Figure 2).

The two papers, "SOC SCI MED" by Album D published in 2008, and "ACAD MED" by Long DM published in 2000, had the most citation counts. Album D's paper has accumulated 221 citations, with an impressive average of 13 citations per year; this study indicated that among medical specialties, neurosurgery has the highest prestige [18]. Similarly, Donlin Martin Long's paper has garnered 190 citations, with an average of 7.6 citations per year, and was about competency-based residency training in neurosurgery [19]. The most cited reference was the Aboud et al. study with 78 times mentioned in studies included in this analysis. This study was about live surgery simulation in neurosurgery [20].

As shown in Figure 3, "surgery" and "simulation" both attained their median frequencies in 2018, with quartiles spanning from 2014 to 2021. Similarly, "neurosurgery" and "education" reached their median frequencies in 2018, with quartile spans from 2014 to 2021. "Impact" and "experience" achieved their medians in 2020, while "medical education", "mortality", "complications", and "operating room" saw their medians in 2016. "Anatomy" and "validation" reached their median frequencies in 2019. Microsurgical anatomy persists from 2002 till now as the most undying term (Figure 3).

Cyprus had 7 articles, all of which were multiple-country publications (MCPs), resulting in an MCP ratio of 1. Belgium had 2 articles, both of which were MCPs, yielding an MCP ratio of 1. Sweden contributed 4 articles, with 1 single-country publication (SCP) and 3 MCPs, giving it a MCP ratio of 0.75. Norway contributed 5 articles, with 2 SCPs and 3 MCPs, resulting in an MCP ratio of 0.6.

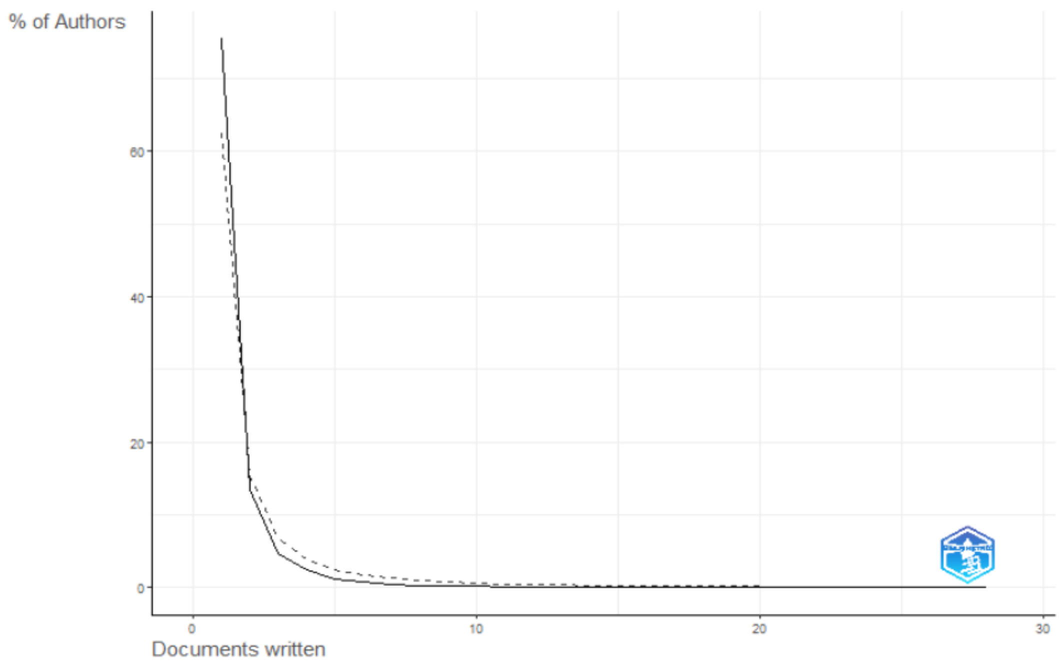

Figure 2. Author productivity in neurosurgery education by the Lotka's law

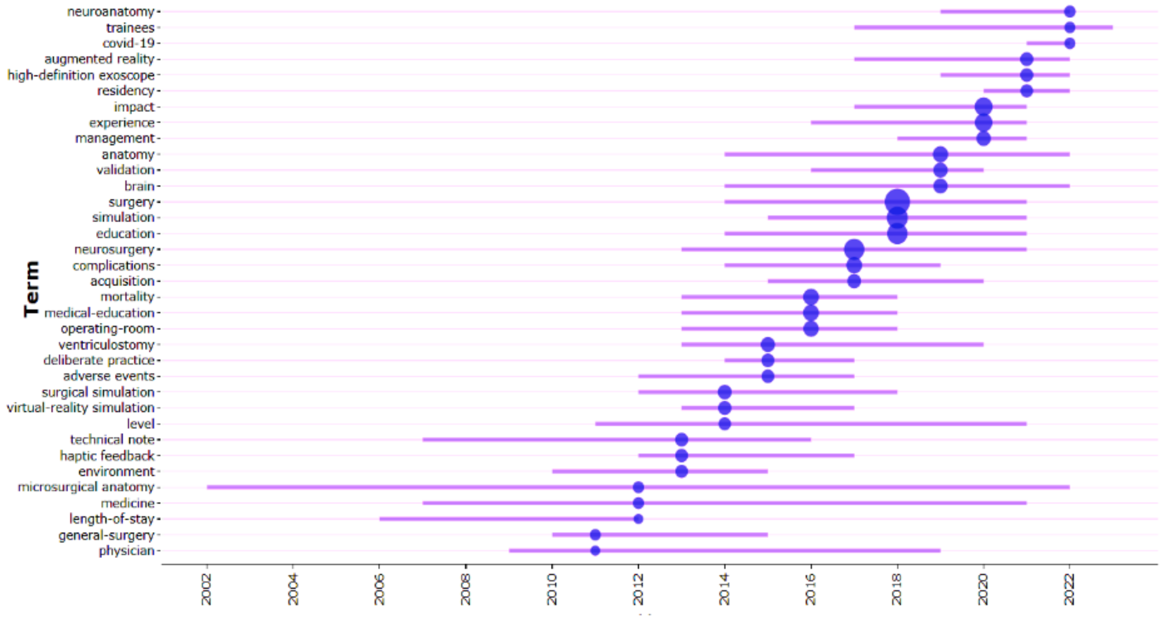

Figure 3. Keyword trend analysis of neurosurgery education based on the year of emergence till end

Notes: Purple line showing the qurtiles and the blue circle is the median number of studies and its size shows the number of articles containing those keywords.

As shown in Figure 4, the USA leads with 775 articles, comprising 715 SCPs and 60 MCPs, resulting in an MCP Ratio of 0.077. The United Kingdom follows with 130 articles, consisting of 118 SCPs and 12 MCPs, yielding an MCP Ratio of 0.092. Canada contributed 114 articles, with 61 SCPs and 53 MCPs, resulting in a relatively high MCP Ratio of 0.465. Germany produced 70 articles, with 60 SCPs and 10 MCPs, giving it an MCP ratio of 0.143.

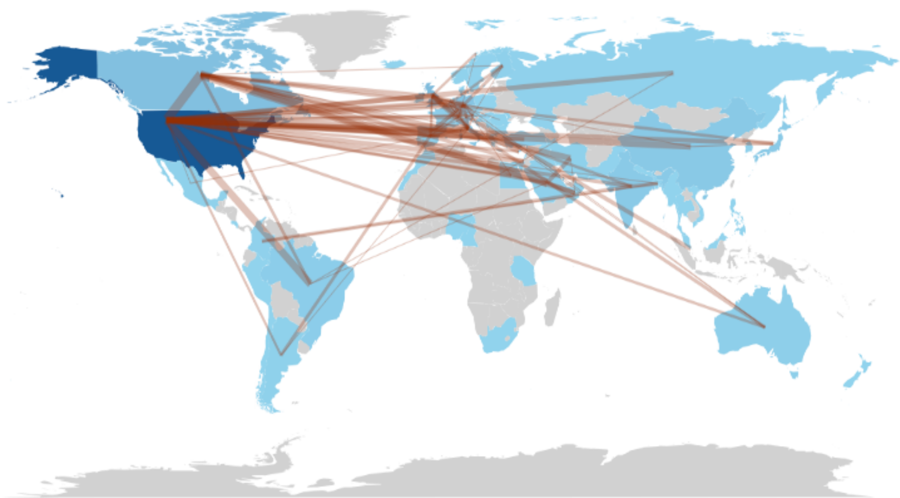

Figure 4. Worldwide collaborative interactions between different countries in the field of neurosurgery education

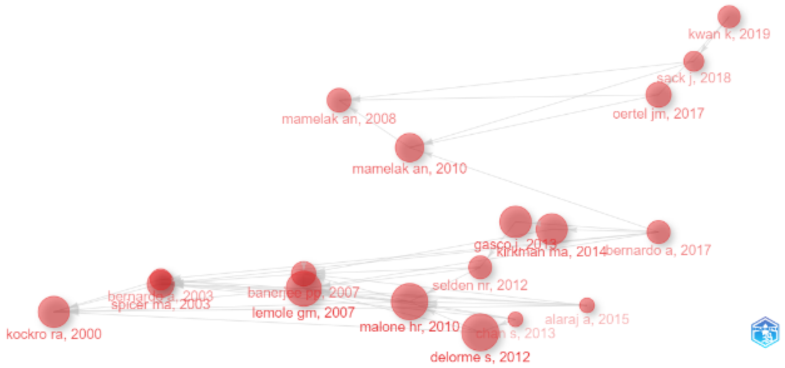

Figure 5. Historical tracing of the citations between the articles

Italy contributed 68 articles, comprising 53 SCPs and 15 MCPs, resulting in an MCP Ratio of 0.221. China contributed 57 articles, with 51 SCPs and 6 MCPs, showing an MCP Ratio of 0.105.

Historical origins of the research field (as summarized in Figure 5) ended up with promising studies by Kockro et al. that utilizing data from the visible human project, the virtual model of the temporal bone was reconstructed from computed tomographic data and segmented to depict middle and inner ear structures, cranial nerves, vessels, and brainstem [21]. Bernard et al.'s study was the second foundation research. In their study, the depiction of neurosurgery and neurosurgeons in 61 movies spanning the history of cinema from 1895 to 2017, across various continents and cinematic genres was evaluated. It showed that these films significantly influence public perceptions and stereotypes regarding neurosurgery [22]. Spicer et al. developed a highly realistic neurosurgical simulator utilizing a distributed computer architecture based on patient-specific data from noninvasive magnetic resonance imaging sequences [23].

4. Discussion

Our study found multiple tips about the education of neurosurgery research. The issue of training anatomy seems to be the most unflinching topic of interest in the field. RPYS analyses showed that the studies that have created the foundation of modern neurosurgery education research also paid significant attention to anatomy education using tools, such as imaging methods and this contributed to simulated learning efforts later. Also, interesting data is provided regarding the inequalities in the publication of neurosurgery education research among different countries, affiliations, different journals, and individual authors.

In this study, educators and researchers can identify trends and patterns in the neurosurgery education literature by analyzing the annual scientific production, citation rates, journals, and affiliation patterns. Educators and funding agencies can allocate resources more effectively by identifying the journals that publish the most neurosurgery education studies and the countries or institutions that lead in contributions. This can involve prioritizing subscriptions to key journals, establishing collaborations with leading institutions, or directing funding towards areas with high research productivity.

A similar study analyzing research productivity and impact throughout the careers of current leaders in American academic neurosurgery who are members of the Society of Neurological Surgeons showed significant wide differences between junior and senior researchers [13]. Our study indicated the most dominant authors of the field, best-cited articles, and historical origins of the research field. In our study, Singh R and Suri A, both from India, led in article publications with 28 and 27 articles respectively, while Lawton MT from the USA followed closely with 25 articles. While the USA had the highest rates of published articles, its international contributions to the research of neurosurgery education were so low.

In a similar bibliographic search that was conducted in WoS-indexed journals up to the year 2022, of systematic reviews of neurosurgery, a final selection of 771 articles was made. The analysis indicated that our study countries in North America and Western Europe are leaders in this field [24].

In another bibliometric study, researchers investigated the application of the idea, development, exploration, assessment, and long-term study (IDEAL) framework in neurosurgery. IDEAL is a methodological approach to ensure research quality in surgery. This study found that most neurosurgery studies support its implementation [25]. While this study was far away from our study scope, it shows the efficiency of bibliometric tools in neurosurgery research. Another study found that H-index stands as a robust predictor for gaining acceptance of neurosurgical first-year residents into neurosurgical research institutions, with the potential for enhancement through early engagement in research [26]. Another study suggests that international medical graduates (IMGs), especially those who attended medical school internationally, may face challenges in advancing from assistant to associate professorship in neurosurgery [27].

Similarly, Venable et al. used Bradford's law to determine core journals in neurosurgery and identified journals of "journal of neurosurgery" and "neurosurgery" and a list of top pediatric neurosurgery publishing journals [28, 29]. Another study in 2018 identified "journal of pediatric surgery", "annals of surgery" and "new England journal of medicine" as the first zone of pediatric neurosurgery based on Bradford's Law [29]. "World neurosurgery" and "neurosurgery" journals with 441 articles (25.34%) were in zone 1 based on Bradford's law, which shows that, unlike the clinical adult and pediatric neurosurgery research, education of neurosurgery is being scoped by other journals.

5. Conclusion

In this bibliometric analysis of literature on neurosurgery education, we observed a significant increase in annual scientific production over the years, indicating growing interest and research activity in this field. Our analysis revealed inequality in publishing and author productivity, as evidenced by Bradford's and Lotka's laws. Despite most authors contributing only a single article, a few researchers, particularly from India, demonstrated high productivity. The United States emerged as the leading contributor in terms of the number of articles. Furthermore, we identified key historical origins of research, including studies on virtual temporal bone models, neurosurgery portrayal in cinema, and the development of realistic neurosurgical simulators.

Study limitations, implications for policymakers, and future studies

This study relied solely on the WoS database, which may not include all relevant literature on neurosurgery education. Policymakers should consider measures to mitigate the inequality observed in publishing and author productivity. Initiatives supporting researchers from underrepresented regions or institutions can help them to contribute to the field. Due to the growing interest and research activity in neurosurgery education, policymakers may prioritize investments in research infrastructures for neurosurgery education. For further research, comparative studies across different databases or research disciplines can be beneficial.

Ethical Considerations

Compliance with ethical guidelines

This article is a review with no human or animal sample.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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