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Original Article

A bibliometric and visualization analysis of global research on vestibular schwannoma

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Abstract: Background: Vestibular schwannoma is the most common benign tumor in the pontocerebellar horn region. As the tumor grows, it often causes severe hearing loss due to compression of nearby nerves, resulting in a lower quality of life. This study examined vestibular schwannoma-related research through a bibliometric and visualization analysis, and it explored current trends and research hot spots. Methods: Research related to vestibular schwannoma published from 2002 to 2021 was searched using the Web of Science Core Collection. The processing and visualization analysis of the data were conducted using R software, VOSviewer, and CiteSpace. Results: A total of 3,909 publications were included in this study, and an overall increasing trend in the annual output of publications was found. The United States, Germany, and the United Kingdom were the most prolific countries, publishing the most articles. Germany had the most frequent international cooperation and the highest centrality score. The Mayo Clinic, University of California, and Harvard University were the three most productive institutions. *Otology & Neurotology* was the most prolific journal, and MJ Link was the most productive and highest scoring author for centrality. Current frontier topics mainly focused on "hearing preservation" and "radiosurgery". A map of trends in topics and a thematic graph revealed that "hearing loss", "vertigo", "magnetic resonance imaging", "radiosurgery", "stereotactic radiosurgery", and "gamma knife" were the topics of focus of current discussions. Conclusion: Hearing preservation is a current frontier topic in this area. Radiosurgery has a promising future in the field of vestibular schwannoma, and stereotactic radiosurgery is a focus of global attention. Bibliometric and visualization analysis offer a unique and objective perspective of the field of vestibular schwannoma and may assist scholars in the identification of new research directions.

Keywords: Bibliometrics, visualization analysis, VOSviewer, CiteSpace, vestibular schwannomas, acoustic neuroma

Introduction

Vestibular schwannomas are the most common benign tumors of the cerebellar horn, originating in Schwann cells produced by the myelin sheath of the vestibular nerve. The progressive loss of hearing and balance and eventual compression of the brainstem caused by vestibular schwannomas result in serious neurological sequelae [1, 2]. This tumor accounts for approximately 8-10% of newly diagnosed intracranial tumors and 90% of all cerebellopontine angle neoplasms [3]. The average age of patients is about 50 years at the time of diagnosis, and over 95% of all diagnosed vestibular schwannomas are sporadic and unilateral, with an annual prevalence of approximately 1 per 100,000 persons, without any gender differences [4]. Patients with a vestibular schwannoma usually present with asymmetric sensorineural hearing loss, asymmetric tinnitus, and/or vertigo. Approximately 10-20% of people diagnosed with vestibular schwannoma report sudden hearing loss at some time in their lives [5]. Notably, the prevalence of vestibular schwannoma among patients treated for sudden sensorineural hearing loss (SSNHL) may differ considerably, with some studies reporting rates ranging from 1.9% to 10.2% [6]. Currently, no clinical characteristics have been estab-

lished to formulate a definite distinction between vestibular schwannoma and SSNHL [1]. Various types of audiometric patterns and the recovery of normal hearing may be observed in patients with SSNHL suffering from vestibular schwannoma.

Although magnetic resonance imaging (MRI) is regarded as the gold standard for establishing a diagnosis of vestibular schwannoma [7], 86% of MRIs are negative, making it an inefficient utilization of resources causing unnecessary uncertainty for the individual [8]. Thorough and efficient examinations have the ability to avoid the use of unnecessary MRI in the diagnosis of vestibular schwannoma, thereby improving cost-effectiveness. A test of the auditory brainstem response, which is highly sensitive to vestibular schwannomas > 10 mm in size, has been recommended for the preliminary assessment of patients with SSNHL [7]. Current microsurgery and radiosurgery are highly effective procedures that have reduced patient mortality and tumor recurrence significantly. In the last two decades, surgeons have been able to access different tumor sites using surgical microscopes and various methods, along with neurophysiologic monitoring of multiple cranial nerves intraoperatively, as well as a better understanding of microsurgical anatomy. Hence, major improvements in surgical techniques have improved their efficacy and reduced morbidity [1, 2]. As a minimally invasive procedure, radiosurgery can greatly improve hearing preservation. However, comparing outcomes of different treatments is difficult at present because microsurgery is often preferred when a tumor is large, whereas radiosurgery is usually performed when a vestibular schwannoma is relatively small [3]. Currently, the best possible treatment for patients with vestibular schwannoma remains unclear.

Bibliometric analysis is a novel method based on mathematics and statistics for analyzing a large number of heterogeneous publications [9]. Combined with visualization software, bibliometric analysis facilitates the collection of data on the contributions of specific fields from multiple perspectives, as well as detailed trends in research or foci [10]. Bibliometric analysis uses citation counts as a surrogate measure for the quality of the research, which is a valid approach to statistical and qualitative assessments of trends in the field [11]. This method not only helps academic teams detect trends in a specific research field, but also provides a way to for them to understand the trends and rankings of research teams and individuals by evaluating the contributions of academic groups and individual researchers objectively through a systematic analysis of the authors, countries, journals, and citations of the included publications [12, 13].

This study analyzed keywords occurring more frequently in publications and recent emerging buzzwords to provide supporting data for current trends that have been identified [14]. Bibliometric analysis has been used in several fields, such as disease management, pharmacology, nursing information, financial big data, energy, environment, climate change, and transportation systems [15-19].

Several reviews have described the epidemiological features, pathophysiological mechanisms, and clinical treatment of vestibular schwannomas [1]. However, no systematic bibliometric analysis combined with a visual analysis of research trends and frontier hotspots, providing an overall framework of vestibular schwannoma, has been published in past decades. Visualization methods can promote an understanding of key points among teams of researchers of relevant research in a more intuitive way than can traditional systematic reviews and meta-analyses. Thus, this two-level method of bibliometric analysis combined with visual analysis has been used extensively to close this gap.

The aim of this study was to conduct a comprehensive analysis of the developing trends in vestibular schwannoma and provide a thorough description and visual representation of the current state and foci of the field. Exploring research frontiers will provide a reference for research teams who are, or will be involved in the field, so that they can choose their direction of research.

Methods

Sources of data and search strategy

The Web of Science Core Collection (WoSCC) is a database including over 10,000 high-quality journals, and it is the most frequently used

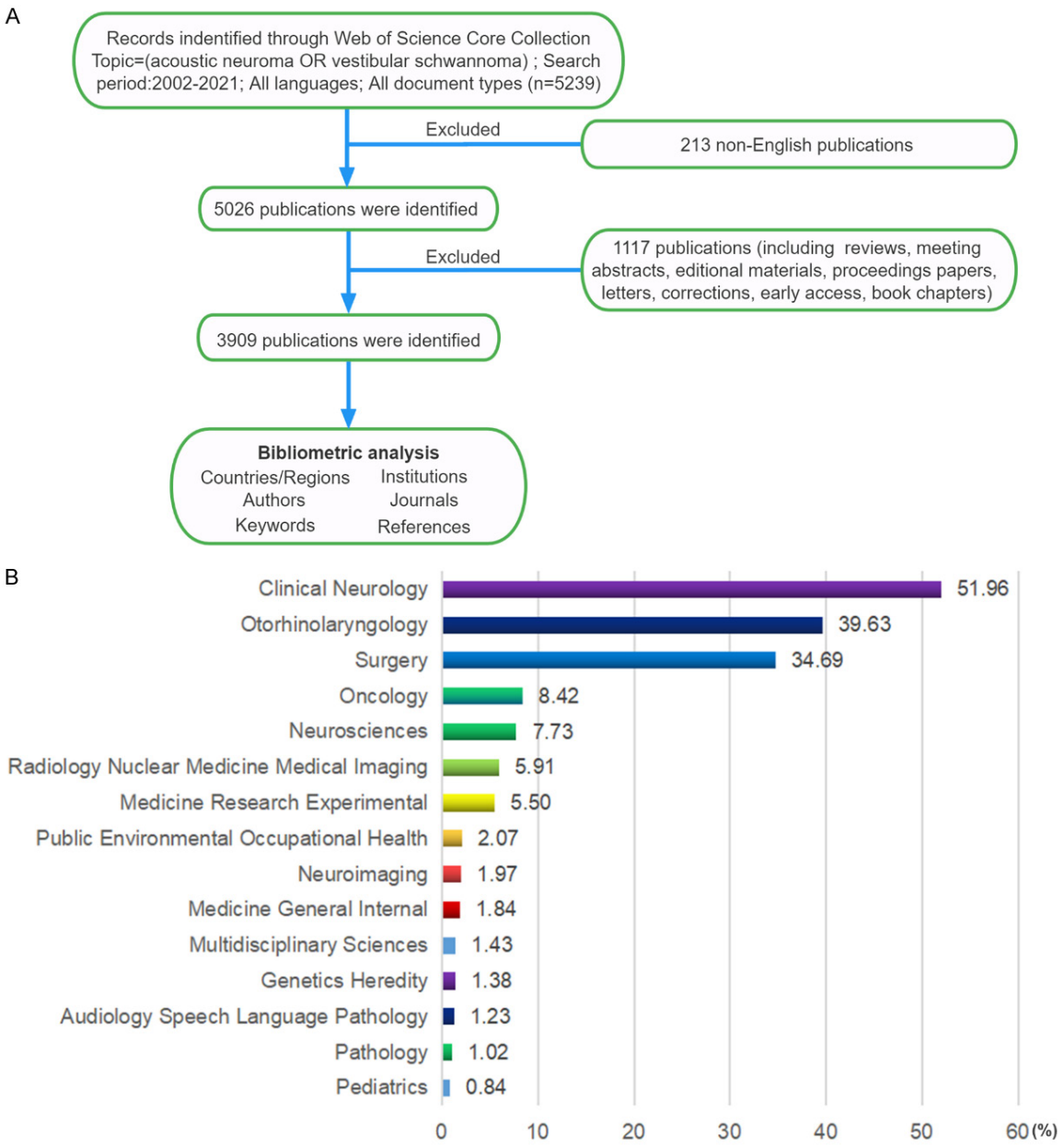

Figure 1. A. Flow chart describing the search strategy and protocol; B. Categories of publication

database for medical bibliometric analyses [20]. In this study, we selected the Social Sciences Citation Index and the Science Citation Index-Expanded of the WoSCC as retrieval repositories for this study. The search formula was set to Topic = Vestibular schwannoma OR acoustic neuroma. To avoid bias caused by database updates, the researchers completed the search and data collection within one day on July 1, 2022. Only English-language articles published between 2002 and 2021 were included in this study. Subsequently, only original articles were included; other article types were excluded. **Figure 1A** depicts the inclusion and exclusion of identified publications and the data analyzed in bibliometric analysis.

Visualization and statistical analyses

A bar graph with annual publications was created using Microsoft Excel 2019. In general, the research productivity of countries, institutions, teams, and journals were evaluated

based on the total number of publications, while the total number of citations of authors, journals, and references indicated overall scholarly influence [21]. We also collected several indicators from Journal Citation Reports 2021, including the impact factor, H-index, and quartiles of journals. The H-index is a mixed quantitative index used to assess the number and level of academic achievements of authors [22]. A higher H-index of an author indicates a greater overall impact of the author's publications. Moreover, the H-index has been used extensively in many previous studies to assess the productivity and academic influence of countries, institutions, and research teams [23]. Visualization was conducted using several visual tools.

The Bibliometrix package in R software (version 4.0.3) and an online bibliometric analysis platform (http://bibliometric.com) were used to analyze collaborations between countries or regions. Bibliometrix is an R package with a set of functions designed for use with quantitative and scientometric studies to analyze the included publications and generate trending topics and thematic maps.

VOSviewer software was used to analyze intuitively the collaborative networks among authors, institutions, and countries, and co-occurrences of keywords, co-citations of references, and citations of journals. The size of the circle represents the number of publications or the frequency of keywords occurrences, and the thickness of the connecting lines indicates the strength of the links. On the network map, different clusters are marked by different colors, and co-occurrences or collaborations are represented by connecting lines. VOSviewer generates three types of visualization graphs: network visualization maps, overlay visualization maps, and density visualization maps. In the present study, VOSviewer (version 1.6.10) was used to analyze co-authorships and keyword co-occurrences.

CiteSpace (version 5.8.R3) was used to perform cluster analysis, identify burst references and keywords, and build a timeline view. Cluster analysis was used to identify important topics in vestibular schwannoma-related fields by classifying keywords and cited references. Examining keyword and reference bursts can be used to identify developing trends in vestibular schwannoma-related research. The higher the intensity of the burst, the more frequently the keyword occurs in the observed time period. The centrality of a node is a critical evaluation metric in a network map, which quantifies the importance of the nodes' locations [24]. Centrality is a criterion for the interaction between individual clusters: a higher centrality indicates a greater central tendency of the cluster in a certain research area and more frequent interactions and cooperation of a country or institution with other countries or institutions [25]. In the present study, we calculated the centrality scores of all countries, institutions, and research teams. CiteSpace was mainly used to conduct a visual analysis of institutions and cited references, and to identify the keywords and cited references with the largest citation bursts, thereby creating a dual map overlay of journals.

Results

Summary of publications

A total of 3,909 publications on vestibular schwannoma were included in the analysis based on the study's search strategy and inclusion criteria. These publications were classified into 80 subject categories based on the criteria for data classification (**Figure 1B**). Of all the topics, Clinical Neurology was the largest proportion of the studies retrieved. The top 5 disciplines with the highest number of articles were Clinical Neurology (2,031, 51.96%), Otorhinolaryngology (1,549, 39.63%), Surgery (1,356, 34.69%), Oncology (329, 8.42%), and Neurosciences (302, 7.73%). The annual production of related publications increased, from 143 (3.7%) in 2002 to 302 (7.7%) in 2021, with an average annual production of 195 publications per year (**Figure 2A**). These articles were cited 78,818 times, with an H-index of 99, and each document was cited an average of 20.17 times. Research on vestibular schwannoma increased dramatically during 2017-2021, with global scholars publishing 1,332 articles during this five-year period, accounting for 34.1% of all relevant publications.

Productive countries or regions and institutions

A total of 76 countries or regions contributed publications in the field of vestibular schwan-

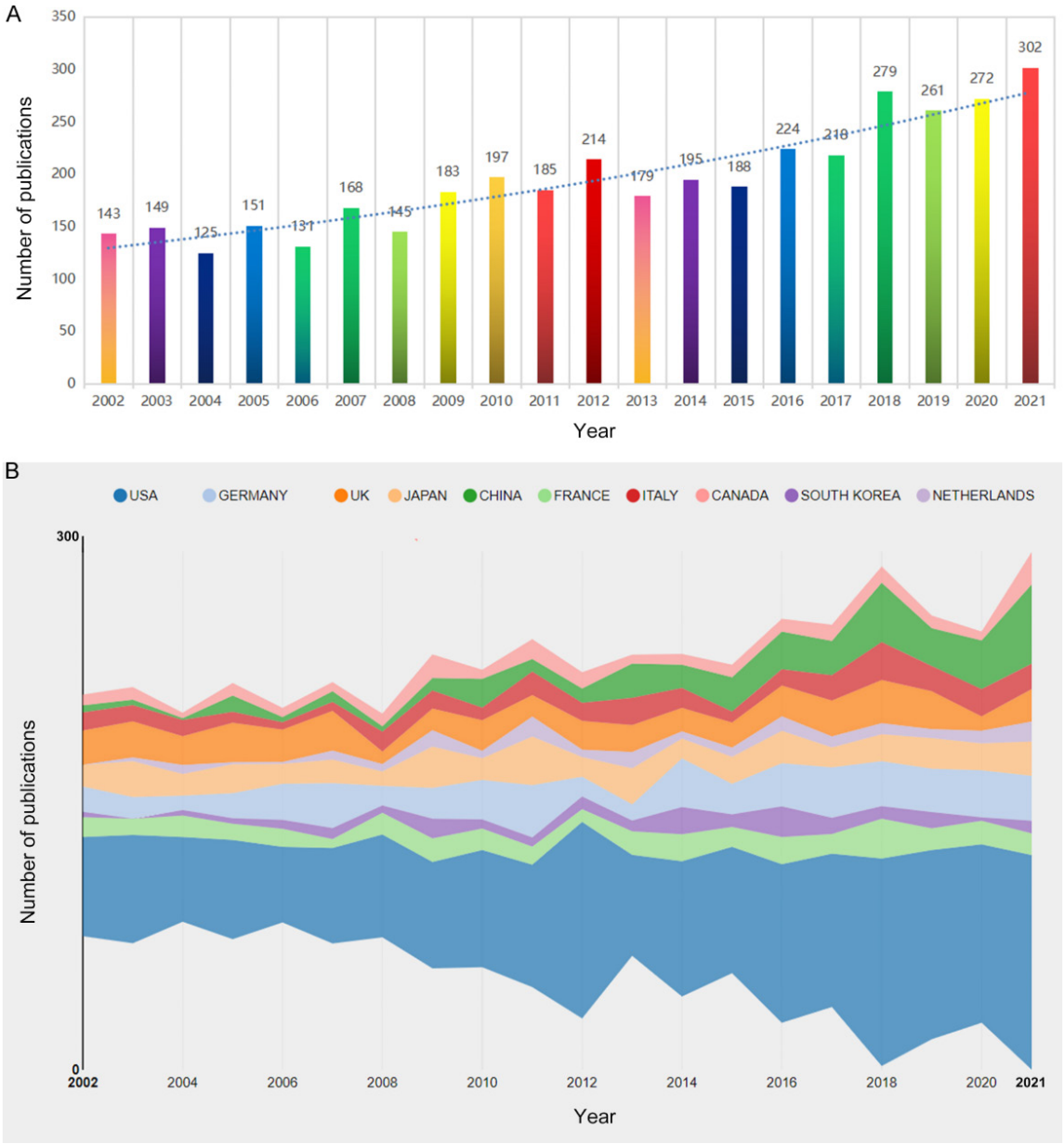

Figure 2. A. Growth trends in publications on vestibular schwannoma from 2012 to 2021; B. Number of annual publications of the top-10 most prolific countries from 2012 to 2021.

noma. The top-10 most prolific countries are reported in **Table 1** and **Figure 2B**. More than 100 publications were published in each of the 10 countries. **Figure 3A** presents the distribution of the number of publications by country worldwide. The USA (1,523) published the most articles, accounting for 39.0% of the world's publications, followed by Germany (397, 10.2%), UK (316, 8.1%), Japan (315, 8.1%), and France (241, 6.2%). International collaborations among countries or regions are shown in **Figure 3B**. Although the USA ranked first for the number of publications, it had a low centrality score, which was probably related to lack of international cooperation. Germany exhibited close cooperation with other countries or regions (centrality = 0.38), followed by Italy (0.25), France (0.18), Japan (0.16), and the Netherlands (0.14).

A total of 2,799 research institutions contributed to vestibular schwannoma-related publica-

Table 1. Contributions of the top-10 most productive countries to research on vestibular schwannomas

Rank	Country	Count	Centrality
1	USA	1523	0.05
2	Germany	397	0.38
3	UK	316	0.00
4	Japan	315	0.16
5	France	241	0.18
6	China	227	0.05
7	Italy	222	0.25
8	Canada	155	0.05
9	South Korea	133	0.05
10	Netherlands	112	0.14

tions. The network of institutional cooperation is presented in **Figure 3C**. Three of the top-10 institutions were from Europe and seven were located in the USA (**Table 2**). The Mayo Clinic ranked first (197, 5.0%) for the number of publications, followed by the University of California (183, 4.7%), Harvard University (169, 4.3%), Udice French Research Universities (156, 4.0%), and the University of Manchester (92, 2.4%). Among these productive institutions, the top-3 rankings for centrality were the University of Manchester (0.37), Massachusetts General Hospital (0.34), and the House Research Institute (0.14), respectively.

Influential authors

A total of 15,692 authors contributed to vestibular schwannoma-related publications. The collaborative network of the authors is depicted in **Figure 4A**, with a minimum number of 10 publications per author. **Table 3** presents the 10 most prolific authors with publications on vestibular schwannoma within in the last 20 years. MJ Link was the most productive author, with 126 articles (H-index = 30), followed by ML Carlson (124 publications with an H-index = 29), and BA Neff (52 publications with an H-index = 20). The relative scarcity of links between the different teams of authors in the network collaborations suggests there was not sufficient collaboration between the research groups or labs conducting vestibular schwannoma-related studies. All of the authors' centrality scores were lower than 0.10, indicating inadequate collaboration among the research teams in this area of medicine. A timeline of authors who had published vestibular schwannoma-related publications was also mapped (**Figure 4B**). Among the top 20 most prolific authors, ML Carlson had been publishing studies in this area for more than 10 years (the first publication was in 2010). Although his research team started late, it has accumulated the largest number of publications.

Analysis of keywords

The contents of the titles and abstracts of the 3,909 publications were used to generate a graph with 266 keywords (8,604 in total) that occurred at least 20 times and were grouped into five clusters (**Figure 5A**). **Figure 5B** shows the overlay visualization of keywords. The earlier appearing keywords are indicated in blue and the most recently appearing keywords are indicated in yellow. The main early hot spots were keywords, such as "brain-tumor", "caloric test", and "severity". In contrast, keywords such as "cochlear implant", "single-sided deafness", "facial-nerve outcomes", and "retrosigmoid approach" have been frontier topics in recent years. The construction of a density map of keywords was based on their frequencies. Radiosurgery and hearing conservation were core parts of the study, in addition to the subject terms (**Figure 5C**).

Figure 5D shows the top 15 largest bursts of keywords; "tumor surgery" (2002-2004), "removal" (2003-2006), and "acoustic neuroma surgery" (2003-2006) received greater attention in the previous period. Recent themes that were more popular included "clinic articles" (2015-2018) and "hearing" (2018-2021). **Figure 6A** shows a map of trends in topics generated when the keywords were analyzed. As can be seen from the graph, the main hot spots after 2017 were "skull base", "cochlear implant", and "translabyrinthine". The map of the keyword themes consisting of a two-dimensional matrix can identify the current focus and predict the direction of research in recent years (**Figure 6B**). Quadrant 4 (bottom right) shows basic topics that were meaningful to the field but not fully developed. Notably, one cluster located in quadrant 4 (the keyword "hearing preservation") corresponds to the last item in the map of the results of the analysis showing the keyword burst, indicating they were potential research topics.

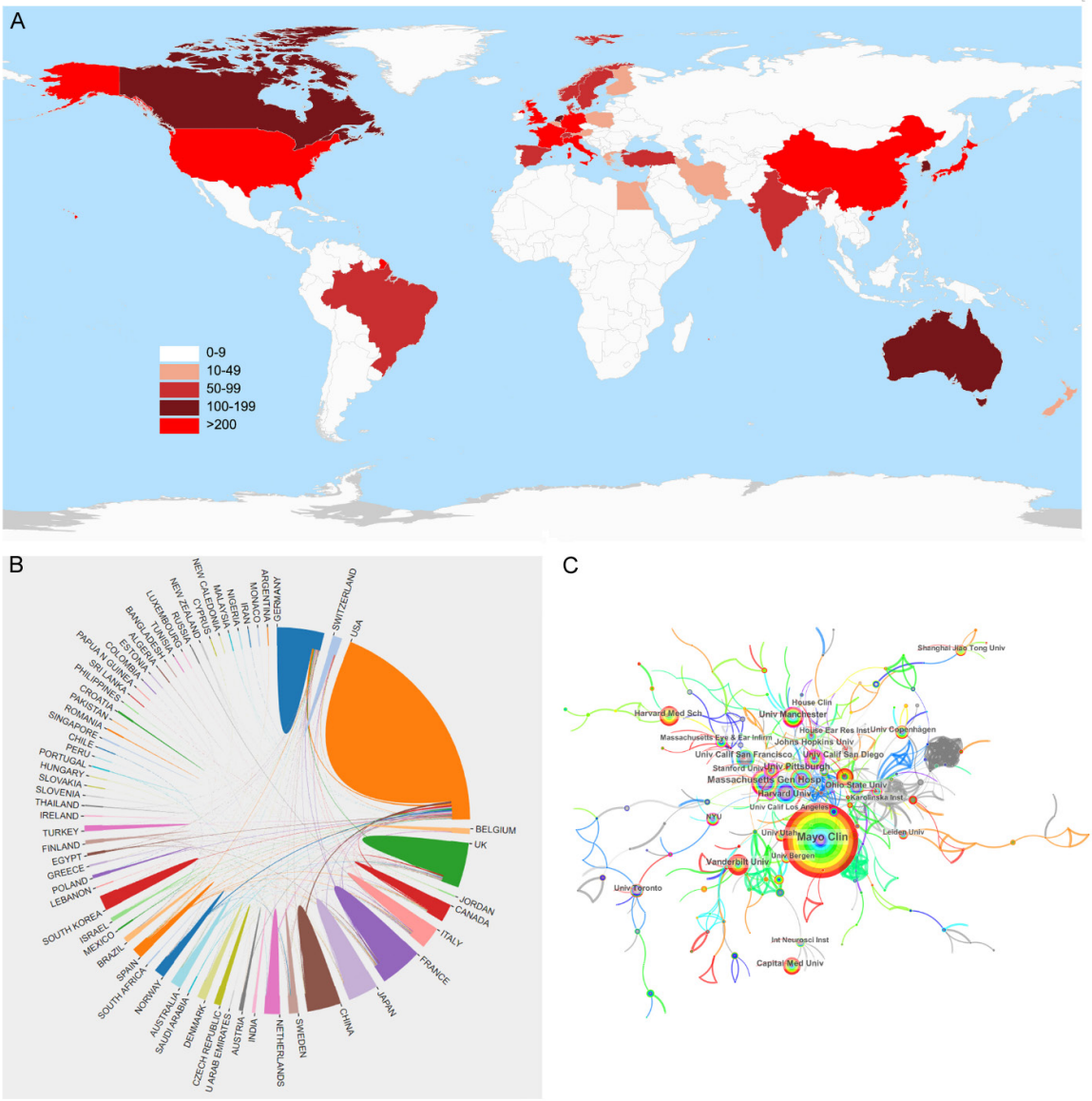

Figure 3. A. Map of contributions of countries by number of publications; B. Cooperation between countries or regions regarding vestibular schwannoma; C. Networks of institutional cooperation and contributions to vestibular schwannoma-related publications.

Cited references with citation bursts

Cited references were analyzed for the detection of bursts to track and capture the evolution of research hot spots. **Figure 6C** shows the top-10 cited references with the largest burst from 2002 to 2021. The red line indicates a sudden increase in citations of that reference during this period, and the blue line represents relative unpopularity. Among the references cited in recent years, "Management of sporadic vestibular schwannomas", by Carlson et al. [26] had the largest burst.

Most cited references

A total of 44,051 cited references were extracted from 3,909 publications to analyze the co-citations, and a cluster graph was built based on the topics. The network map of the cited references consisted of 132 nodes and 129 links; the time slice was set to 1 year and the period was set to 2012-2021 (**Figure 7**). **Table 4** shows the top 10 most frequently cited referenced; all of them were published after 2000 and were cited more than 300 times. A study by Stachler et al. [7] published in *Otolaryngology-*

Table 2. Contributions of the top-10 most productive institutions to research on vestibular schwannomas

Rank	Institution	Count	Country	Centrality
1	Mayo Clinic	197	USA	0.05
2	University of California	183	USA	0.12
3	Harvard university	169	USA	0.10
4	Udice French Research Universities	156	France	0.01
5	University of Manchester	92	UK	0.37
6	Massachusetts General Hospital	91	USA	0.34
7	Assistance Publique-Hopitaux de Paris	78	France	0.00
8	House Research Institute	78	USA	0.14
9	Pennsylvania Commonwealth System of Higher Education	75	USA	0.00
10	Johns Hopkins University	71	USA	0.09

Head and Neck Surgery was the most cited article (654 times). To avoid the influence of year of publication, the effects of time and co-citation were taken into account in the co-occurrence analysis, and the timeline of the clusters were mapped (**Figure 8**). The results showed that "surgery" (Cluster #1) was a relatively early hot spot. "Radiosurgery" (Cluster #0), "hearing preservation" (Cluster #1), and "diffusion tensor imaging" (Cluster #7) represented the current research focus.

Higher impact journals

Figure 9A is a dual overlay diagram of journals, showing the classification of journal themes and citation relationships among journals. The right and left sides represent the citings and the cited journals, respectively. The map shows four main routes of citation (one in orange, two in gray, three in pink, and three in green). The orange route indicates articles published in molecular, biology, and immunology journals that are often cited in molecular, biology, and genetics journals. The gray routes indicate articles from dentistry, dermatology, and surgery journals that are cited in molecular, biology, genetics, and health, nursing, and medicine journals. The green paths show studies published in medicine, medical, and clinical journals that are often cited in health, nursing, medicine, molecular biology, genetics, and psychology, education, and social journals. The pink paths represent studies published in molecular, biology, and genetics journals, often citing articles published in neurology, sports, and ophthalmology journals.

A total of 3,909 publications were retrieved from 201 journals, of which 8 published more than 100 articles. We ranked the top-10 most popular journals with 1,811 published articles during the past two decades, accounting for 46.3% of total publications (**Table 5**). It is worth noting that the publisher with seven of the top-10 journals is located in the USA and the remaining three are in Europe. The top-5 journals with the most publications were *Otology & Neurotology* (548, 14.0%), the *Journal of Neurosurgery* (267, 6.8%), *Laryngoscope* (169, 4.3%), *World Neurosurgery* (156, 4.0%), and *Neurosurgery* (153, 3.9%), all of them from the USA (**Figure 9B**).

Discussion

Vestibular schwannoma is a benign, extra-axial, slow-growing tumor [27], which, if left untreated for a long time, may grow to a size resulting in serious neurologic complications, such as hydrocephalus, brainstem compression, or brain herniation, which are the main causes of death [28]. In recent years, the mortality and disability rates of vestibular schwannoma have been controlled; that is, they have been reduced from a rate higher than 50% in 1913 (as reported at the London International Medical Conference) to less than 1% currently [29]. However, there is no standardized system for the diagnosis or the prognostic evaluation of vestibular schwannoma. Outcomes, such as hearing preservation and postoperative reconstruction of auditory function in some patients are unsatisfactory, and many issues remain to be addressed. It is necessary to provide a comprehensive overview of the current state of research in this area and to identify hot spots and research frontiers. These are the first qualitative and quantitative analyses of vestibular

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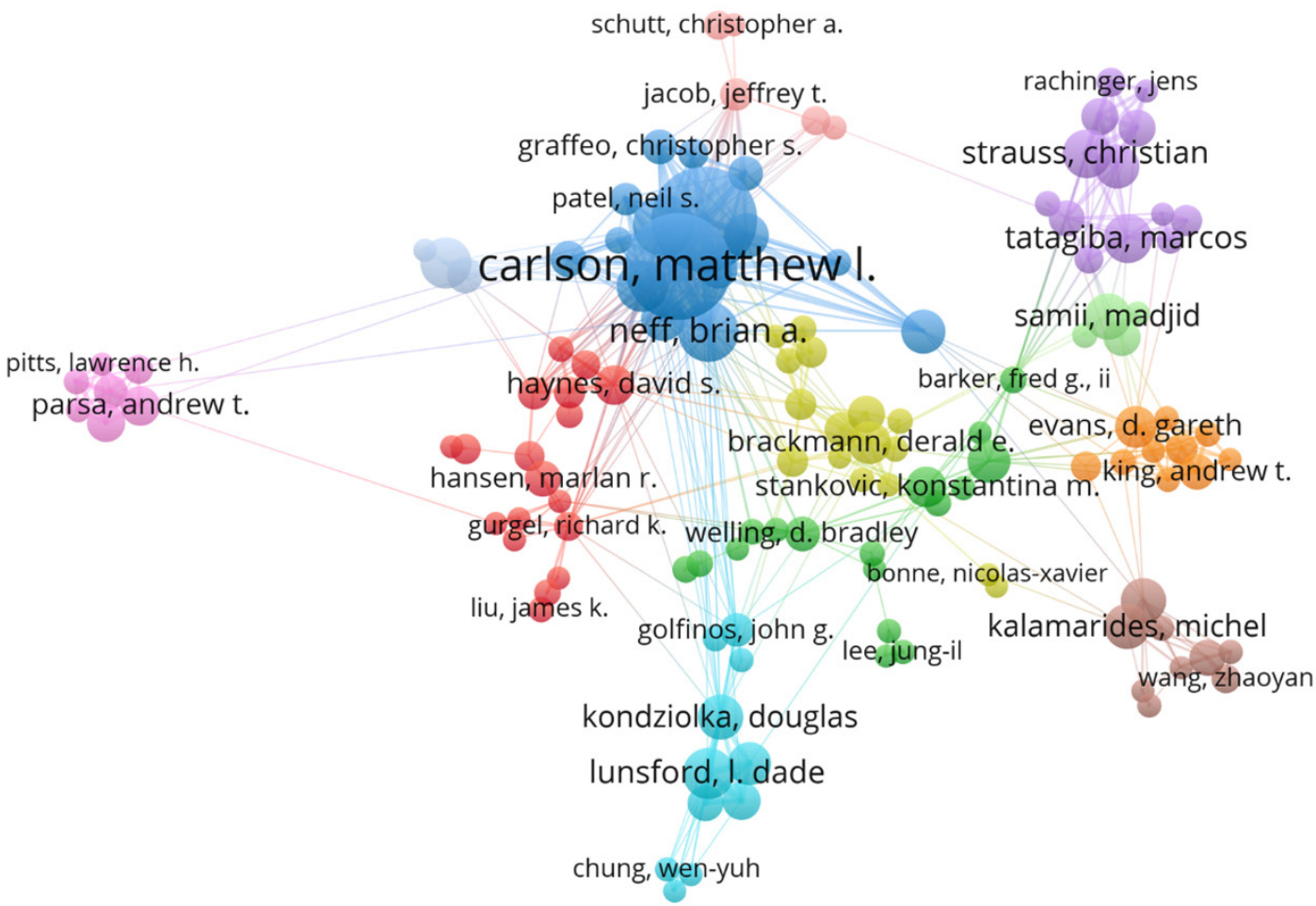
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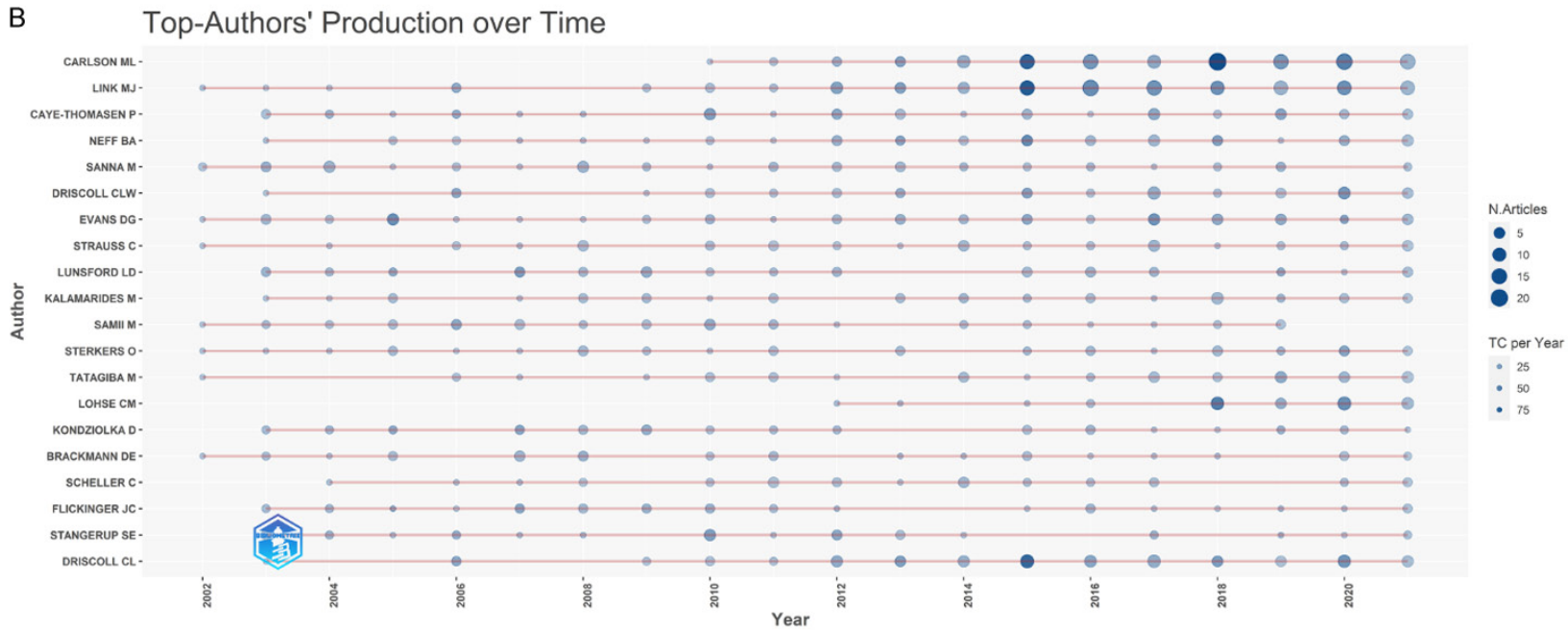


Figure 4. A. Visualization of authors' cooperative networks for vestibular schwannoma; B. Top-20 most prolific authors' productivity related to vestibular schwannoma.

Table 3. Productivity of the top 10 most prolific authors of research on vestibular schwannoma

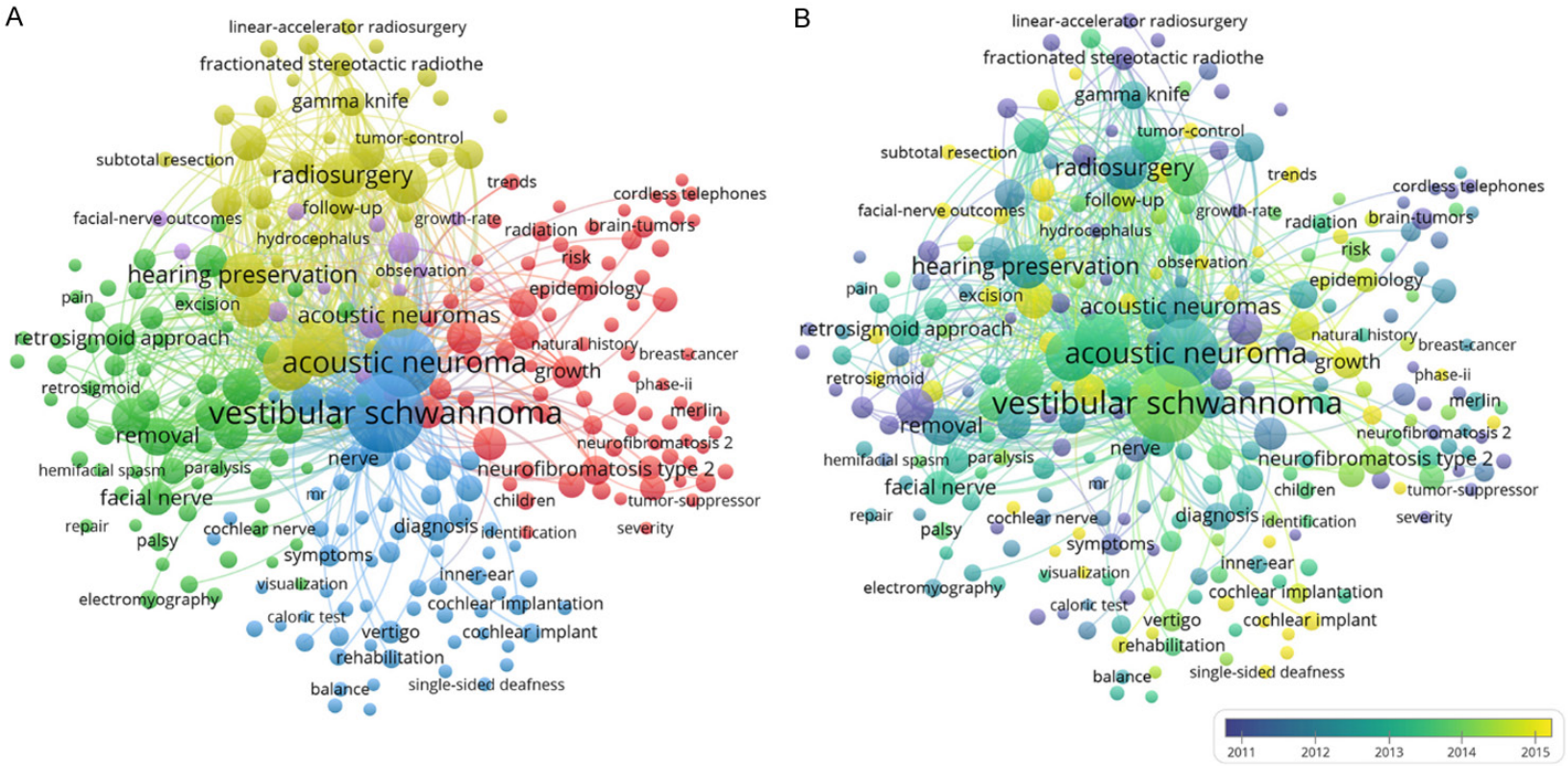
Rank	Author	Count	Country	Country	Centrality	Total number of citations	Mean number of citations	H-index
1	Link MJ	126	USA	0.08	0.00	2,857	22.67	30
2	Carlson ML	124	USA	0.07	0.00	2,406	19.40	29
3	Neff BA	52	USA	0.03	0.00	1,469	28.25	20
4	Caye-thomasen P	51	Denmark	0.00	0.00	1,922	37.69	23
5	Driscoll CLW	51	USA	0.03	0.00	1,184	23.22	19
6	Sanna M	49	Italy	0.00	0.00	1,539	31.41	23
7	Strauss C	46	Germany	0.00	0.00	689	14.98	15
8	Evans DG	44	UK	0.01	0.00	1,442	32.77	23
9	Kalamarides M	44	France	0.01	0.00	842	19.14	18
10	Lunsford LD	44	USA	0.01	0.00	2,198	49.95	23

schwannoma-related publications using bibliometric methods combined with visual analysis of research articles published during the past two decades and retrieved from databases.

Our results show that vestibular schwannoma is gaining academic attention as the number of vestibular schwannoma-related research articles worldwide has steadily increased over the last two decades. Based on the distribution of countries in **Table 1**, it was evident that the country with the most published articles was the USA (1,523, 39.0%), followed by Germany (397, 10.1%), accounting for 49.1% of the total number of publications. These findings suggest that these two countries are leading contributors to the field of vestibular schwannoma. The academic capacity of a country is mainly determined by the country's economic status. Government spending on health care may be another critical indicator of medical research output [30]. The USA outpaces other countries in health expenditures, with an annual average of $10,202 per resident, which may explain its high number of publications [31]. Among these countries, Germany undertakes international cooperation most frequently, which is reflected in its high centrality score. Although Germany had the second highest number of publications, none of its institutions reached any of the top 10 rankings, whereas two French institutions published nearly 150 studies on vestibular schwannoma, which is inconsistent with that country's ranking for the total number of publications. Many of these publications were based on collaboration, which suggests that inter-country collaboration is an important way to increase the number of publications and that developing broad inter-country collaboration might be more important than inter-institutional collaboration.

An analysis of the characteristics of highly productive journals can contribute to the understanding of current trends [32]. *Otology & Neurotology* has published the most vestibular schwannoma-related studies in recent years, indicating its high level of concern about the field, and it provides an effective publishing platform for scholarly exchange. Among the top 10 journals with the most published research on vestibular schwannoma, all of them were located in the USA and western European countries. In contrast, no publishers were located in East Asia, although China and South Korea were also two crucial countries contributing to the field of vestibular schwannoma. This finding highlights the urgent need to establish an influential international journal in Asia. The dual-map of journals suggests that vestibular schwannoma has developed from a single discipline to a cross-disciplinary field.

We found a gradual upward trend in the publications of many countries, which might be due to the development of national economies and increased financial support for academic research [33]. To reduce the gap between advanced and emerging countries, we suggest: 1) an emphasis on relevant knowledge and new technologies in the social environment; 2) an increase in the investment in natural research by the government; 3) improving the evaluation system for researchers, emphasizing the quantity and quality of publications, and increasing the percentage of core journals; and 4) encour-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hemifacial spasm
paralysis
neurofibromatosis type 2
facial nerve
mr
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tumor-suppressor
repair
cochlear nerve
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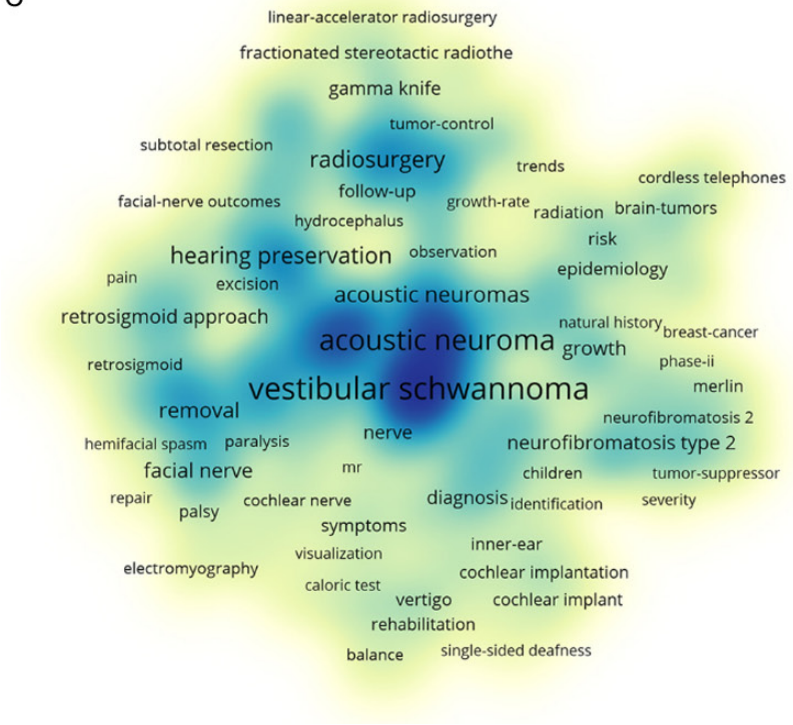

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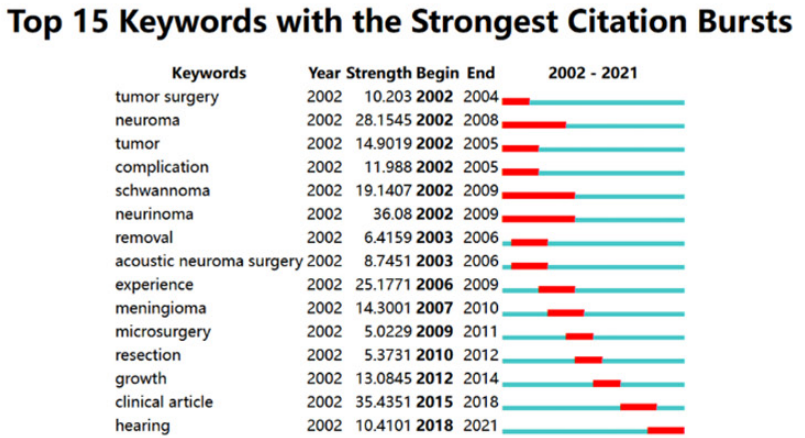
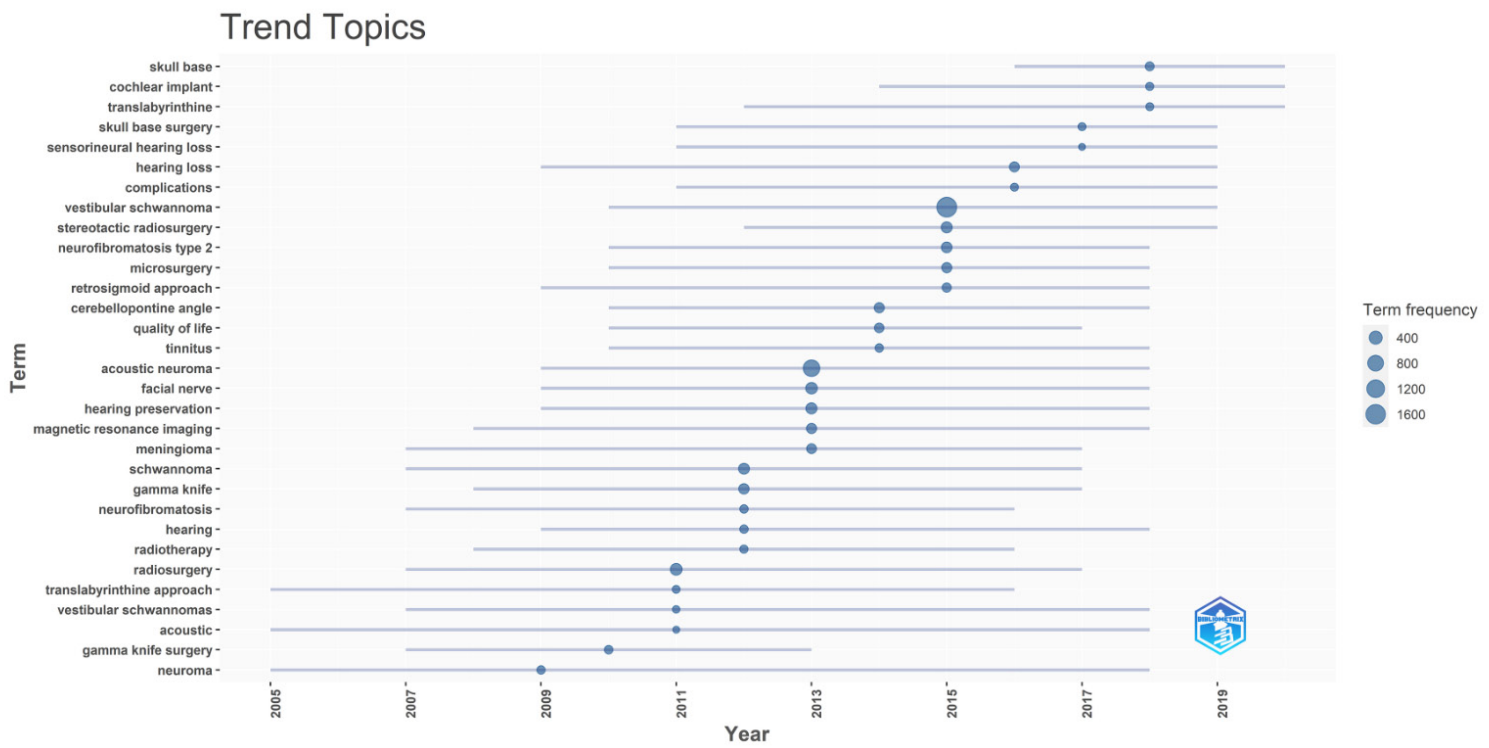
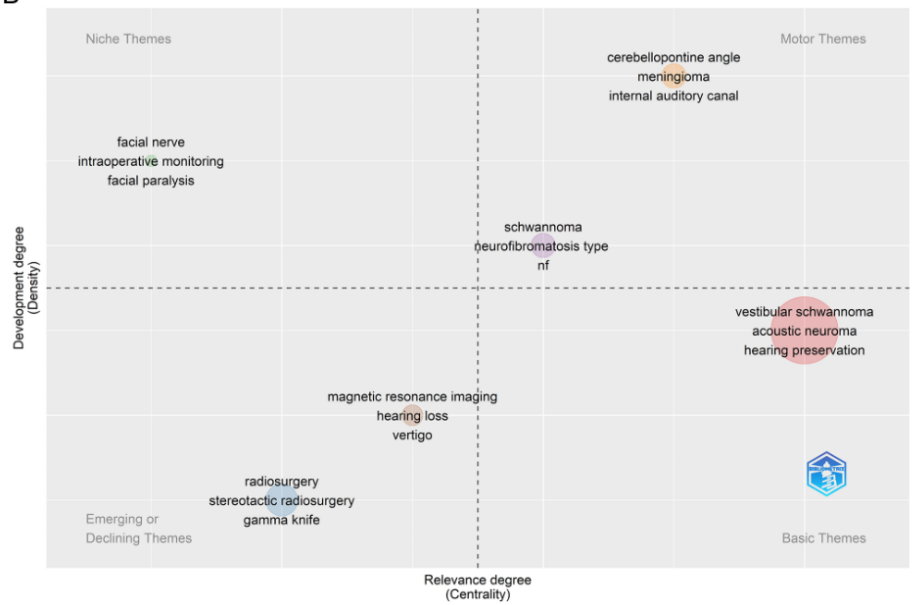


Figure 5. A. A graph of keyword clustering; B. A time-series map of keyword co-occurrence; C. Construction of a density map for visualization of keyword was based on keyword co-occurrence; D. The largest bursts of citations of research on vestibular schwannoma (2002-2021).

A


Trend Topics
skull base
cochlear implant
translabyrinthine
skull base surgery
sensorineural hearing loss
hearing loss
complications
vestibular schwannoma
stereotactic radiosurgery
neurofibromatosis type 2
microsurgery
retrosigmoid approach
cerebellopontine angle
quality of life
tinnitus
acoustic neuroma
facial nerve
hearing preservation
magnetic resonance imaging
meningioma
schwannoma
gamma knife
neurofibromatosis
hearing
radiotherapy
radiosurgery
translabyrinthine approach
vestibular schwannomas
acoustic
gamma knife surgery
neuroma
Term
2005
2007
2009
2011
2013
2015
2017
2019
Year
Term frequency
400
800
1200
1600

B



C

Top 20 References with the Strongest Citation Bursts

References	Year	Strength	Begin	End	2002 - 2021
Flickinger JC, 2001, J NEUROSURG, V94, P1, DOI	2001	38.7163	2002	2006	
Prasad D, 2000, J NEUROSURG, V92, P745, DOI	2000	20.05	2002	2005	
Foote KD, 2001, J NEUROSURG, V95, P440, DOI	2001	15.6882	2003	2006	
Andrews DW, 2001, INT J RADIAT ONCOL, V50, P1265, DOI	2001	13.9242	2003	2006	
Lonn S, 2004, EPIDEMIOLOGY, V15, P653, DOI	2004	17.6989	2006	2009	
Lunsford LD, 2005, J NEUROSURG, V102, P195, DOI	2005	39.2058	2006	2010	
Combs SE, 2005, INT J RADIAT ONCOL, V63, P75, DOI	2005	16.8697	2007	2010	
Hasegawa T, 2005, NEUROSURGERY, V57, P257, DOI	2005	20.632	2007	2010	
Pollock BE, 2006, NEUROSURGERY, V59, P77, DOI	2006	19.9861	2008	2011	
Samii M, 2006, J NEUROSURG, V105, P527, DOI	2006	29.7209	2008	2011	
Chopra R, 2007, INT J RADIAT ONCOL, V68, P845, DOI	2007	30.947	2008	2012	
Stangerup SE, 2006, OTOL NEUROTOL, V27, P547, DOI	2006	23.2115	2008	2011	
Samii M, 2010, J NEUROSURG, V112, P860, DOI	2010	14.8801	2011	2014	
Nikolopoulos TP, 2010, OTOL NEUROTOL, V31, P478, DOI	2010	11.9187	2012	2015	
Hasegawa T, 2011, J NEUROSURG, V115, P1078, DOI	2011	8.3459	2013	2016	
Arthurs BJ, 2011, NEUROSURG REV, V34, P265, DOI	2011	11.5098	2013	2016	
Hasegawa T, 2013, J NEUROSURG, V118, P557, DOI	2013	22.2675	2014	2018	
Stangerup SE, 2012, OTOLARYNG CLIN N AM, V45, P257, DOI	2012	17.105	2014	2017	
Carlson ML, 2013, J NEUROSURG, V118, P579, DOI	2013	14.7083	2015	2018	
Carlson ML, 2015, OTOLARYNG CLIN N AM, V48, P407, DOI	2015	7.7013	2016	2021	

Figure 6. A. Trends in topics are mapped by occurrences of terminology; B. Thematic graphic of occurrences of keywords; C. The top-20 cited references with the largest citation bursts.

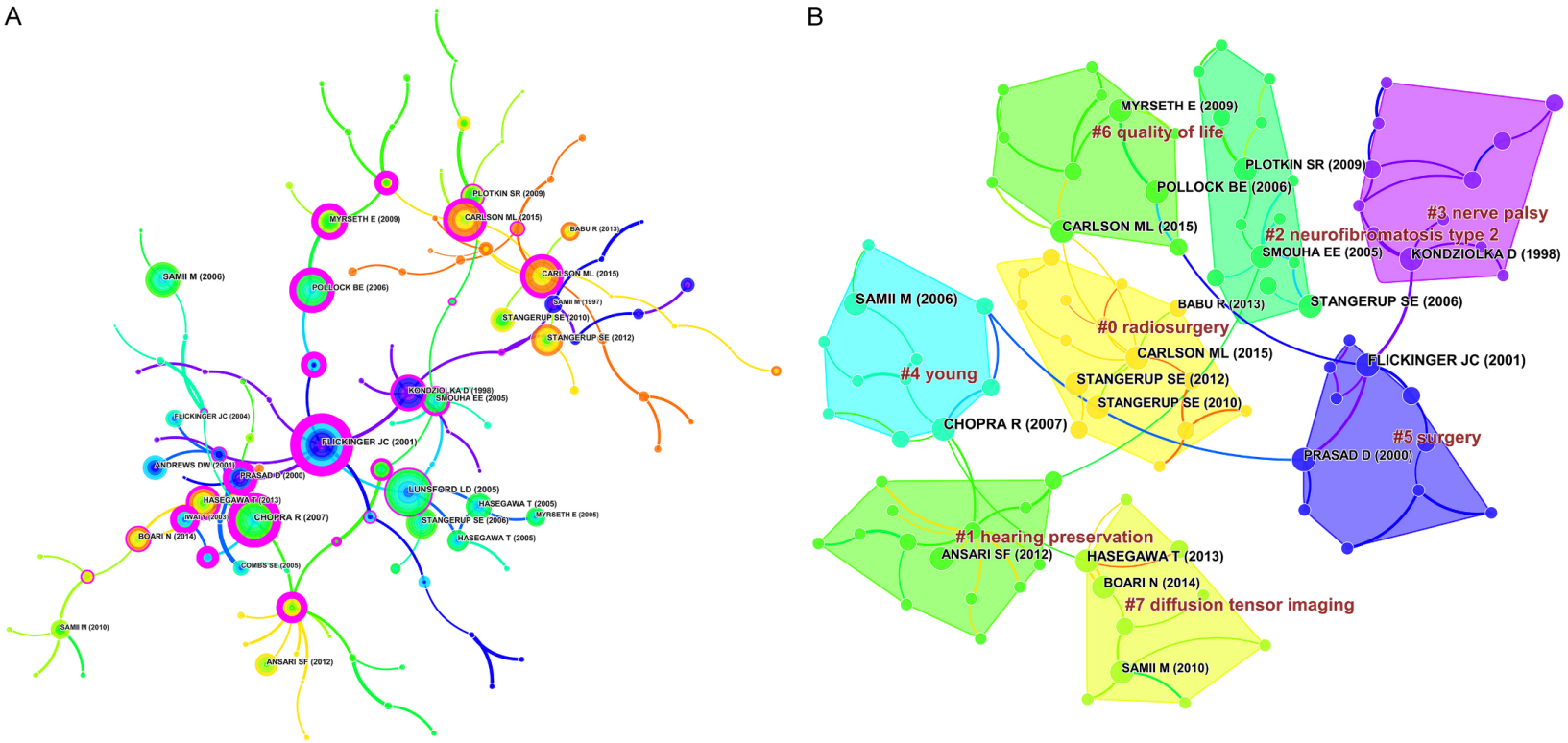


Figure 7. A. A network visualization map of co-cited references; B. A cluster of co-cited references related to vestibular schwannoma.

Table 4. Top 10 most co-cited research articles on vestibular schwannoma

Rank	Title	Journal	First Author	Year	Citations
1	Clinical Practice Guideline: Sudden Hearing Loss	Otolaryngology-Head and Neck Surgery	Stachler, RJ	2012	654
2	A simple dose gradient measurement tool to complement the conformity index	Journal of Neurosurgery	Paddick, I	2006	356
3	Radiosurgery of vestibular schwannomas: summary of experience in 829 cases	Journal of Neurosurgery	Lunsford, LD	2005	307
4	Patient outcomes after vestibular schwannoma management: a prospective comparison of microsurgical resection and stereotactic radiosurgery	Neurosurgery	Pollock, BE	2006	301
5	Hearing Improvement after Bevacizumab in Patients with Neurofibromatosis Type 2	New England Journal of Medicine	Plotkin, SR	2009	294
6	Improved preservation of hearing and facial nerve function in vestibular schwannoma surgery via the retrosigmoid approach in a series of 200 patients	Journal of Neurosurgery	Samii, M	2006	277
7	The natural history of vestibular schwannoma	Otology & Neurotology	Stangerup, SE	2006	276
8	New and modified reporting systems from the consensus meeting on systems for reporting results in vestibular schwannoma	Otology & Neurotology	Kanzaki, J	2003	251
9	Diagnostic criteria for schwannomatosis	Neurology	MacCollin, M	2005	238
10	Incidence of vestibular schwannoma and neurofibromatosis 2 in the North West of England over a 10-year period: higher incidence than previously thought	Otology & Neurotology	Evans, DGR	2005	223

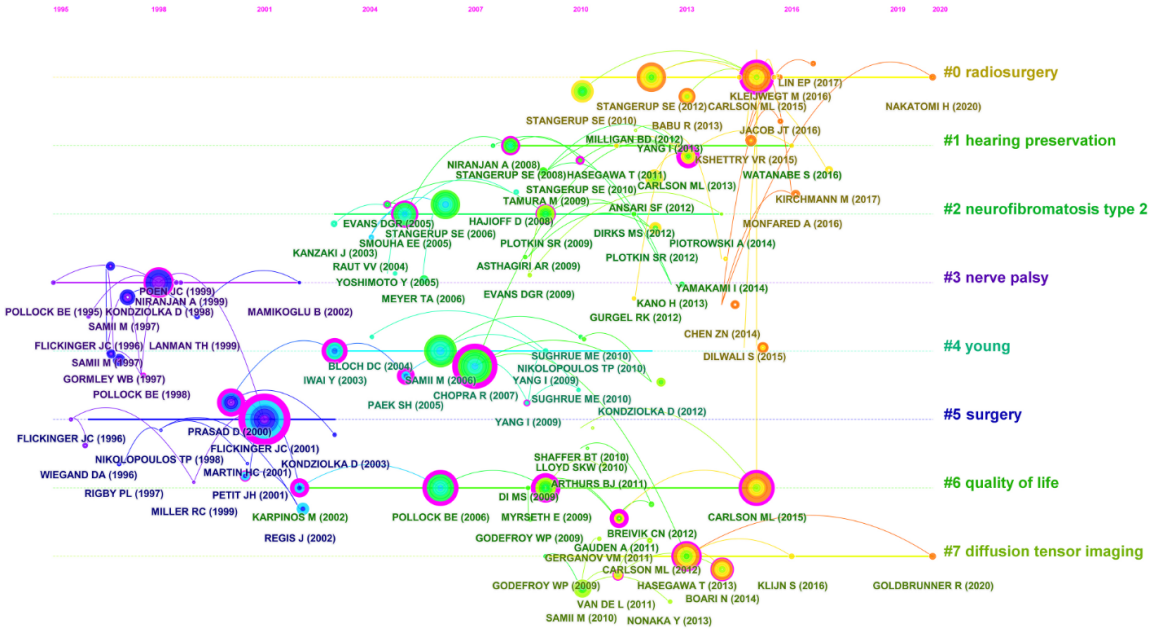
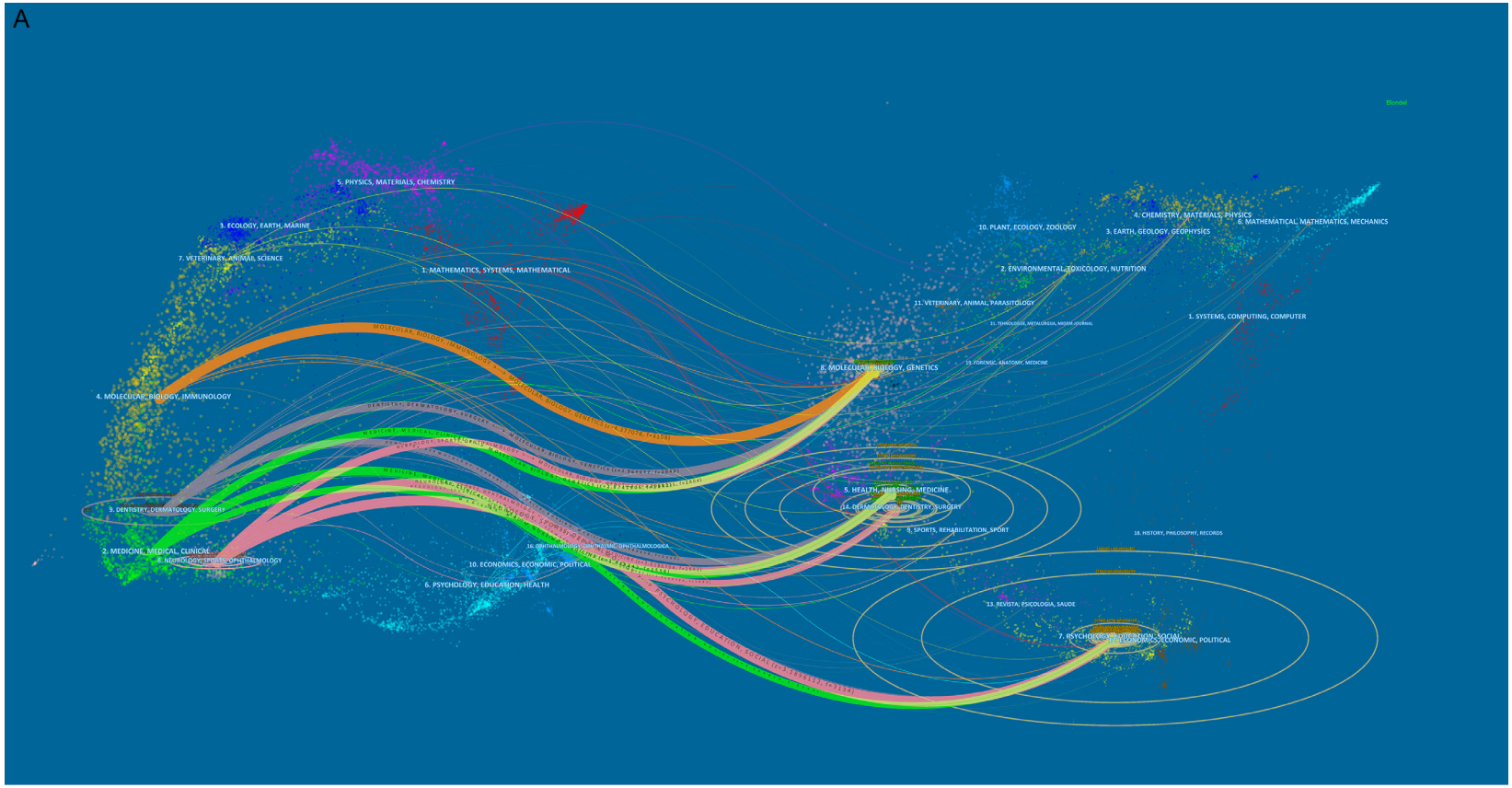


Figure 8. A timeline view of co-cited references with corresponding tags.

aging interdisciplinary cooperation to produce high quality articles.

The analysis of the keyword bursts and the distribution of keyword co-occurrences are important research foci of this field. Asymmetric hearing loss is one of the most common symptoms of vestibular schwannoma, accounting for approximately 51-88% of all symptomatic presentations, with sudden deafness as the first symptom in approximately 8-18% of cases [34]. The exact mechanism of sudden hearing loss due to auditory neuroma is unclear. Most scholars suggest that it is related to compression of the internal auditory artery and the cochlear nerve by vestibular schwannoma [35]. It is speculated that the sudden hearing loss associated with auditory neuroma may be due to acute ischemia, obstruction of venous return caused by the tumor's compression of vessels in the inner ear, direct compression of the cochlear nerve with edema and degeneration, or a combination of both factors leading to inner ear hair cell dysfunction. A relationship between auditory neuroma and the degree of hearing loss has been reported, but the results are inconsistent. Some scholars have suggested there is no correlation between the size of an auditory neuroma and the degree of hearing loss, whereas others have suggested that small tumors are more likely to cause sudden deafness than medium or large tumors, and that hearing loss is more severe with a relatively poor prognosis [36, 37]. A study found that long-term hearing stability ranged from 41% to 57% among patients with untreated vestibular schwannomas and conservative management [38]. Hearing preservation rates 3 and 10 years after radiation therapy have been found to be approximately 74% and 44.5%, respectively [39, 40]. Paek et al. [41] conducted an 8-year follow-up study that showed a 46% rate of serviceable hearing preservation 5 years after radiosurgery treatment. Another study showed that the rate of hearing persistence of patients with vestibular schwannoma more than 5 years after surgery was 70% [38]. These studies indicate that some patients with vestibular schwannoma have effective hearing preservation after surgical intervention.

The timeline view of the cited references in this study shows that radiosurgery is a frontier topic in this field. Within the last few decades, the treatment of auditory neuroma has undergone tremendous developmental advances. These major shifts from preserving life and reducing lethality to preserving facial nerve function and hearing and to performing auditory function reconstruction, illustrate the advances in the knowledge of this disease and the treatment and rehabilitation tools in modern medicine.


A
5. PHYSICS, MATERIALS, CHEMISTRY
3. ECOLOGY, EARTH, MARINE
7. VETERINARY, ANIMAL, SCIENCE
1. MATHEMATICS, SYSTEMS, MATHEMATICAL
4. MOLECULAR, BIOLOGY, IMMUNOLOGY
9. DENTISTRY, DERMATOLOGY, SURGERY
2. MEDICINE, MEDICAL, CLINICAL
8. NEUROLOGY, PSYCHIATRY, OPHTHALMOLOGY
10. ECONOMICS, ECONOMIC, POLITICAL
6. PSYCHOLOGY, EDUCATION, HEALTH
10. PLANT, ECOLOGY, ZOOLOGY
4. CHEMISTRY, MATERIALS, PHYSICS
5. MATHEMATICAL, MATHEMATICS, MECHANICS
3. EARTH, GEOLOGY, GEOPHYSICS
2. ENVIRONMENTAL, TOXICOLOGY, NUTRITION
11. VETERINARY, ANIMAL, PARASITOLOGY
1. SYSTEMS, COMPUTING, COMPUTER
8. MOLECULAR, BIOLOGY, GENETICS
5. HEALTH, NURSING, MEDICINE
14. DERMATOLOGY, DENTISTRY, SURGERY
9. SPORTS, REHABILITATION, SPORT
18. HISTORY, PHILOSOPHY, RECORDS
13. REVISTA, PSICOLOGIA, SAUDE
7. PSYCHOLOGY, EDUCATION, SOCIAL
10. ECONOMICS, ECONOMIC, POLITICAL

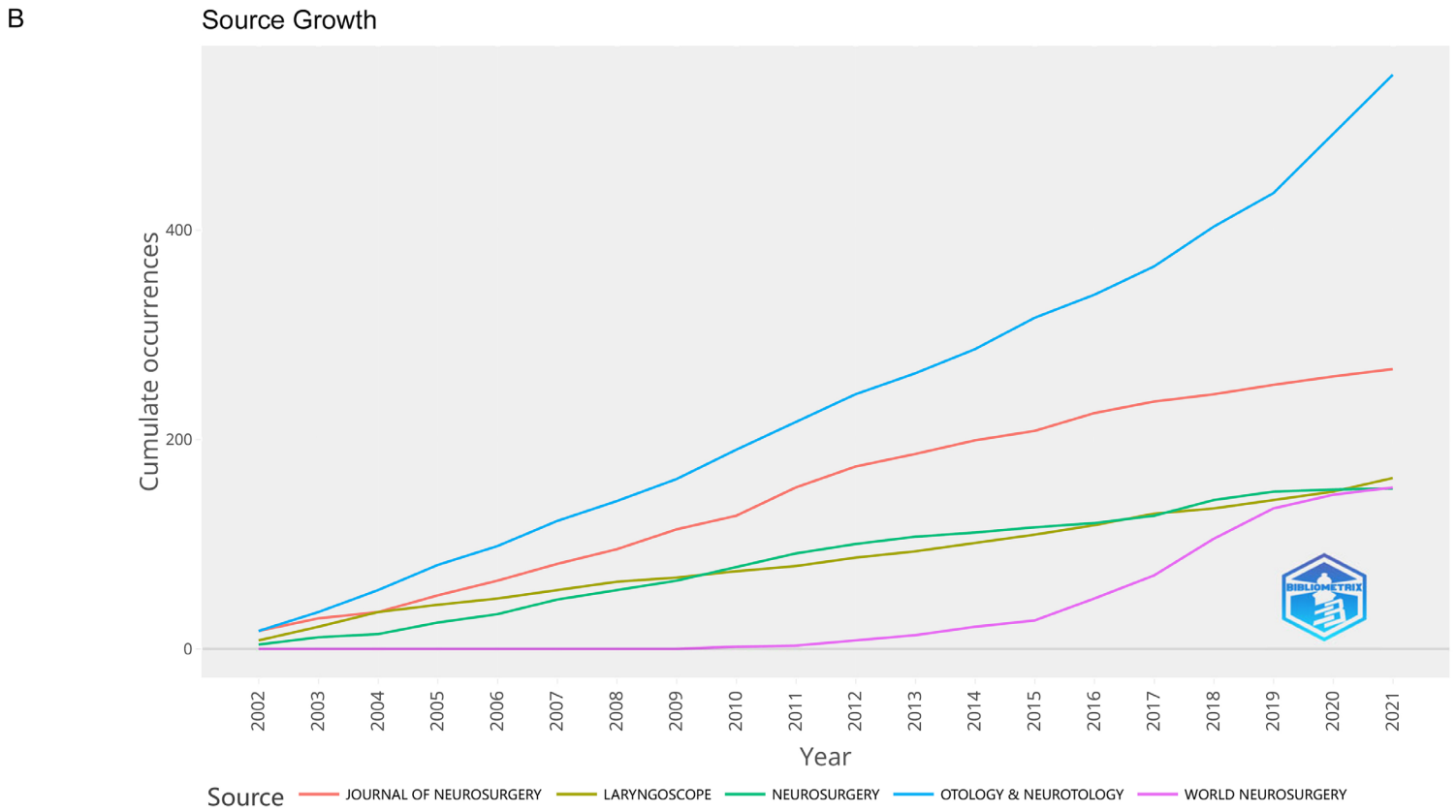


Figure 9. A. The dual-map overlay of journals publishing and citing research on vestibular schwannoma; B. Cumulative trends in the number of publications of the top-5 most productive journals from 2002 to 2021.

Table 5. Top 10 most productive journals in the field of vestibular schwannoma

Rank	Journal	Count	Country	Journal citation reports (2021)	Impact factor (2021)	Total number of citations	Mean number of citations	H-index
1	Otology & Neurotology	548	USA	Q3	2.619	11,217	20.47	52
2	Journal of Neurosurgery	267	USA	Q1	5.408	10,404	38.97	55
3	Laryngoscope	169	USA	Q3	2.970	4,245	25.12	36
4	World Neurosurgery	156	USA	Q4	2.210	1,494	9.580	20
5	Neurosurgery	153	USA	Q1	5.315	6203	40.54	45
6	Journal of Neurological Surgery Part B-Skull Base	111	USA	Q4	1.407	702	6.320	14
7	Otolaryngology-Head And Neck Surgery	111	USA	Q1	5.591	3,133	28.23	32
8	Acta Neurochirurgica	105	Austria	Q3	2.816	1,379	13.13	22
9	European Archives of Oto-Rhino-Laryngology	97	Germany	Q2	3.236	1,161	11.97	20
10	Acta Oto-Laryngologica	94	Norway	Q4	1.698	1,461	15.54	23

The treatment of vestibular schwannoma requires individualized strategies based on multiple factors, such as the location, size, and growth rate of the tumor and the age and hearing status of the patient. Most researchers now emphasize that small auditory neuromas require follow-up observation [42]. Surgical treatment, such as stereotactic radiosurgery (SRS) and combined microscopic and endoscopic surgery can be used to treat fast-growing or large tumors. With an accumulation of long-term clinical practice and a large amount of clinical data, the efficacy and safety of SRS in the treatment of vestibular schwannoma has been widely recognized. It has become an effective treatment for this disease, showing a high tumor control rate and fewer side effects [43, 44]. Considering patient comfort, quality of life, treatment costs, and potential procedural complications (bleeding, cerebrospinal fluid leakage, meningitis, hearing, and nervous system injury), SRS has shown a significant advantage as an alternative to surgical treatment [45]. Treatment with SRS is more suitable for patients who do not want to undergo surgical treatment, are elderly, or are physically unable to tolerate general anesthesia. There is no standardized system for the diagnosis or prognostic evaluation of vestibular schwannoma. Therefore, the length of follow-up reported in retrospective studies is insufficient for a complete and adequate assessment of the efficacy of SRS in the treatment of vestibular schwannoma, and criteria for the length of follow-up vary widely among studies. For the treatment of vestibular schwannoma, future efforts should focus on strengthening international cooperation, promoting the development of uniform standards, standardizing follow-up data collection, and designing prospective studies to more accurately evaluate SRS technology in the treatment of vestibular schwannoma.

Limitations

This study has some limitations. First, considering that WoSCC is the most frequently used database for bibliometric analysis, we did not search other databases, which might have led to overlooking some of the research literature. Second, we included only English language publications; non-English articles were ignored, which may have led to some bias. Last, new high-impact publications might not have been included in the scope of our analysis because of their low citation rate. Despite these limitations, we believe our findings provide a comprehensive overview of vestibular schwannoma research, which may offer guidance and a clearer perspective of the current research on vestibular schwannoma.

Conclusion

Our findings indicate that vestibular schwannoma is of interest to academics, as evidenced by the increasing number of articles each year. Cooperation between countries, institutions, and teams is insufficient and needs to be strengthened to facilitate the progress of research in this field. Hearing conservation has been the focus of research for the last few years. The application of radiosurgery, especially SRS in the treatment of vestibular schwannoma, has become a research hotspot and deserves closer attention. In conclusion, researchers, especially those new to the field, can profit from our study. Our results will enhance their understanding of the current hot spots and research frontiers of vestibular schwannomas.

Acknowledgements

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Disclosure of conflict of interest

None.

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References

[1] Chandrasekhar SS, Tsai Do BS, Schwartz SR, Bontempo LJ, Faucett EA, Finestone SA, Hollingsworth DB, Kelley DM, Kmucha ST, Moonis G, Poling GL, Roberts JK, Stachler RJ, Zeitler DM, Corrigan MD, Nnacheta LC and Satterfield L. Clinical practice guideline: sudden hearing loss (update). Otolaryngol Head Neck Surg 2019; 161: S1-S45.

[2] Yang W, Mei X, Li X, Zhou Y, Zhong J, Liu H, Li L and Hu H. The prevalence and clinical characteristics of vestibular schwannoma among patients treated as sudden sensorineural hearing loss: a 10-year retrospective study in southern China. Am J Otolaryngol 2020; 41: 102452.
[3] Park CE, Park BJ, Lim YJ and Yeo SG. Functional outcomes in retrosigmoid approach microsurgery and gamma knife stereotactic radiosurgery in vestibular schwannoma. Eur Arch Otorhinolaryngol 2011; 268: 955-959.
[4] Tos M, Stangerup SE, Cayé-Thomasen P, Tos T and Thomsen J. What is the real incidence of vestibular schwannoma? Arch Otolaryngol Head Neck Surg 2004; 130: 216-220.
[5] Sauvaget E, Kici S, Kania R, Herman P and Tran Ba Huy P. Sudden sensorineural hearing loss as a revealing symptom of vestibular schwannoma. Acta Otolaryngol 2005; 125: 592-595.
[6] Sweeney AD, Carlson ML, Shepard NT, McCracken DJ, Vivas EX, Neff BA and Olson JJ. Congress of neurological surgeons systematic review and evidence-based guidelines on otologic and audiologic screening for patients with vestibular schwannomas. Neurosurgery 2018; 82: E29-E31.
[7] Stachler RJ, Chandrasekhar SS, Archer SM, Rosenfeld RM, Schwartz SR, Barrs DM, Brown SR, Fife TD, Ford P, Ganiats TG, Hollingsworth DB, Lewandowski CA, Montano JJ, Saunders JE, Tucci DL, Valente M, Warren BE, Yaremchuk KL and Robertson PJ; American Academy of Otolaryngology-Head and Neck Surgery. Clinical practice guideline: sudden hearing loss. Otolaryngol Head Neck Surg 2012; 146 Suppl: S1-35.
[8] Glasziou P, Moynihan R, Richards T and Godlee F. Too much medicine; too little care. BMJ 2013; 347: f4247.
[9] Chen C, Dubin R and Kim MC. Emerging trends and new developments in regenerative medicine: a scientometric update (2000-2014). Expert Opin Biol Ther 2014; 14: 1295-1317.
[10] Du YH, Yang RY, Wang Q, Wang LY, Liang LC, Zhu L, Sun Y and Cai M. Bibliometric analysis study on the mechanisms of brain energy metabolism disorders in Alzheimer's disease from 2000 to 2020. Front Neurol 2021; 12: 670220.
[11] Zhang J, Chen P and Miao L. A bibliometric and scientific knowledge-map study of the chimeric antigen receptor (CAR) natural killer (NK) cell-related research from 2010 to 2022. Front Immunol 2022; 13: 969196.
[12] Chen P, Zhong C, Jin S, Zhang Y, Li Y, Xia Q, Cheng J, Fan X and Lin H. Global trends in research of lipid metabolism in T lymphocytes from 1985 to 2022: a bibliometric analysis. Front Immunol 2022; 13: 884030.
[13] Ma L, Ma J, Teng M and Li Y. Visual analysis of colorectal cancer immunotherapy: a bibliometric analysis from 2012 to 2021. Front Immunol 2022; 13: 843106.
[14] Zhou F, Zhang T, Jin Y, Ma Y, Xian Z, Zeng M and Yu G. Worldwide tinnitus research: a bibliometric analysis of the published literature between 2001 and 2020. Front Neurol 2022; 13: 828299.
[15] Kostrzewski M and Melnik R. Condition monitoring of rail transport systems: a bibliometric performance analysis and systematic literature review. Sensors (Basel) 2021; 21: 4710.
[16] Liu J, Liu S, Shi Q and Wang M. Bibliometric analysis of nursing informatics research. Stud Health Technol Inform 2021; 284: 47-49.
[17] Nobanee H. A bibliometric review of big data in finance. Big Data 2021; 9: 73-78.
[18] Zhou F, Zhang T, Jin Y, Ma Y, Xian Z, Zeng M and Yu G. Developments and emerging trends in the global treatment of chronic rhinosinusitis from 2001 to 2020: a systematic bibliometric analysis. Front Surg 2022; 9: 851923.
[19] Hou Y and Wang Q. A bibliometric study about energy, environment, and climate change. Environ Sci Pollut Res Int 2021; 28: 34187-34199.
[20] Shi Y, Luo J, Wang X, Zhang Y, Zhu H, Su D, Yu W and Tian J. Emerging trends on the correlation between neurotransmitters and tumor progression in the last 20 years: a bibliometric analysis *via* citespace. Front Oncol 2022; 12: 800499.
[21] Ding H, Wu C, Liao N, Zhan Q, Sun W, Huang Y, Jiang Z and Li Y. Radiomics in oncology: a 10-year bibliometric analysis. Front Oncol 2021; 11: 689802.
[22] Ioannidis JPA, Baas J, Klavans R and Boyack KW. A standardized citation metrics author database annotated for scientific field. PLoS Biol 2019; 17: e3000384.
[23] Shen Z, Wu H, Chen Z, Hu J, Pan J, Kong J and Lin T. The global research of artificial intelligence on prostate cancer: a 22-year bibliometric analysis. Front Oncol 2022; 12: 843735.
[24] Ma L, Ma J, Teng M and Li Y. Visual analysis of colorectal cancer immunotherapy: a bibliometric analysis from 2012 to 2021. Front Immunol 2022; 13: 843106.
[25] Hao KJ, Jia X, Dai WT, Huo ZM, Zhang HQ, Liu JW and Wang XB. Mapping intellectual structures and research hotspots of triple negative breast cancer: a bibliometric analysis. Front Oncol 2022; 11: 689553.
[26] Carlson ML, Link MJ, Wanna GB and Driscoll CL. Management of sporadic vestibular schwannoma. Otolaryngol Clin North Am 2015; 48: 407-422.

[27] Lin EP and Crane BT. The management and imaging of vestibular schwannomas. AJNR Am J Neuroradiol 2017; 38: 2034-2043.
[28] Ramaswamy AT and Golub JS. Management of vestibular schwannomas for the radiologist. Neuroimaging Clin N Am 2019; 29: 173-182.
[29] Pellet W. History of vestibular schwannoma surgery. Prog Neurol Surg 2008; 21: 6-23.
[30] Wu H, Cheng K, Guo Q, Yang W, Tong L, Wang Y and Sun Z. Mapping knowledge structure and themes trends of osteoporosis in rheumatoid arthritis: a bibliometric analysis. Front Med (Lausanne) 2021; 8: 787228.
[31] Sun HL, Bai W, Li XH, Huang H, Cui XL, Cheung T, Su ZH, Yuan Z, Ng CH and Xiang YT. Schizophrenia and inflammation research: a bibliometric analysis. Front Immunol 2022; 13: 907851.
[32] Zhao Y, Zhang X, Song Z, Wei D, Wang H, Chen W, Sun G, Ma W and Chen K. Bibliometric analysis of ATAC-Seq and its use in cancer biology via nucleic acid detection. Front Med (Lausanne) 2020; 7: 584728.
[33] Ma C, Su H and Li H. Global research trends on prostate diseases and erectile dysfunction: a bibliometric and visualized study. Front Oncol 2021; 10: 627891
[34] Marinelli JP, Lohse CM and Carlson ML. Incidence of vestibular schwannoma over the past half-century: a population-based study of Olmsted County, Minnesota. Otolaryngol Head Neck Surg 2018; 159: 717-723.
[35] Goldbrunner R, Weller M, Regis J, Lund-Johansen M, Stavrinou P, Reuss D, Evans DG, Lefranc F, Sallabanda K, Falini A, Axon P, Sterkers O, Fariselli L, Wick W and Tonn JC. EANO guideline on the diagnosis and treatment of vestibular schwannoma. Neuro Oncol 2020; 22: 31-45.
[36] del Río L, Lassaletta L, Alfonso C, Sarriá MJ and Gavilán J. Clinical tumoral size dissociation in acoustic neuroma: reality or measure distortion? Acta Otorrinolaringol Esp 2006; 57: 345-349.
[37] Yanagihara N and Asai M. Sudden hearing loss induced by acoustic neuroma: significance of small tumors. Laryngoscope 1993; 103: 308-311.
[38] Ahsan SF, Huq F, Seidman M and Taylor A. Long-term hearing preservation after resection of vestibular schwannoma: a systematic review and meta-analysis. Otol Neurotol 2017; 38: 1505-1511.
[39] Stangerup SE, Thomsen J, Tos M and Cayé-Thomasen P. Long-term hearing preservation in vestibular schwannoma. Otol Neurotol 2010; 31: 271-275.
[40] Godefroy WP, Kaptein AA, Vogel JJ and van der Mey AG. Conservative treatment of vestibular schwannoma: a follow-up study on clinical and quality-of-life outcome. Otol Neurotol 2009; 30: 968-974.
[41] El-Shehaby AMN, Reda WA, Abdel Karim KM, Nabeel AM, Emad Eldin RM and Tawadros SR. Hearing preservation after Gamma Knife radiosurgery for cerebellopontine angle meningiomas. J Neurosurg 2018; 129: 38-46.
[42] Kirchmann M, Karnov K, Hansen S, Dethloff T, Stangerup SE and Caye-Thomasen P. Ten-year follow-up on tumor growth and hearing in patients observed with an intracanalicular vestibular schwannoma. Neurosurgery 2017; 80: 49-56.
[43] Braunstein S and Ma L. Stereotactic radiosurgery for vestibular schwannomas. Cancer Manag Res 2018; 10: 3733-3740.
[44] Rykaczewski B and Zabek M. A meta-analysis of treatment of vestibular schwannoma using Gamma Knife radiosurgery. Contemp Oncol (Pozn) 2014; 18: 60-66.
[45] Persson O, Bartek J Jr, Shalom NB, Wangerid T, Jakola AS and Förander P. Stereotactic radiosurgery vs. fractionated radiotherapy for tumor control in vestibular schwannoma patients: a systematic review. Acta Neurochir (Wien) 2017; 159: 1013-1021.