Observational Study

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Looking backward toward the future

A bibliometric analysis of the last 40 years of meningioma global outcomes

Serdal Kenan Köse, PhD[a,*], Gülçin Aydoğdu, PhD[b], Emre Demir, PhD[b], Murat Kiraz, MD[c]

Abstract

This study is the first comprehensive bibliometric analysis about meningioma to date. The aim of this study is to identify the most influential publications in this field through citation and co-citation analysis, to examine international collaborations, to identify the conceptual framework of the subject and emerging trending topics through keyword analysis, and to identify the most productive countries, authors and journals. 9619 articles on meningioma published between 1980 and 2023 were downloaded from the Web of Science (WoS) database and statistically analyzed. In this study, various bibliometric techniques were utilized, including trend keyword analysis, thematic evolution analysis, factor analysis, conceptual structure analysis, citation and co-citation analyses. Bibliometric network visualization maps were created to identify trend topics, citation analysis and cross-country collaborations. The Exponential Smoothing estimator was used to predict article productivity in the coming years. The first 3 countries that contributed the most to the literature were respectively; USA (2664, 27.7%), Japan (972, 10.1%), Germany (943, 9.8%). The first three most productive journals were respectively; Journal of Neurosurgery (number of article = 496), World Neurosurgery (399), Acta Neurochirurgica (378). The most productive author was Mcdermott MW (number of article = 88) and the most active institution was the University of California System (number of article = 470). In addition to high-grade meningiomas, the most studied topics from past to present have been magnetic resonance imaging, recurrence, radiation therapy, and skull base. As a result of the analyses to determine trend topics, the subjects studied in recent years were diagnostic and imaging methods, surgical and treatment methods, prognosis and survival, epidemiology and quality of life, and with the advancement of technology, machine learning and prediction models. Scientific collaboration was seen primarily in articles from western countries, especially the USA, European countries, and Canada. However, there was also a not insignificant effect in developing countries such as China, India, and Turkey.

Abbreviations: CI = confidence interval, CNS = central nervous system, N = number of article, USA = United States of America, WoS = Web of Science.

Keywords: bibliometric analysis, brain tumor, meningioma, skull base meningioma

1. Introduction

Meningiomas are the most common primary central nervous system (CNS) tumors. As reported by histology, meningiomas comprise 37.6% of all primary CNS tumors and 53.3% of all benign CNS tumors.[1] In addition to being widespread, meningioma is also a very special tumor for brain surgeons. It shows that there can be complete recovery after removal of an intercranial tumor and is historically important in respect of the development of brain surgery techniques.[2] For centuries this interesting tumor has been a subject of research in the fields of surgery, anatomy, and pathology because of its characteristic appearance and ability to reach an extremely large size. The tendency to produce characteristic hyperostosis has been clearly revealed in skulls which can be traced back to prehistoric times. The importance of Harvey Cushing in meningioma is well known, as in 1922 to prevent confusion over several names he recommended the use of the currently used term "meningioma" taking the tissue origin of the tumor into consideration.[3,4] Since that time there has been a rapid increase in the literature related to the term meningioma. With each passing year there is an increase in both the number of scientists researching meningioma and the number of articles which are required reading for brain surgeons who frequently encounter meningioma in daily practice.

For this type of study formal consent is not required.

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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

[a] Department of Biostatistics, Ankara University, Faculty of Medicine, Ankara, Turkey, [b] Department of Biostatistics, Hitit University, Faculty of Medicine, Çorum, Turkey, [c] Department of Neurosurgery, Yüksek İhtisas University, Faculty of Medicine, Ankara, Turkey.

* Correspondence: Serdal Kenan Köse, Department of Biostatistics, Ankara University, Faculty of Medicine, Ankara 06230, Turkey (e-mail: skkose@gmail.com).

How to cite this article: Köse SK, Aydoğdu G, Demir E, Kiraz M. Looking backward toward the future: A bibliometric analysis of the last 40 years of meningioma global outcomes. Medicine 2024;103:32(e39241).

Received: 22 April 2024 / Received in final form: 18 July 2024 / Accepted: 19 July 2024

http://dx.doi.org/10.1097/MD.0000000000039241

In recent years, bibliometric analyses used for the quantitative and qualitative evaluation of scientific literature have proven to be highly beneficial for the advancement of science. The need for bibliometric analyses is increasing parallelly with the rising number of publications.[5,6] Bibliometrics involves the statistical analysis of scientific publications such as articles. Bibliometric analyses are research methods that examine scientific publications using numerical data, evaluating relationships among authors, publication trends, citation patterns, frequency of keyword usage, and the impact of scientific publications in specific fields.[7] These analyses are used to track the evolution of scientific discoveries, understand developments in specific areas, identify research trends, and comprehend changes in scientific communication.[8] Citation analyses assess the extent to which a paper is referenced by other studies, while keyword analyses examine the frequency of specific terms and terminological developments.[7,8] Factor analyses, on the other hand, are statistical methods used to uncover hidden relationships and patterns within multivariate datasets.[9] These analyses play a crucial role in determining research strategies, identifying gaps in the literature, and providing guidance for future studies.[6,8] Bibliometric studies offer researchers time savings compared to literature reviews by summarizing the literature and highlighting current trends, thereby presenting new ideas to researchers.[7]

In bibliometric analyses, predicting future publication counts can be utilized to evaluate the academic performance of a research group or a scientist. Additionally, forecasting future publication counts can assist in managing research projects from financial and timing perspectives. Therefore, accurately predicting future publication counts can contribute to the effective management of research strategies and resources.[5–7]

Bibliometric analyses play a significant role in understanding the scientific literature, monitoring the progress of a field, and identifying best practices in the field of medical science. They can help understand trends in medical research, such as which diseases or treatments receive more attention or which areas are developing more (Monitoring Scientific Developments). By indicating which treatment methods or approaches are under more extensive investigation and identifying areas with greater research gaps, bibliometric analyses can guide medical research (Guidance in Disease and Treatment Fields). Bibliometric analyses can be employed to determine which treatment methods or disease management strategies are more evidence-based (Identification of Best Practices). They can also help identify which researchers have more influence in specific medical areas or which fields they specialize in (Identification of Specialization Areas).[5–8]

The aim of this study is to scan original articles published since 1980 using bibliometric methods, and to identify the most impactful publications in this field through citation and co-citation analyses. It also aims to outline the conceptual framework of the subject through keyword analyses, identify emerging trend topics, assess the most influential journals, countries, and authors in terms of global productivity, and investigate international collaborations.

2. Methods

2.1. Research strategy

The screening of literature was conducted using the Web of Science Core Collection (WoS by Clarivate Analytics) database. The search period was defined as 1980–2023. Initially, all studies containing the word meningioma were accessed (access date: June 19, 2024). In our search strategy, we used "*meningioma**." By using the * symbol during the search, we included all studies with titles encompassing "*meningioma*" (such as: "*meningioma*," "*meningiomas*," "*meningiomatosis*," "*meningiomatous*," and "*meningiomal*"). To be able to reach similar studies (results can show a small amount of difference according to different access dates), the screening codes used by the researchers were: (Title: meningioma* and Exclude: Veterinary Sciences and Zoology (Timespan = (1980–2023))).

2.2. Statistical analysis

In this study, various bibliometric techniques were utilized, including trend keyword analysis, thematic evolution analysis, factor analysis, conceptual structure analysis, citation and co-citation analyses. Bibliometric analyses were performed using the biblioshiny interface within the bibliometrix library (http://www.bibliometrix.org/), an R Studio tool for science mapping, and VOSviewer (Version 1.6.18; Leiden University's Centre for Science and Technology Studies, Leiden, the Netherlands), an open-access bibliometric software.[9,10] Both the Bibliometrix and VOSviewer software packages are widely used in academic literature to visualize and construct bibliometric networks, each offering unique advantages compared to the other.

Detailed Application Steps for the Analyses: Firstly, data was downloaded from the Web of Science Core Collection (WoSCC) in plain text format. This data included information such as authors, titles, abstracts, keywords, publication dates, and citation counts, which are essential for bibliometric analyses. Then, the Bibliometrix library was loaded in R Studio, and the biblioshiny interface was launched. The downloaded data was uploaded into the interface. Once the data was loaded, various analyses were performed using appropriate commands, including trend keyword analysis to determine the frequency of keyword usage over time and identify trending topics, thematic evolution analysis to examine the evolution of specific themes over time, factor analysis to explore relationships among bibliometric data through principal component analysis, conceptual structure analysis to reveal the conceptual relationships and network structure among scientific publications, citation analysis to identify the most influential publications and authors based on the number of citations received, and co-citation analysis to analyze works that are frequently cited together to determine the structure and relationships within scientific communities.

Additionally, the downloaded plain text file was uploaded to VOSviewer, where bibliometric analyses were conducted. A keyword burst analysis visualization map was created using the VOSviewer software. The keyword burst analysis visualization map was created using VOSviewer software. In the keyword burst analysis visualization map, the keywords highlighted in red represent topics that have gained attention, become popular, and rapidly increased in recent literature or the analyzed articles. These keywords may signify current trends or emerging subjects in the relevant field. Keywords shown in green and yellow, while still important, have not experienced as rapid an increase as those in red. Keywords highlighted in blue are less frequently used or were popular in earlier periods. Keywords displayed in larger font sizes are more frequently used or deemed more significant in the analyzed articles, often representing focal points or main themes of the study. The color proximity of a keyword to red indicates its level of association with other keywords and the strength of these associations. This signifies the keyword's significant relationships with other keywords and its importance in the field. Hot zones in specific areas of the map, characterized by dense clusters of neighboring keywords with high weights, highlight the main themes and focal points within this field.[8]

Statistical analyses were performed using SPSS version 22.0 software (IBM Corporation, Chicago). Conformity of the data to normal distribution was assessed with the Kolmogorov–Smirnov test. After examination of the number of articles in previous years, Exponential Smoothing (taking seasonal correction into account) was used in the Microsoft Office Excel program to predict the number of articles which may be published in the

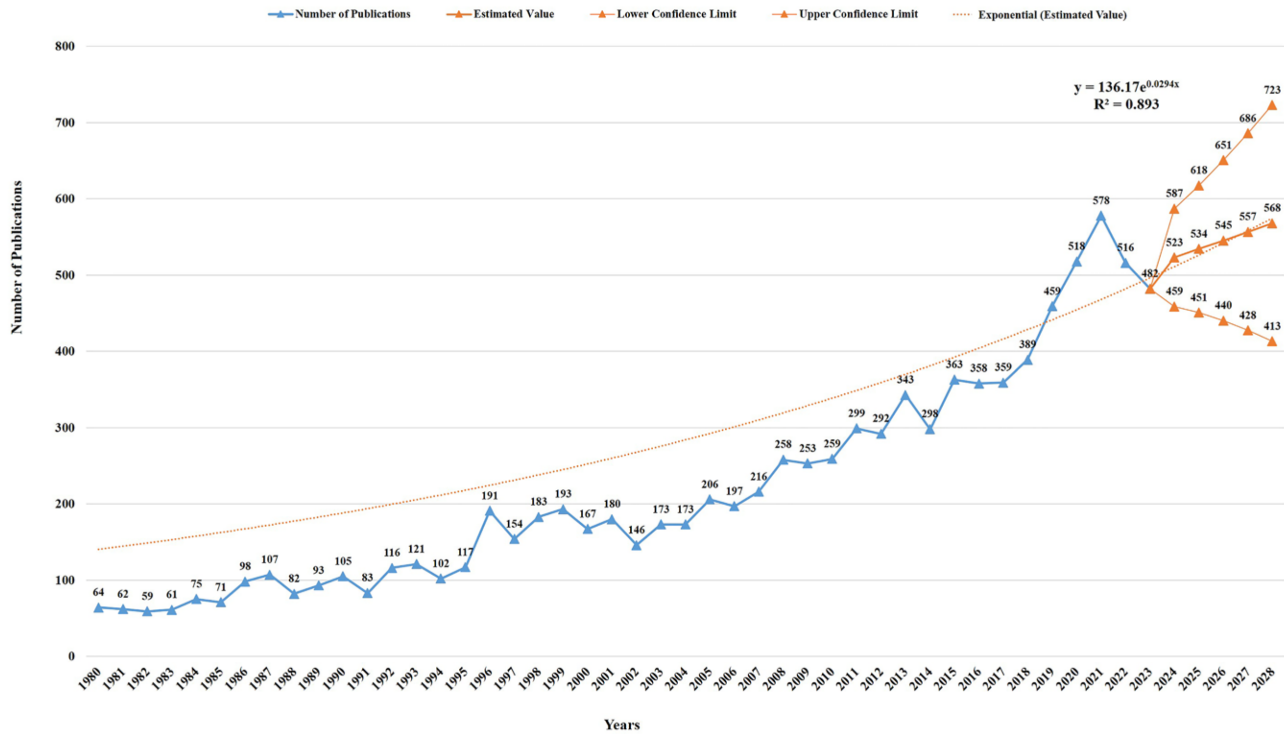

Figure 1. A line chart showing the distribution per year of the number of articles on the subject of meningioma and the number of articles expected to be published in the next 5 years.

future. A value of $P < .05$ was accepted as the level of statistical significance.

This article does not include any studies with human participants or animals by any of the authors. Therefore, ethics committee approval is not required.

3. Results

As a result of the literature scan, a total of 16,447 publications indexed in the WoS database were found to have been published on the subject of meningioma between 1980 and 2023. After the exclusion of 253 publications in the field of Veterinary Sciences and Zoology, a total of 16,194 publications were obtained (16,447–253 = 16,194), of which 9619 were categorized as article. Distribution of 16,194 publications on meningioma; Article (9619, 59.4%), Meeting Abstracts (2806, 17.3%), Editorial Materials (1373, 8.5%), Review Articles (1035, 6.4%), Letters (800, 4.9%), Proceedings Papers (428, 2.6%), and the rest were in other publication types (Note, Correction, Book Chapters, Early Access, News Item, Retracted Publication, Retraction, Correction, Addition, Discussion, Book, Reprint, Biographical-Item, Book Review, Data Paper). Bibliometric analyzes were carried out with 9619 articles from a total of 16,194 publications in the Article publication category. The language of publication was English in 9148 (95.1%) of these articles and the remainder were published in other languages. (French: 144, Spanish: 93, German: 87, Japanese: 57, Russian: 25, Portuguese: 22, Czech: 13, Turkish: 7, Italian: 6, Korean: 6, Polish: 4, Ukrainian: 3, Chinese: 2, Croatian: 1, Serbo Croatian: 1). Almost all of these articles were scanned in the SCI-Expanded (n = 8648, 89.9%) and Emerging Sources Citation Index (n = 886, 9.2%) indexes. (The remaining studies Conference Proceedings Citation Index – Science, Social Sciences Citation Index, Book Citation Index Science, Arts & Humanities Citation Index, and Conference Proceedings Citation Index – Social Science & Humanities was also scanned).

3.1. Development and future distribution of publications on meningioma from past to present

The distribution per year of the number of articles on the subject of meningioma is shown in Figure 1. The Exponential Smoothing prediction model was used to predict the number of articles which may be published in the next 5-year period of 2024 to 2028, and the prediction values obtained are shown in Figure 1. As 2024 had not been completed, this year was included in the prediction model. According to the prediction model results, 523 (95% CI: 459–587) articles would be published in 2024, and 568 (95% CI: 413–723) in 2028 (Fig. 1).

3.2. The most productive countries and active research areas on the topic of meningioma

World color density map illustrating the distribution of article counts by country, and an international collaboration map are depicted in Figure 2. The top 20 countries that contribute the most to the literature about Meningioma (more than 100 published articles) were respectively USA (2664, 27.7%), Japan (972, 10.1%), Germany (943, 9.8%), China (880, 9.1%), Italy (600, 6.2%), United Kingdom (484, 5%), France (468, 4.9%), India (401, 4.2%), Turkey (305, 3.2%), Canada (298, 3.1%), South Korea (293, 3%), Spain (271, 2.8%), Switzerland (214, 2.2%), Netherlands (177, 1.8%), Brazil (165, 1.7%), Taiwan (162, 1.7%), Australia (143, 1.5%), Sweden (140, 1.5%), Austria (119, 1.2%), Israel (110, 1.1%).

The top 10 research areas in which articles on meningioma are most frequently tagged are Neurosciences Neurology (n = 5577, 57.9%), Surgery (n = 3729, 38.7%), Oncology (n = 1742, 18.1%), Radiology Nuclear Medicine Medical Imaging (n = 969, 10%), Pathology (n = 829, 8.6%), General Internal Medicine (n = 526, 5.4%), Ophthalmology (n = 235, 2.4%), Otorhinolaryngology (n = 218, 2.2%), Research Experimental Medicine (n = 215, 2.2%), and Pediatrics (n = 160, 1.6%).

3.3. The most active authors on the topic of meningioma

The list of the top 30 most active authors on the subject of meningioma was provided in Table 1. The most prolific authors, who have published 40 and more articles about meningioma respectively Mcdermott MW (number of article = 88), Perry A (N = 69), Lunsford LD (N = 57), Mawrin C (N = 56), Sahm F (N = 49), Samii M (N = 48), Kondziolka D (N = 45), Tatagiba M (N = 45), Von Deimling A (44), Wang L (N = 44), Wu Z (N = 44), Zhang JT (N = 44), Nakamura M (N = 43), Gong Y (N = 42), Kalamarides M (N = 42), Zadeh G (N = 42), Dunn IF (N = 41), Black PM

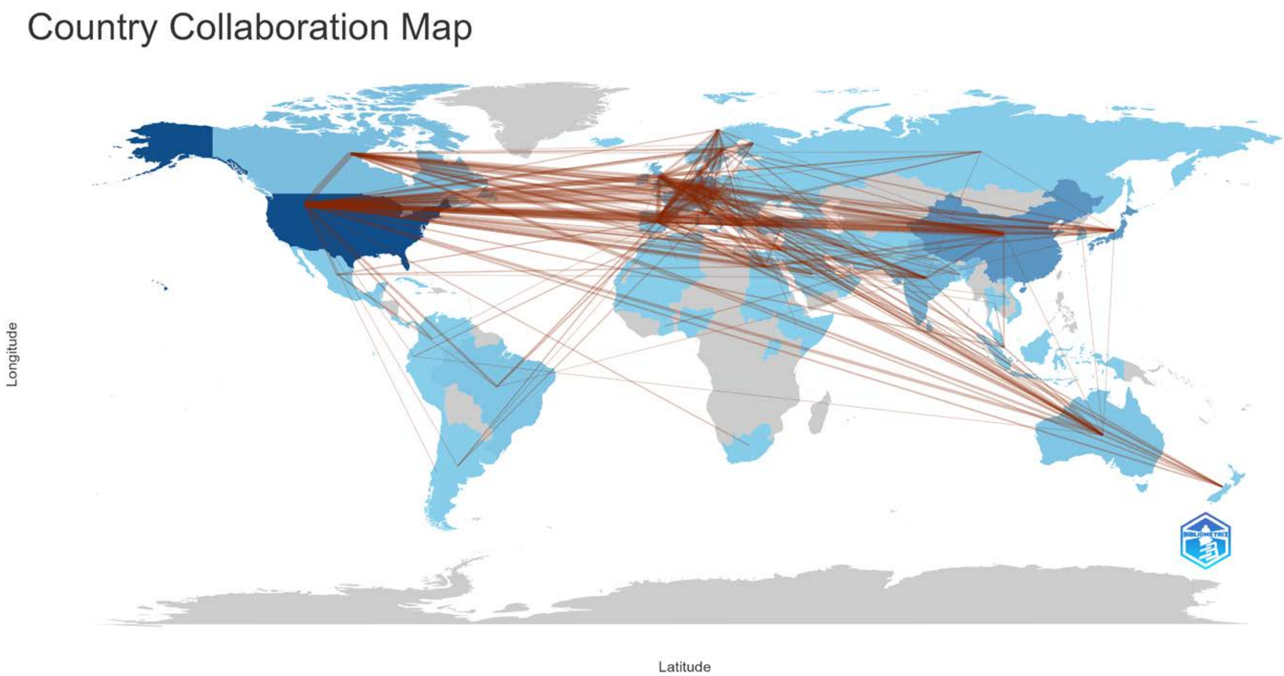

Figure 2. World color density map illustrating the distribution of article counts by country, and an international collaboration map. This map considers the nationality of all authors contributing to an article. The higher the number of articles a country contributes, the higher the color intensity.

Table 1

The list of the top 30 most active authors and institutions on the subject of meningioma.

No	Author	RC	Institution	RC
1	Mcdermott MW	88	University of California System	470
2	Perry A	69	Harvard University	323
3	Lunsford LD	57	Harvard Medical School	229
4	Mawrin C	56	Massachusetts General Hospital in Boston	156
5	Sahm F	49	Mayo Clinic	151
6	Samii M	48	Commonwealth of Pennsylvania System of Higher Education (PCSHE)	147
7	Kondziolka D	45	Brigham Women's Hospital	145
8	Tatagiba M	45	Assistance Publique Hopitaux Paris (APHP)	144
9	Von Deimling A	44	Helmholtz Association	144
10	Wang L	44	Capital Medical University	142
11	Wu Z	44	University System of Ohio	134
12	Zhang JT	44	Ruprecht Karls University Heidelberg University	133
13	Nakamura M	43	University of Pittsburgh	130
14	Gong Y	42	University of Toronto	129
15	Kalamarides M	42	German Cancer Research Center (DKFZ)	126
16	Zadeh G	42	University of Texas System	120
17	Dunn IF	41	Institut National De La Sante Et De La Recherche Medicale Inserm	115
18	Black PM	40	Eberhard Karls University of Tubingen	112
19	Magill ST	40	Cleveland Clinic Foundation	110
20	Couldwell WT	39	Fudan University	104
21	Sheehan JP	38	University of London	103
22	Zhang J	38	Universite Paris Cite	99
23	Al-mefty O	37	Johns Hopkins University	95
24	Debus J	37	Egyptian Knowledge Bank (EKB)	91
25	Kim JH	37	Karolinska Institutet	89
26	Jenkinson MD	36	University of Virginia	87
27	Flickinger JC	35	Sapienza University Rome	84
28	Lee JH	35	University of Utah	80
29	Stummer W	35	Utah System of Higher Education	80
30	Yoshida K	35	University Health Network Toronto	78

Table 2

The 85 most productive journals that have published more than 20 articles on meningioma.

Journals	RC	C	AC	Journals	RC	C	AC
Journal of Neurosurgery	496	26956	54.3	Neurosurgery Clinics of North America	38	613	16.1
World Neurosurgery	399	5110	12.8	International Journal of Cancer	36	1654	45.9
Acta Neurochirurgica	378	8468	22.4	Radiation Oncology	35	843	24.1
Journal of Neuro-Oncology	371	9470	25.5	Brain Pathology	34	1230	36.2
Neurosurgery	359	21089	58.7	Journal of Computer Assisted Tomography	34	830	24.4
Journal of Clinical Neuroscience	215	3239	15.1	Medicine	34	144	4.2
Surgical Neurology	204	7769	38.1	Neurochirurgia	33	394	11.9
Clinical Neurology and Neurosurgery	165	1992	12.1	Cancer Research	32	2530	79.1
British Journal of Neurosurgery	152	2231	14.7	Stereotactic and Functional Neurosurgery	31	737	23.8
Neurosurgical Review	115	1927	16.8	Journal of Neuroradiology	30	392	13.1
American Journal of Neuroradiology	102	3629	35.6	Oncology Letters	29	163	5.6
Neuroradiology	102	2216	21.7	Anticancer Research	28	241	8.6
Neurochirurgie	97	893	9.2	European Radiology	28	642	22.9
Neurologia Medico-Chirurgica	94	928	9.9	Journal of Neurological Surgery Part A-Central European Neurosurgery	28	134	4.8
Cureus Journal of Medical Science	93	268	2.9	Human Pathology	27	1247	46.2
Neuro-Oncology	91	4830	53.1	Clinical Imaging	26	401	15.4
Frontiers in Oncology	90	600	6.7	Folia Neuropathologica	26	223	8.6
Journal of Neurological Surgery Part B-Skull Base	84	690	8.2	Neurological Research	26	386	14.8
Neurosurgical Focus	81	2686	33.2	Pediatric Neurosurgery	26	500	19.2
International Journal of Radiation Oncology Biology Physics	76	5244	69.0	Rivista Di Neuroradiologia	26	6	0.2
Cancer	74	4741	64.1	Chinese Medical Journal	25	201	8.0
Cancers	71	472	6.6	Journal of Nuclear Medicine	25	1216	48.6
Childs Nervous System	71	1009	14.2	Neurologia I Neurochirurgia Polska	25	180	7.2
Clinical Neuropathology	61	984	16.1	Neuroradiology Journal	25	111	4.4
Neurology India	61	460	7.5	Neurosurgery Quarterly	25	39	1.6
Neuropathology	59	831	14.1	International Journal of Oncology	25	483	19.3
Acta Neuropathologica	58	2147	37.0	European Journal of Radiology	24	677	28.2
Journal of Korean Neurosurgical Society	58	601	10.4	Pathology Research and Practice	24	502	20.9
Neurological Surgery	57	259	4.5	Skull Base Surgery	24	321	13.4
Turkish Neurosurgery	57	339	5.9	Bmj Case Reports	23	15	0.7
Plos One	54	1107	20.5	Journal of Laryngology and Otology	23	250	10.9
Journal of Craniofacial Surgery	51	150	2.9	Ophthalmic Plastic and Reconstructive Surgery	23	162	7.0
Journal of Neuropathology and Experimental Neurology	48	1847	38.5	Acta Cytologica	22	253	11.5
Neurocirugia	47	194	4.1	Journal of Neurology Neurosurgery and Psychiatry	22	1503	68.3
Arquivos De Neuro-Psiquiatria	44	305	6.9	BMC Cancer	21	350	16.7
Cancer Genetics and Cytogenetics	44	1320	30.0	Brazilian Neurosurgery-Arquivos Brasileiros De Neurocirurgia	21	2	0.1
Scientific Reports	43	619	14.4	Clinical Cancer Research	21	1091	52.0
Interdisciplinary Neurosurgery-Advanced Techniques and Case Management	43	32	0.7	Journal of Neuro-Ophthalmology	21	369	17.6
American Journal of Surgical Pathology	42	2888	68.8	Neuro-Ophthalmology	20	43	2.2
Operative Neurosurgery	40	341	8.5	Oncotarget	20	570	28.5
Neuropathology and Applied Neurobiology	39	1099	28.2	Radiotherapy and Oncology	20	812	40.6
Brain Tumor Pathology	38	485	12.8	International Journal of Surgery Case Reports	20	61	3.1
Neuro-Oncology Advances	38	286	7.5				

AC = average citation per document, C = number of citation, RC = record count.

(N = 40), and Magill ST (N = 40) it was determined as. The authors with the highest local impact were Perry A (h_index: 40; Total Citation (TC): 5401), Mcdermott MW (h_index: 35; TC: 3210), Samii M (h_index: 29; TC: 2870), and Black PM (h_index: 29; TC: 2492).

3.4. The most active institutions on meningioma

The list of the top 30 most active institutions on the subject of meningioma was provided in Table 1. Meningioma at least 100 or more published articles about the most active institutions which respectively; the University of California System (number of article = 470), Harvard University (N = 323), Harvard Medical School (N = 229), Massachusetts General Hospital in Boston (N = 156), Mayo Clinic (N = 151), Commonwealth of Pennsylvania System of Higher Education (PCSHE) (N = 147), Brigham Women's Hospital (N = 145), Assistance Publique-Hopitaux Paris (APHP) (N = 144), Helmholtz Association (N = 144), Capital Medical University (N = 142), University System of Ohio (N = 134), Ruprecht Karls University Heidelberg University (N = 133), University of Pittsburgh (N = 130), University of Toronto (N = 129), German Cancer Research Center (DKFZ) (N = 126), University of Texas System (N = 120), Institut National De La Sante Et De La Recherche Medicale Inserm (N = 115), Eberhard Karls Universität Tubingen University (N = 112), Cleveland Clinic Foundation (N = 110), Fudan University (N = 104), and University of London (N = 103) it was determined as.

3.5. The most active journals on the topic of meningioma

The total 9619 articles on the subject of meningioma were published in 1310 different journals. The 85 most active journals publishing 20 or more articles are shown in Table 2. The total citations obtained by the journals and the number of citations per article are shown in Table 2. It was determined that the journals that contributed the most to the literature on meningioma were Journal of Neurosurgery, World Neurosurgery, Acta Neurochirurgica, Journal of Neuro-Oncology, Neurosurgery, Journal of Clinical Neuroscience, Surgical Neurology, respectively. According to the average number of citations received per article published by active journals, the most influential journals were Cancer Research (The average number of citations the journal receives per article = 79.1), International Journal of Radiation Oncology Biology Physics (69), American Journal of Surgical Pathology (68.8), Journal of Neurology Neurosurgery and Psychiatry (68.3), Cancer (64.1), Neurosurgery (58.7), and Journal of Neurosurgery (54.3), respectively. The most influential journals publishing articles on meningioma, based on h-index (25 and above) and total citations (over 2000), were Journal of Neurosurgery (h_indeksi: 90; Total Citation (TC): 26956), Neurosurgery (h_indeksi: 85; TC: 21089), Journal of Neuro-Oncology (h_indeksi: 51; TC: 9470), Acta Neurochirurgica (h_indeksi: 49; TC: 8468), Surgical Neurology (h_indeksi: 47; TC: 7769), International Journal of Radiation Oncology Biology Physics (h_indeksi: 45; TC: 5244), Neuro-Oncology (h_indeksi: 45; TC: 4830), Cancer (h_indeksi: 43; TC: 4741), American Journal of Neuroradiology (h_indeksi: 34; TC: 3629), World Neurosurgery (h_indeksi: 33; TC: 5110), Journal of Clinical Neuroscience (h_indeksi: 32; TC: 3239), Neurosurgical Focus (h_indeksi: 32; TC: 2686), American Journal of Surgical Pathology (h_indeksi: 29; TC: 2888), Neuroradiology (h_indeksi: 28; TC: 2216), British Journal of Neurosurgery (h_indeksi: 27, TC: 2231), Cancer Research (h_indeksi: 27, TC: 2530), and Acta Neuropathologica (h_indeksi: 25; TC: 2147), respectively.

3.6. Citation analysis on the topic of meningioma

From the total of 9619 articles on the subject of meningioma, the 20 articles that received the most citations are listed in Table 3. The mean number of citations per year received by these articles is shown in the last column of Table 3.

When the total number of citations obtained by the articles was evaluated, the study with the most citations was determined to be the study entitled "Meningioma – Analysis of Recurrence and Progression Following Neurosurgical Resection" by Mirimanoff et al (1985) published in the Journal of Neurosurgery.[11] This was followed by "Genomic Analysis of Non-NF2 Meningiomas Reveals Mutations in TRAF7, KLF4, AKT1, and SMO" by Clark et al (2013) published in Science,[12] and "DNA methylation-based classification and grading system for meningioma: a multicentre, retrospective analysis" by Sahm et al (2017) published in Lancet Oncology.[13] The fourth and fifth most effective studies were "Meningioma grading - An analysis of histologic parameters" by Perry et al (1997) published in the American Journal of Surgical Pathology[14] and "Postoperative irradiation for subtotally resected meningiomas - a retrospective analysis of 140 patients treated from 1967 to 1990" by Goldsmith et al (1994) published in the Journal of Neurosurgery.[15]

When the mean number of citations obtained per year were examined the most effective study by Sahm et al (2017) published in Lancet Oncology,[13] followed by a study was "EANO guideline on the diagnosis and management of meningiomas" by Goldbrunner et al (2021) published in Neuro-Oncology.[16] The third most effective study by Clark et al (2013) published in Science.[12] The fourth and fifth most effective studies were "A clinically applicable integrative molecular classification of meningiomas" by Nassiri et al (2021) published in the Nature,[17] and "Genomic sequencing of meningiomas identifies oncogenic SMO and AKT1 mutations" by Brastianos et al (2013) published in Nature Genetics.[18]

3.7. Co-citation analysis on the topic of meningioma

There were a total of 88,320 studies cited in the references section of all 9619 articles published on meningioma. Among these studies, the first 19 studies with more than 250 citations (with the most co-citations) were respectively Simpson (1957) (co- citation; CC = 1296), Louis et al (2016) (CC = 634), Mirimanoff et al (1985) (CC = 587), Wiemels et al (2010) (CC = 469), Louis et al (2007) (CC = 383), Perry et al (1997) (CC = 370), Goldbrunner et al (2016) (CC = 364), Perry et al (1999) (CC = 349), Goldsmith et al (1994) (CC = 348), Adegbite et al (1983) (CC = 328), Whittle et al (2004) (CC = 310), Clark et al (2013) (CC = 308), Jaaskelainen (1986) (CC = 303), Jaaskelainen et al (1986) (CC = 282), Riemenschneider (2006) (CC = 268), Rogers (2015) (CC = 266), Ostrom et al (2015), Claus et al (2005) (CC = 262), Aghi et al (2009) (CC = 252).[11,12,14,15,19–32]

The results of the RPYS analysis conducted to identify the years in which significant results were published are presented in Figure 3.

3.8. Analyzing conceptual structures through trend topics, word clouds, factor analysis, and thematic evolution

A total of 10,682 different keywords were used in the 9619 articles published on the subject of meningioma. The 50 distinct author keywords most frequently used in articles from past to present (with at least 59 co-occurrences) were presented in Figure 4A. The search keyword "meningioma" was not included in Figure 4A. Additionally, synonymous terms such as recurrence/recurrent, malignant meningioma/malignant meningiomas, magnetic resonance image/MRI were consolidated.

Table 3

The top 20 most cited articles published on meningioma.

No	Article	Author	Journal	PY	TC	AC
1	Meningioma – analysis of recurrence and progression following neurosurgical resection	Mirimanoff RO. et al.	Journal of Neurosurgery	1985	793	19.83
2	Genomic analysis of Non-NF2 meningiomas reveals mutations in TRAF7, KLF4, AKT1, and SMO	Clark VE. et al.	Science	2013	604	50.33
3	DNA methylation-based classification and grading system for meningioma: a multicentre, retrospective analysis	Sahm F. et al.	Lancet Oncology	2017	513	64.13
4	Meningioma grading – an analysis of histologic parameters	Perry A. et al.	American Journal of Surgical Pathology	1997	496	17.71
5	Postoperative irradiation for subtotally resected meningiomas – a retrospective analysis of 140 patients treated from 1967 to 1990	Goldsmith BJ. et al.	Journal of Neurosurgery	1994	485	15.65
6	Evidence for the complete inactivation of the NF2 gene in the majority of sporadic meningiomas	Ruttledge MH. et al.	Nature Genetics	1994	474	15.29
7	Malignancy in meningiomas – a clinicopathologic study of 116 patients, with grading implications	Perry A. et al.	Cancer	1999	468	18
8	Genomic sequencing of meningiomas identifies oncogenic SMO and AKT1 mutations	Brastianos PK. et al.	Nature Genetics	2013	449	37.42
9	Petrosal approach for petroclival meningiomas	Almefty O. et al.	Neurosurgery	1988	435	11.76
10	The recurrence of intracranial meningiomas after surgical-treatment	Adegbite AB. et al.	Journal of Neurosurgery	1983	411	9.79
11	Seemingly complete removal of histologically benign intracranial meningioma - late recurrence rate and factors predicting recurrence in 657 patients – a multivariate-analysis	Jaaskelainen J.	Surgical Neurology	1986	387	9.92
12	Anterior transpetrosal-transtentorial approach for sphenopetroclival meningiomas – surgical method and results in 10 patients	Kawase T. et al.	Neurosurgery	1991	371	10.91
13	Atypical and anaplastic meningiomas - radiology, surgery, radiotherapy, and outcome	Jaaskelainen J. et al.	Surgical Neurology	1986	349	8.95
14	Germline BAP1 mutation predisposes to uveal melanoma, lung adenocarcinoma, meningioma, and other cancers	Abdel-Rahman MH. et al.	Journal of Medical Genetics	2011	338	24.14
15	Long-term recurrence rates of atypical meningiomas after gross total resection with or without postoperative adjuvant radiation	Aghi MK. et al.	Neurosurgery	2009	337	21.06
16	Analysis of genomic alterations in benign, atypical, and anaplastic meningiomas: toward a genetic model of meningioma progression	Weber RG. et al.	Proceedings of The National Academy of Sciences of The United States of America	1997	333	11.89
17	Morbidity, mortality, and quality of life following surgery for intracranial meningiomas – a retrospective study in 257 cases	Chan RC. and Thompson GB.	Journal of Neurosurgery	1984	328	8
18	Endoscopic endonasal resection of anterior cranial base meningiomas	Gardner PA. et al.	Neurosurgery	2008	313	18.41
19	Solitary fibrous tumor of the meninges: a lesion distinct from fibrous meningioma – a clinicopathologic and immunohistochemical study	Carneiro SS. et al.	American Journal of Clinical Pathology	1996	313	10.79
20	Outcome of aggressive removal of cavernous sinus meningiomas	Demonte F. et al.	Journal of Neurosurgery	1994	310	10

AC = average citation per year, PY = publication year, TC = total citation.

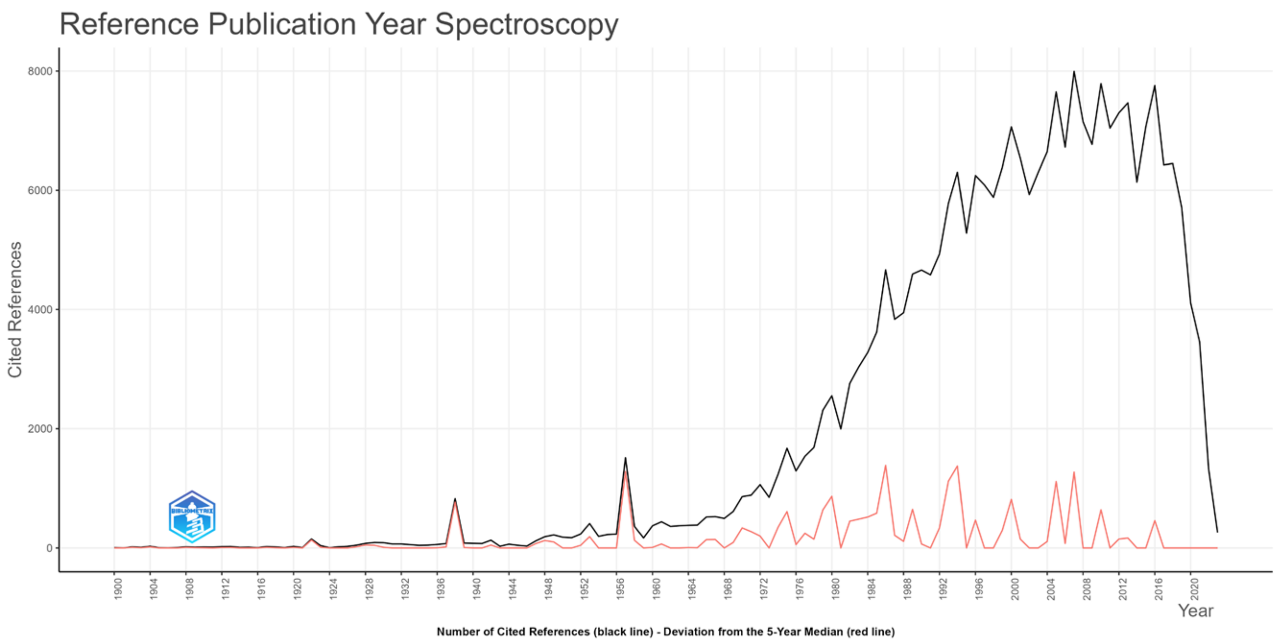

Figure 3. A line graph presenting the results from the Reference Publication Year Spectroscopy (RPYS) analysis. In this figure, the black line represents the number of references cited each year. The red line shows the deviation of the annual citation count from the expected value. Years in which the red line peaks indicate years with higher-than-expected citations. In this graph, between 1900 and 1980, significant peaks are observed in 1938, 1957, 1975 and 1980. In the following years, a rapid increase in interest in the subject was observed, with significant peaks in 1986, 1994, 2000, 2005, 2007, and 2016. 2007 has been identified as the year with the highest academic interest in the subject.

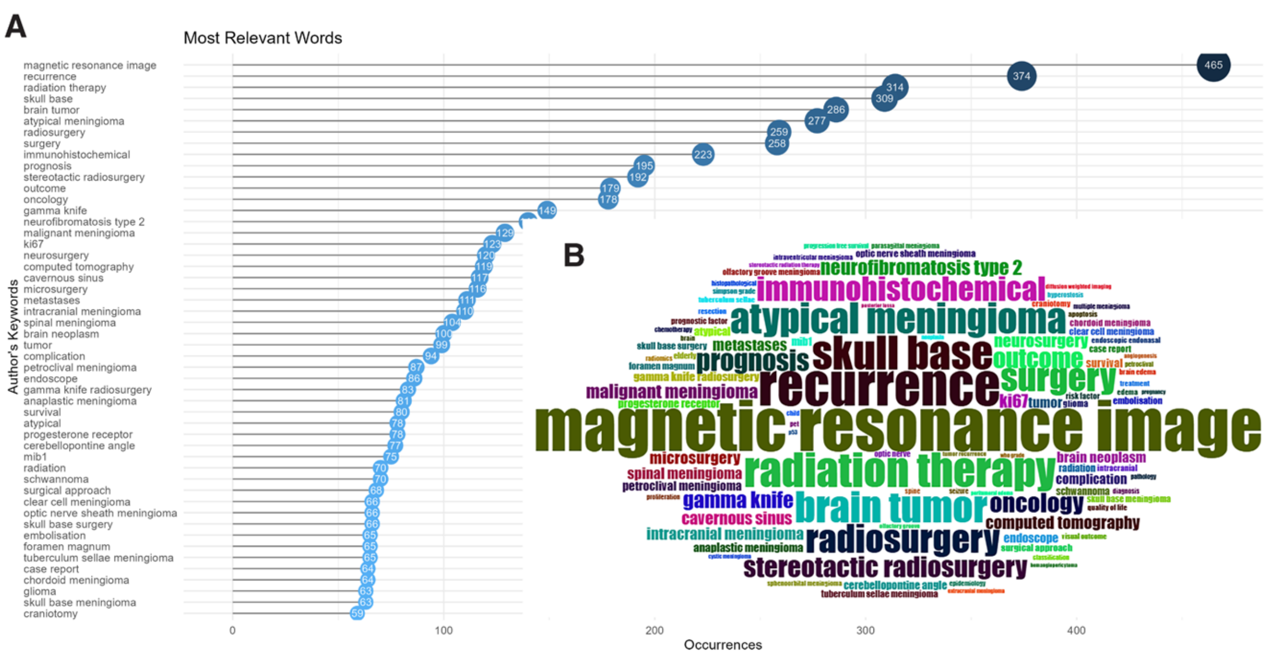

Figure 4. A. A graphic depicting the distribution of the top 50 keywords most commonly used in articles on meningioma from the past to the present. B. Visualization of a word cloud analysis featuring the 100 most frequently used keywords by authors in articles. This figure illustrates the frequency and importance of the keywords used by the authors in two different ways. In part A (left), the most frequently used keywords and their respective counts are shown. "Magnetic resonance image" (465 times), "recurrence" (374 times), "radiation therapy" (314 times), "skull base" (309 times), "brain tumor" (286 times), "atypical meningioma" (277 times), "radiosurgery" (259 times), "surgery" (258 times), "immunohistochemical" (223 times), and "prognosis" (195 times) are the most frequently used terms. In part B (right), a word cloud visually represents the frequency of the keywords. Larger and bolder words represent terms that are used more frequently in the related literature. "Magnetic resonance image," "recurrence," "radiation therapy," "skull base," "brain tumor," "atypical meningioma," "radiosurgery," "surgery," "immunohistochemical," and "prognosis" are the most frequently used terms. These graphs help quickly understand the focus areas of the study and the significance of the keywords in the literature.

The WordCloud visualization obtained using the authors Keyword in the Biblioshiny application is presented in Figure 4B. Upon examining the WordCloud analysis based on the 100 most frequently used author keywords, it is observed that the topic of meningioma primarily revolves around concepts such as magnetic resonance image, recurrence, radiation therapy, skull base, brain tumor, atypical meningioma, radiosurgery, surgery, immunohistochemical, prognosis, stereotactic radiosurgery, outcome, oncology, gamma knife, and neurofibromatosis type 2.

The keyword burst analysis visualization map, which shows the usage of keywords used in at least 5 different articles with the VOSviewer, is presented in Figure 5A. The close-up detailed view of the Hot zone on the visualization map is presented in Figure 5B. Keywords with the most intense connections and located in hotter spots included magnetic resonance image, recurrence, skull base, radiation therapy, atypical meningioma, surgery, stereotactic radiosurgery, brain tumor, prognosis, outcome, oncology, gamma knife, and radiosurgery. These keywords indicate important topics in the research field and strong relationships among these topics.

Trend analysis using author keywords in two different time periods was conducted in the Biblioshiny application, requiring a minimum of 4 co-occurrences across different articles. The findings of keyword analysis for the periods 1980 to 2012 are presented in Figure 6, and for the period 2013 to 2023 in Figure 7. To identify trending topics, the keyword analysis conducted in these 2 time periods revealed that before 2000, topics such as brain, neoplasms, meninges, cell kinetics, bromodeoxyuridine, human meningioma, tissue culture, immunocytochemistry, platelet-derived growth factor, proliferating cell nuclear antigen, growth factor, cell culture, image analysis, epidermal growth factor, gadolinium, operative approach, flow cytometry, steroid, and ectopic were prominent. From 2000 to 2012, trends included angiography, malignant tumor, carcinoembryonic antigen, childhood, electron microscopy, ultrastructure, tentorium, receptor, cerebral angiography, meninges, rhabdoid tumor, dal-1, clivus, chromosome, osteolysis, brain neoplasm, fish (floresan in situ hibridizasyon), cyst, multiple meningioma, proliferation, angiogenesis, mib1, pituitary adenoma, skull, computed tomography, cavernous sinus, progesterone receptor, immunohistochemical, ki67, embolization, clear cell meningioma, chordoid meningioma, child, surgical approach, glioma, brain, brain tumor, metastases, intraventricular meningioma. From 2013 to 2018, trending topics included malignant meningioma, intracranial meningioma, cerebellopontine angle, radiation therapy, radiosurgery, schwannoma, magnetic resonance image, microsurgery, foramen magnum, recurrence, skull base, surgery, atypical meningioma, outcome, spinal meningioma, oncology, endoscope, survival. In the last 5 years, trend topics comprised endoscopic endonasal, quality of life, PET, neurosurgery, progression free survival, WHO grade, case report, machine learning, gross total resection, radiomics, asymptomatic, immunotherapy, and prediction model.

Factor analysis was conducted to determine the conceptual structure of the topic of meningioma using author keywords. The factor analysis visualization performed using Multiple Correspondence Analysis and the prevalent topics within each factor are shown in Figure 8. According to the findings of the factor analysis, the general structure of the meningioma literature was found to consist of four sub-factors: red, purple, green, and turquoise.

Thematic evolution analysis was conducted using author keywords to determine the conceptual structure of the topic of meningioma. The analysis was performed for two distinct periods: 1980 to 2013 and the last 10 years (2014–2023). Thematic maps obtained for the periods 1980 to 2013 and the last decade are shown in Figures 9 and 10, respectively. Upon examining the thematic maps for the two separate periods, it was found that from the past to 2013, niche themes included parasagittal meningioma, superior sagittal sinus, progesterone, tuberculum sellae meningioma, tuberculum sellae, visual outcome, and endoscope; motor themes encompassed brain tumor, recurrence, immunohistochemical, and atypical meningioma; and core themes consisted of radiation therapy, radiosurgery, skull base, surgery, ki67, mib 1, progesterone receptor, angiogenesis, magnetic resonance image, computed tomography, embolization, and brain edema. In the last decade, niche themes included progesterone, immunotherapy, and target therapy; motor themes comprised magnetic resonance image, computed tomography, radiomics, and PET; and core themes involved recurrence, atypical meningioma, radiation therapy, surgery, neurofibromatosis type 2, immunohistochemical, malignant meningioma, anaplastic meningioma, radiosurgery, gamma knife, and microsurgery.

4. Discussion

When the distribution over the years was examined of the 9619 articles published on the subject of meningioma, there were seen to be 3 different publication trends in the years 1980 to 1995, 1996 to 2006, and 2007 to 2023. Mean 89 (range, 59–121) articles per year were published between 1980 and 1995, and 178 (range, 146–206) between 1996 and 2006. The trend for an increase in the number of articles started in 2007, and mean 367 (range, 216–578) articles per year were published between

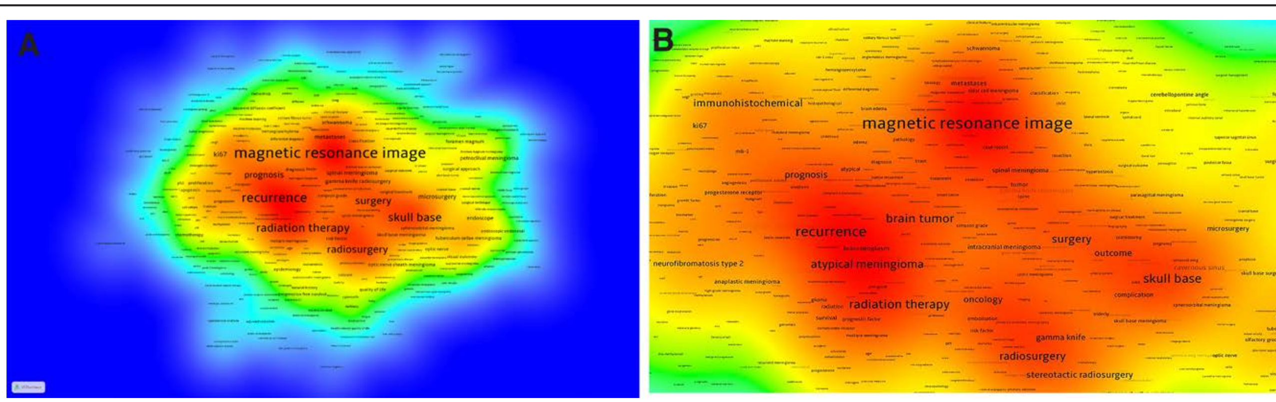

Figure 5. A. Visualization of keyword burst analysis. The color spectrum ranges from blue to green and yellow. The more keywords there are in the vicinity of a keyword, and the higher the weights of these neighboring keywords, the closer the keyword's color will be to red. Keyword weights increase in green, yellow, and red hues. B. Close-up detailed view of the Hot zone on the visualization map. This figure depicts the density map of keywords. Part A (left) presents a density map showing where specific keywords are more intensively used and which topics are more extensively studied. The color red represents the highest density, while blue represents the lowest. Part B (right) presents the same density map in a more detailed word cloud format. The density of keywords is indicated by the size and color of the words. In both maps, keywords such as "magnetic resonance image," "recurrence," and "radiation therapy" stand out as the most intensively used terms. These graphics help visually understand the most frequently used keywords in the literature and their density.

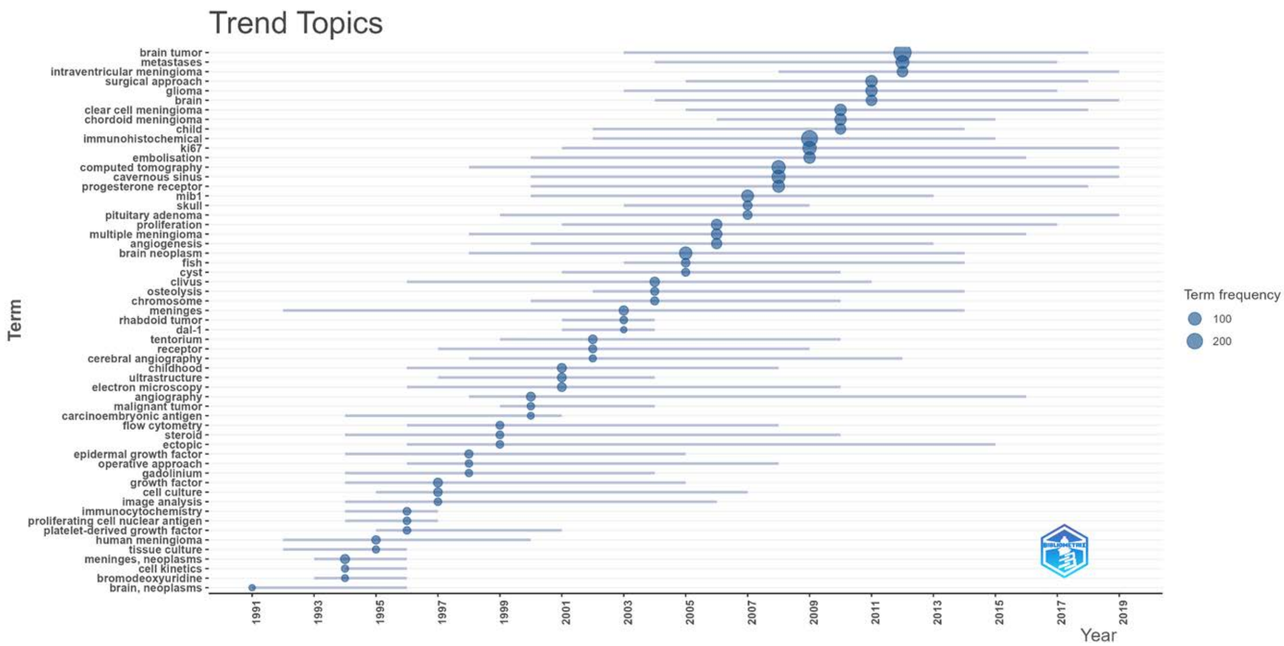

Figure 6. A graphic depicting the most frequently used trend keywords between 1980 and 2012. This graph shows the trend keywords for the period between 1980 and 2012. The lines and blue circles in the graph represent the years certain keywords were used and their frequency. Lines: For each keyword, the lines indicate the years during which the keyword was widely used. Blue Circles: Each blue circle indicates how frequently a keyword was used within a specific year. The size of each circle corresponds to the frequency of the keyword's usage in that year, with larger circles indicating more frequent usage. For example, trend topics between 2011 and 2012 included brain tumor, metastases, intraventricular meningioma, surgical approach, glioma, and brain.

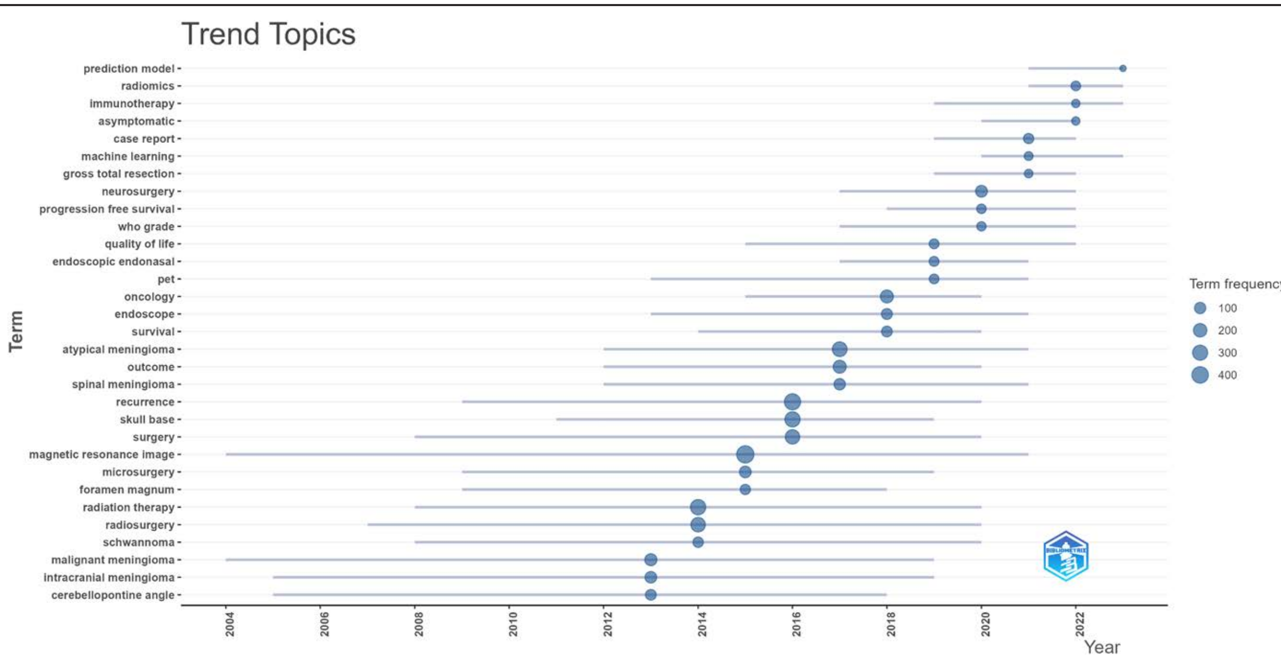

Figure 7. A graphic depicting the most frequently used trend keywords between 2013 to 2023. The horizontal lines denote the years when keywords were utilized, with circle sizes indicating the frequency of usage. This graph shows the trend keywords for the period between 2013-2023. The lines and blue circles in the graph represent the years certain keywords were used and their frequency. Lines: For each keyword, the lines indicate the years during which the keyword was widely used. Blue Circles: Each blue circle indicates how frequently a keyword was used within a specific year. The size of each circle corresponds to the frequency of the keyword's usage in that year, with larger circles indicating more frequent usage. For example, trend topics in the last 5 years include endoscopic endonasal procedures, quality of life assessments, PET scans, neurosurgery, progression-free survival rates, WHO grading, case reports, machine learning applications, gross total resection surgeries, radiomics, asymptomatic conditions, immunotherapy advancements, and prediction models.

2007 and 2023. When the results were examined for the predicted number of articles in the next 5 years (2024–2028), it can be said that the trend for an increasing number of articles will continue. Furthermore, from Figure 1, we observe that articles related to meningioma continue to show an increasing trend even after 2019. While the COVID-19 pandemic was expected to impact publications on meningioma, we can state that there hasn't been such an effect.

When the number of published articles of countries around the world were evaluated, the 16 most active countries contributing the most to the literature about meningioma were seen to be developed countries (USA, Japan, Germany, Italy,

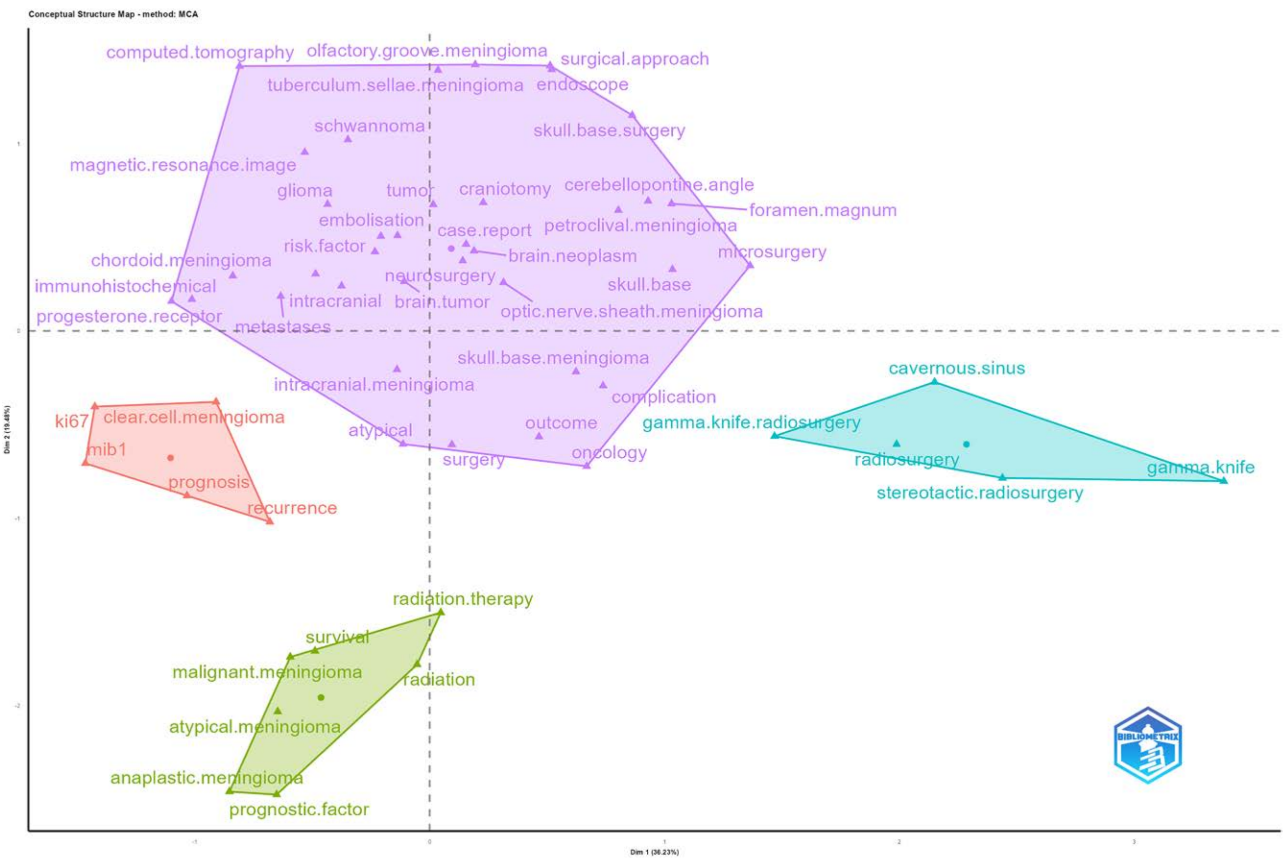

Figure 8. A conceptual structure map illustrating the findings of factor analysis conducted using Multiple Correspondence Analysis. The origin of the map represents the center of the research topic and illustrates the principal topics. Each color corresponds to a distinct sub-factor.

United Kingdom, France, Canada, South Korea, Spain, Switzerland, Netherlands, Taiwan, Australia, Sweden, Austria, Israel), and another 4 countries (China, India, Turkey, Brazil) were developing countries. These developing countries of China, India, Turkey, and Brazil, are countries with large economies. The majority of bibliometric studies in literature have reported that the level of development of a country has a positive effect on academic productivity and international cooperation power.[5–7] The correlation findings we discovered in meningioma article productivity and international collaboration parallel the literature. However, besides the economic development of countries associated with article productivity, it should be noted that various factors affecting scientific productivity include research infrastructure (such as the number of universities and advanced laboratories), investment and funding (provision of funds for publication fees, support for international scientific collaboration, etc.), education and talent (strategies for cultivating qualified human resources for scientific research), scientific publishing services, incentive and reward systems.[33,34] It is important to acknowledge that many of these factors are directly linked to the developmental levels of countries.

Evaluating the bibliometric analysis findings where we identified more productive and impactful journals in the field of meningioma, researchers interested in working on this subject could be advised to primarily consider the more productive journals. However, if researchers aim for greater post-publication impact, we can suggest they prioritize effective journals with higher citation rates.

In this study, the most impactful studies were identified using citation analysis based on the total number of citations, the average number of citations per year and the number of co-citations. Citation analysis measures the scientific impact of a study by assessing how much a study is cited. Co-citation analysis determines the relationship between two different studies by examining how often they are cited together by the same article. The average number of citations per year offsets the advantage of older studies having more time to be cited.[5,9] We recommend that researchers who wish to study in this field first examine these studies identified by citation and co-citation analyses. In this way, they can better understand both the impact of individual studies and the links between studies.

Reference Publication Year Spectroscopy (RPYS) analysis is used to determine the temporal development of a topic or field by utilizing citation analyses, offering insights into the historical progression and periodic trends of the subject.[9] According to the RPYS analysis findings conducted on the historical development of the topic of meningioma, the first notable peak occurred in 1938. Following this peak, a second peak was observed in 1957. In subsequent years, the interest in the topic showed a rapid upward trend, with significant peaks occurring in 1975, 1980, 1986, 1994, 2000, 2005, 2007, and 2016. It was determined that the year 2007 marked the highest level of academic interest in the subject. These peak periods are likely associated with major developments or significant discoveries in the field of meningioma.

When the most frequently used keywords from past to present are evaluated, it is observed that research has primarily focused on imaging and diagnostic methods (magnetic resonance image; computed tomography; immunohistochemical; mib1; ki67), treatment and surgical techniques (radiation therapy; radiosurgery; stereotactic radiosurgery; gamma knife; gamma knife radiosurgery; microsurgery; surgical approach; skull base surgery; embolization; craniotomy),

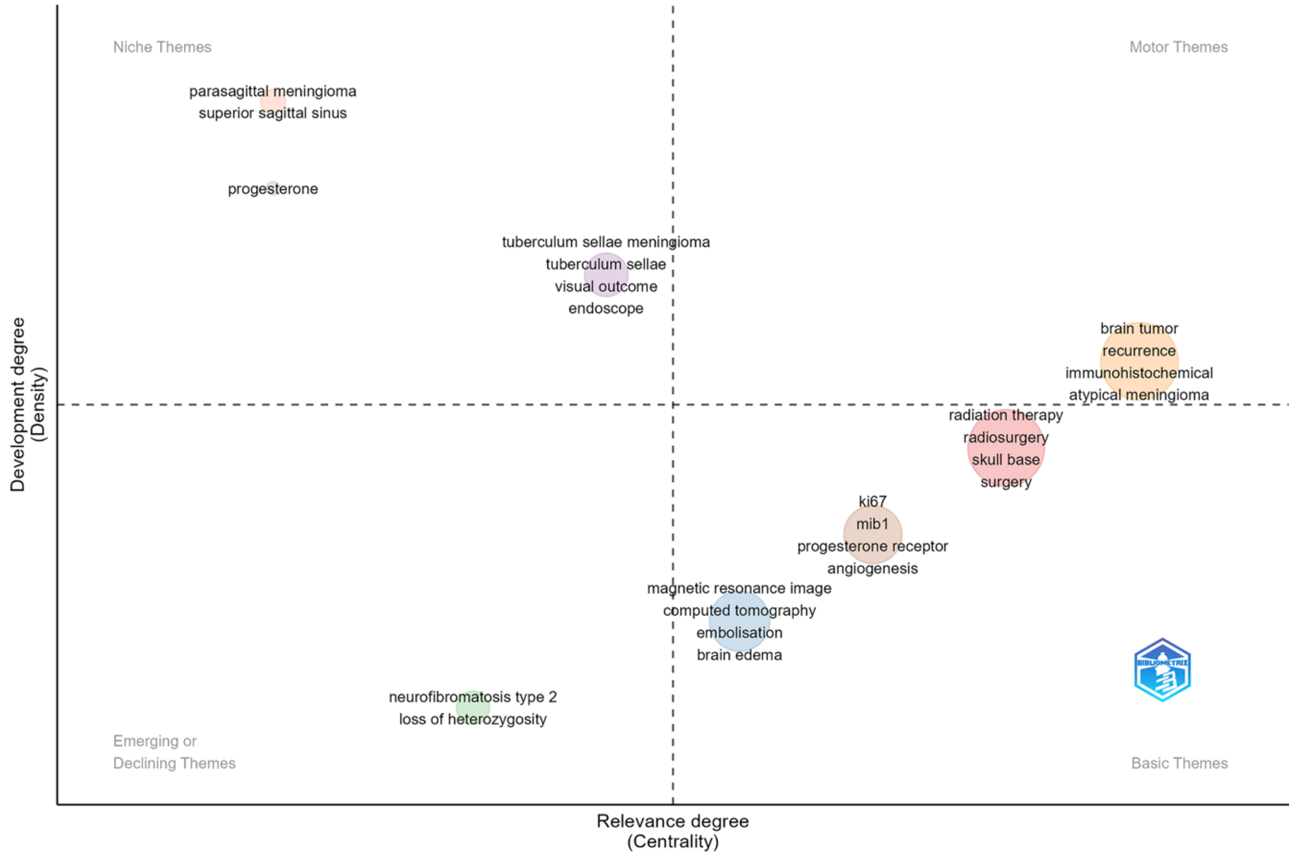

Figure 9. Thematic evolution maps for the periods 1980–2013.

Types of diseases and related tumors (atypical meningioma; malignant meningioma; neurofibromatosis type 2; intracranial meningioma; spinal meningioma; brain neoplasm; anaplastic meningioma; clear cell meningioma; optic nerve sheath meningioma; chordoid meningioma; schwannoma), brain and skull structures (skull base; brain tumor; cavernous sinus; intracranial; cerebellopontine angle; foramen magnum; tuberculum sellae meningioma; petroclival meningioma), clinical conditions and complications (metastases; tumor; complication), and pathological and physiological processes (recurrence; prognosis; outcome; oncology; survival; atypical; progesterone receptor; radiation). The studies encompass a broad research area aimed at understanding complications associated with meningioma, treatment options, and the molecular foundations of the disease. These findings underscore the broad scope of meningioma research, reflecting a comprehensive analysis of its multifaceted nature and diverse treatment approaches. This body of knowledge not only sets a solid foundation for future investigations but also paves the way for innovative advancements in understanding and treating meningioma.

Analyzing the keyword analysis conducted for different time periods to determine trend topics, in the early periods (before 2000), key areas included disease and diagnostic methods (brain neoplasms; meninges; human meningioma), cellular and molecular research (cell kinetics; bromodeoxyuridine; tissue culture; immunocytochemistry; platelet-derived growth factor; proliferating cell nuclear antigen; growth factor; epidermal growth factor), research methods and techniques (image analysis; flow cytometry; gadolinium), and treatment and surgical approaches (operative approach; steroid; ectopic). From 2000 to 2018, the focus shifted towards imaging and diagnostic methods (angiography; cerebral angiography; computed tomography; electron microscopy; ultrastructure; fluorescence in situ hybridization (FISH); magnetic resonance image), diseases and classifications (malignant tumor; childhood; rhabdoid tumor; pituitary adenoma; glioma; brain neoplasm; multiple meningioma; intraventricular meningioma; clear cell meningioma; chordoid meningioma; metastases; malignant meningioma; intracranial meningioma; cerebellopontine angle; schwannoma; spinal meningioma), molecular and genetic research (carcinoembryonic antigen; dal-1; chromosome; mib1; progesterone receptor; immunohistochemical; ki67), surgical and treatment approaches (embolization; surgical approach; radiation therapy; radiosurgery; microsurgery; surgery), and anatomical and structural studies (tentorium; clivus; skull; cavernous sinus; skull base; foramen magnum; spinal meningioma; cerebellopontine angle).

Over the last 5 years, the emphasis has been on surgical and treatment methods (endoscopic endonasal; neurosurgery; gross total resection; immunotherapy), diagnostic methods and imaging (PET; radiomics), prognosis and survival (progression free survival; WHO grade, asymptomatic), epidemiology and quality of life (quality of life), and the advancement of technology with machine learning and prediction models. Trend analyses show how the scientific focus of meningioma research has changed over time.

The findings of thematic evolution analysis are crucial as they show the basic, emerging or declining, niche, and motor themes for different time periods. Researchers can see in detail the rising and falling topics of each period from the visuals. In the last decade, it can be said that niche and motor themes have particularly focused on treatment options and imaging techniques.

In the literature, numerous bibliometric studies have been conducted on other tumors as well. In a recently published article, Alcantara et al (2023) identified the global trends of articles

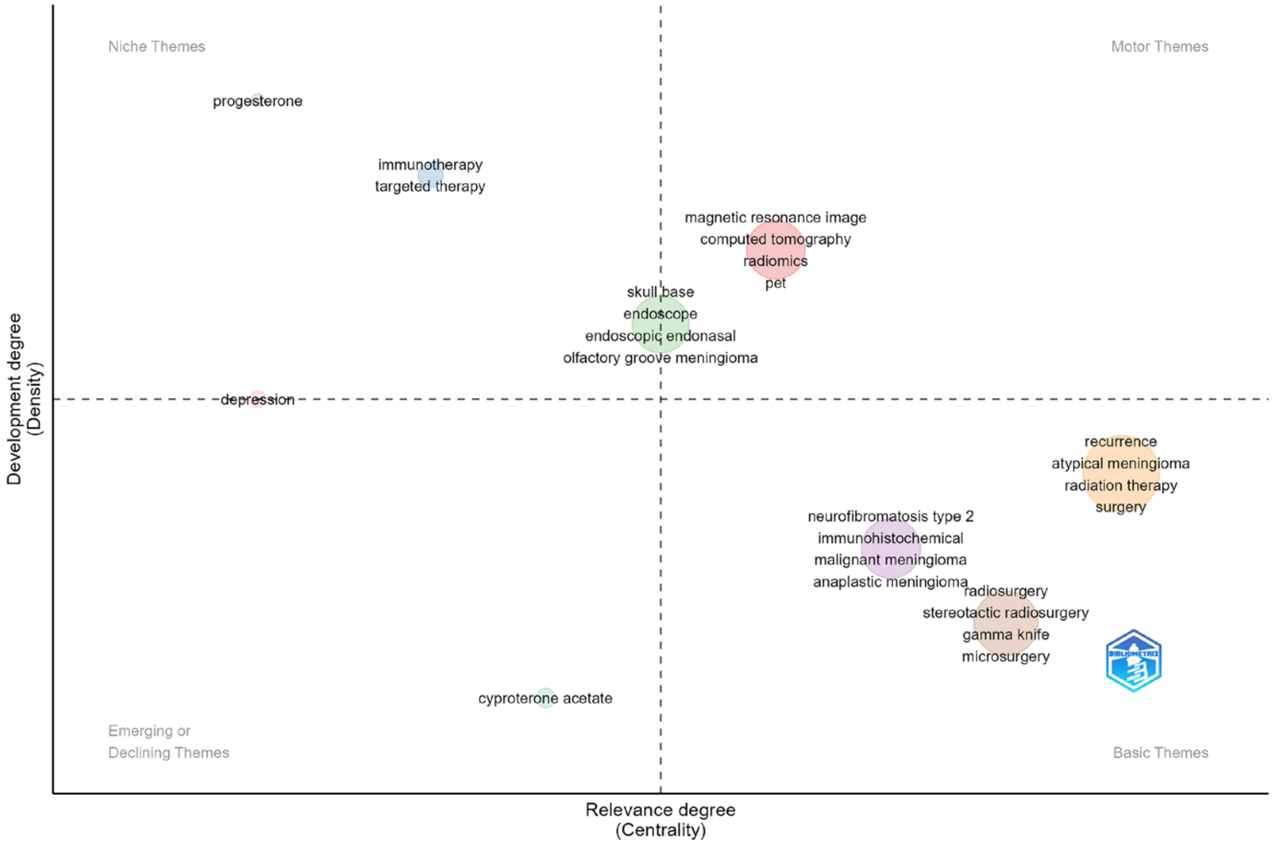

Figure 10. Thematic evolution maps for the periods 2014–2023. Thematic maps obtained for each period; top right quadrant: motor themes (1), bottom right quadrant: basic themes (2), bottom left quadrant: emerging or declining themes (3), top left quadrant: highly specialized/niche themes (4). When assessing findings, it is important to consider motor themes, which represent the primary and prominent themes in a research field, often reflecting widely studied topics across numerous studies. In contrast, niche themes typically signify narrower or more specialized subjects focused on specific areas of interest, often representing new and emerging research topics compared to motor themes.

about medulloblastoma and discussed the anticipated research topics for medulloblastoma in the coming years.[35] Another bibliometric study conducted by Zhang et al (2022) on brain tumors highlighted global trends in glioma radiotherapy and contributed to the literature search for researchers investigating glioma radiotherapy.[36]

When the results obtained from the literature were examined, it was concluded that there was no comprehensive bibliometric study on the subject of meningioma. In November 2016, Almutairi et al (2017) conducted a title-specific search of the Scopus database to determine articles related to meningioma with a high number of citations, and identified the top 100 studies with the most citations.[37] The results obtained in the study by Almutairi et al (2017) were similar to those of the current study. By focusing on all aspects of meningioma, the current study is the first comprehensive bibliometric study on this subject. Therefore, this study can be considered to show superior aspects to other bibliometric studies. Other superior aspects of the current study can be said to be that in addition to citation and co-citation analyses, global productivity, and trend research topics were also examined. Of the WoS, PubMed, and Scopus databases, only the WoS database was used in the literature search of this study.

The reason for this was that the PubMed database is not preferred in bibliometric analyses as citation analyses cannot be performed using this database, and the effect level of the Scopus database is low for some indexed journals. That only the WoS database was used could be said to be a limitation of this study.[5–7] However, the most important reason for selecting the WoS database, which has been widely used in other bibliometric studies in literature, was that compared to other databases, it indexes articles published in journals with higher impact levels (journals scanned in SCI-Expanded and E-SCI indexes).[5–7,38] Another limitation of our study is the exclusion of analyses for the year 2024. This is because the year 2024 is not yet complete. As mentioned in some studies in the literature, it is not recommended to include an incomplete year in bibliometric analyses. Therefore, we included up to the year 2023 in our analyses.

5. Conclusion

In this bibliometric analysis, a summary is presented of the analyses of 9619 articles published on the subject of meningioma between 1980 and 2023. The scientific productivity on the subject of meningioma showed a chronological increase over the years. In addition to high-grade meningiomas, the most studied topics from past to present have been magnetic resonance imaging, recurrence, radiation therapy, and skull base. As a result of the analyses to determine trend topics, the subjects studied in recent years were diagnostic and imaging methods, surgical and treatment methods, prognosis and survival, epidemiology and quality of life, and with the advancement of technology, machine learning and prediction models. Scientific collaboration was seen primarily in articles from western countries, especially the USA, European countries, and Canada. However, there was also a not insignificant effect in developing countries such as China, India, and Turkey. There was found to be significant global collaboration on the subject of meningioma, but there can be considered to be a need to encourage research in under-developed countries in particular.

Author contribution

Conceptualization: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Data curation: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir.
Formal analysis: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir.
Investigation: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Methodology: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Resources: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Software: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Supervision: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Validation: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Visualization: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Writing – original draft: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.
Writing – review & editing: Serdal Kenan Köse, Gülçin Aydoğdu, Emre Demir, Murat Kiraz.

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