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RESEARCH

A bibliometric analysis of research trends and hotspots of pilocytic astrocytoma from 2004 to 2023

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Abstract

Pilocytic astrocytoma (PA) is a WHO grade I neoplasm with a favorable prognosis. It is the most common pediatric benign tumor. Recently, PA has attracted more and more attention and discussion from scholars. The aim of this study is to comprehensively generalize the evolution of this field over the past two decades through bibliometric analysis and to predict future research trends and hotspots. The literature over the last two decades (2004–2023) related to PA was obtained from the Web of Science Core Collection (WoSCC) database. Bibliometric analyses were conducted based on the following aspects: (1) Annual publication trends; (2) Publications, citations/co-citations of different countries/institutions/journals/authors; (3) the map of Bradford's Law and Lotka's Law for core journals and author productivity; (4) Co-occurrence, cluster, thematic map analysis of keywords. All analyses were performed on VOSviewer and R bibliometrix package, and Excel 2024. Our results showed that research on PA displayed a considerable development trend in the past 20 years. The USA had a leading position in terms of scientific outputs and collaborations. Meanwhile, German Cancer Research Center contributed the most publications. *Child's Nervous System* had the highest number of publications and *Acta Neuropathologica* was the most co-cited journal on this subject. Gutmann, D.H. and Louis, D.N. were the authors with the most articles and co-citations in this field. The research emphases were molecular mechanisms, neurofibromatosis, pilomyxoid astrocytoma, differential diagnosis, and therapy. We systematically analyzed the literature on PA from a bibliometric perspective. The demonstrated results of the knowledge mapping would provide valuable insights into the global research landscape.

Keywords Bibliometrics · Pilocytic astrocytoma · Pilomyxoid astrocytoma · Low-grade glioma · Pediatric brain tumor · BRAF

Introduction

According to the report of Central Brain Tumor Registry of the United States (CBTRUS), Pilocytic astrocytoma (PA) is classified as a WHO grade I tumor. For children (0–14 years), PA accounts for 19.5% of CNS tumors. As individuals aged, the incidence rate of PA fell and was higher in the younger age groups [1]. It is the most common benign brain tumor in children. PA is found in the cerebellum, optic chiasma, hypothalamus, cerebral hemispheres, and brainstem, 80% of which is found in the cerebellum [2]. The majority of pilocytic astrocytomas (PAs), especially those originating in the cerebellum, exhibit *BRAF* fusions or, less commonly, *BRAF V600E* mutations [3]. The discussion section will provide a detailed exploration of molecular alterations in PAs.

In general, PAs present a highly favorable prognosis, with an overall 10-year survival rate exceeding 90% [4, 5]. However, in the case of incomplete resection, progression, and recurrence, patients have less Progression-Free Survival (PFS) and Overall Survival (OS) [4, 6]. In addition, adult patients and those with the pilomyxoid astrocytoma (PMA) variant tend to have a less favorable prognosis [7–10]. Most

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researchers agreed that the extent of resection (EOR) was the predominant prognostic factor of PA. The rate of recurrence for PA at any intracranial location is highly dependent on an initial EOR [11–17]. The primary tumor location has demonstrated an independent association with Event-Free Survival (EFS) and PFS among pediatric patients with PA [11, 14]. Some studies have found significant associations between molecular factors and survival outcomes. *BRAF* fusion, oncogenic mutations of *FGFR1*, insulin-like growth factor 2 mRNA binding protein 3 (IMP3, IGF2BP3), and gain of whole chromosome 7 were found to be significantly associated with EFS and OS [16, 18, 19]. Radiologically, tumors demonstrating invasion, solid composition, and exophytic components are prone to recurrence [11, 12]. In adults, multiple studies have identified higher age as a significant prognostic factor [8, 17, 20–23].

Bibliometric analysis is a quantitative method used to portray knowledge structures and trends in a field, simultaneously assessing research output, productivity, and impact [24]. The conventional classification and summarization of literature heavily rely on subjective author judgments, posing challenges to analyzing a substantial volume of literature comprehensively and accurately. To tackle this challenge, employing scientific cartography through bibliometric quantitative analysis can illuminate the structure and evolution of research domains [25]. Tools like VOSviewer [26] and the R package "bibliometrix" [27] are frequently used to visually represent literature analysis findings, particularly in medical disciplines. Noteworthy is the significant surge in the literature on Pilocytic Astrocytoma (PA) over the past two decades. In 2022, Bauman et al. identified the top 100 most cited publications on PA via bibliometric analysis [28]. Nevertheless, our search results indicate a total of 2565 publications from 2004 to 2023, suggesting a potential oversight of some important literature in their analysis. Additionally, their coverage of trend topics might have been limited. This study aims to comprehensively generalize the development of this domain over the past two decades through bibliometric analysis and to forecast future research directions.

Methods

Data collection

Documents were extracted from the Web of Science Core Collection (WoSCC) database on October 28th, 2024 using the search query: "(((((TS = (pilocytic astrocytoma)) OR TS = (pilocytic astrocytomas)) OR TS = (juvenile pilocytic astrocytoma)) OR TS = (juvenile pilocytic astrocytomas)) OR TS = (pilomyxoid astrocytoma)) OR TS = (pilomyxoid astrocytomas)" with a period of 2004–2023. The search was confined to articles and reviews, and only publications in English were considered. The detailed process of data collection is illustrated in Fig. 1.

Data analysis

VOSviewer (version 1.6.19) serves as a robust software tool facilitating the creation of bibliometric maps derived from network data. It offers visualization and exploration capabilities for these maps [26, 29]. In our analysis, we utilized network visualization and overlay visualization techniques to construct networks encompassing countries, institutions, journals, authors, references, and keywords. Connections within these networks are established through co-authorship, co-occurrence, citation, and co-citation links. The color, node size, and line thickness between nodes signify numbers, clusters, and the degree of collaboration of these items [30]. Additionally, utilizing the "bibliometrix" package (version 4.3.0) in the R programming language [27, 31], we mapped the global distribution network, core sources by Bradford's Law, author productivity through Lotka's Law, and the trend topics. What's more, quantitative changes in annual publications were analyzed using Microsoft Excel 2024.

Results

Quantitative analysis of publications

Performing a quantitative analysis of publications in a specific field serves as a valuable tool to discern prominent trends and focal points. In this study, we identified 1988 publications, comprising 1687 articles and 301 reviews, through the screening process illustrated in Fig. 1. As is depicted in Fig. 2, the number of publications per year has steadily increased over the past 20 years, with occasional dips, and peaked in 2022. We can notice that the number of publications in 2004 was 46, indicating a sustained and substantial scholarly attention toward PA.

Country and institution

These publications came from 83 countries and 2364 institutions. The top 10 countries are distributed in North America ($n = 2$), Europe ($n = 5$), and Asia ($n = 3$) (Table 1). Among the most productive countries, the USA led with 756 publications (38.03%), followed by Germany ($n = 251$, 12.63%), England ($n = 135$, 6.79%), and Japan ($n = 135$, 6.79%). International collaborations of active countries/regions were assessed and presented in a network visualization map (Fig. 3A). Then, we filtered and visualized 34 countries with 10 or more publications (Fig. 3B). The thickness of links between any

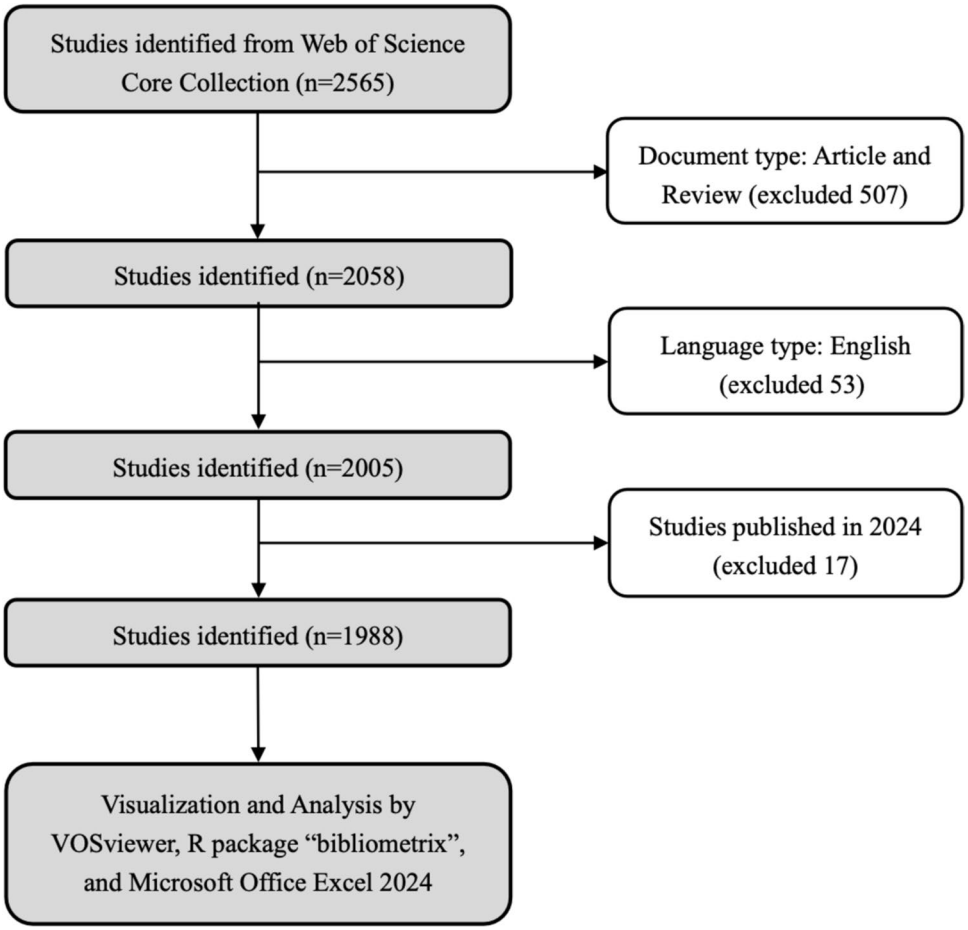


Fig. 1 Flowchart displaying the data collection process

two countries or regions indicates the strength of collaboration and the node size represents the amount of publications [32]. Notably, the network visualization map reveals that the USA has close cooperation with Germany, Canada, England, Italy, Switzerland, France, and Brazil. Based on Fig. 3B, it can be said that China has become an active country in this field, particularly due to the studies conducted after 2016, suggesting a significant increase in its contributions.

The top 10 institutions are situated across three countries: the USA ($n=4$), Germany ($n=3$), and Canada ($n=3$). German Cancer Research Center (Germany), Washington University in St. Louis (Canada), St. Jude Children's Research Hospital (USA), University of California, San Francisco (USA), and Johns Hopkins University (USA) have published over 50 papers. Subsequently, we visualized the institution co-authorship analysis using VOSviewer, which included institutions with a minimum of 20 publications. As illustrated in Fig. 4, the German Cancer Research Center works closely with Heidelberg University and Heidelberg University Hospital.

Journals and co-cited journals

Our bibliometric analysis identified 481 journals that have published articles on PA, with the top 10 journals accounting for 595 publications (29.93%). *Child's Nervous System* had the highest number of publications ($n=131$, 6.69%), followed by *Journal of Neuro-oncology* ($n=99$, 4.98%), and *World Neurosurgery* ($n=61$, 3.07%). As is shown in Table 2, the journal and the co-cited journal with the highest impact factor are *Neuro-oncology* (IF = 16.4, Q1) and *Journal of Clinical Oncology* (IF = 37.4, Q1). Despite relatively lower publication counts for the *Journal of Neurosurgery* ($n=39$) and *Acta Neuropathologica* ($n=38$), their total citations were notably high, both being classified under the Q1 category in the 2024 JCR partition.

Subsequently, we conducted a visual analysis of co-authorship among journals and co-cited journals using VOSviewer. This analysis included journals and co-cited journals with a minimum of 10 publications and 400 co-citations. Figure 5A illustrates active cooperation between *Child's Nervous System* and journals like *Journal of*

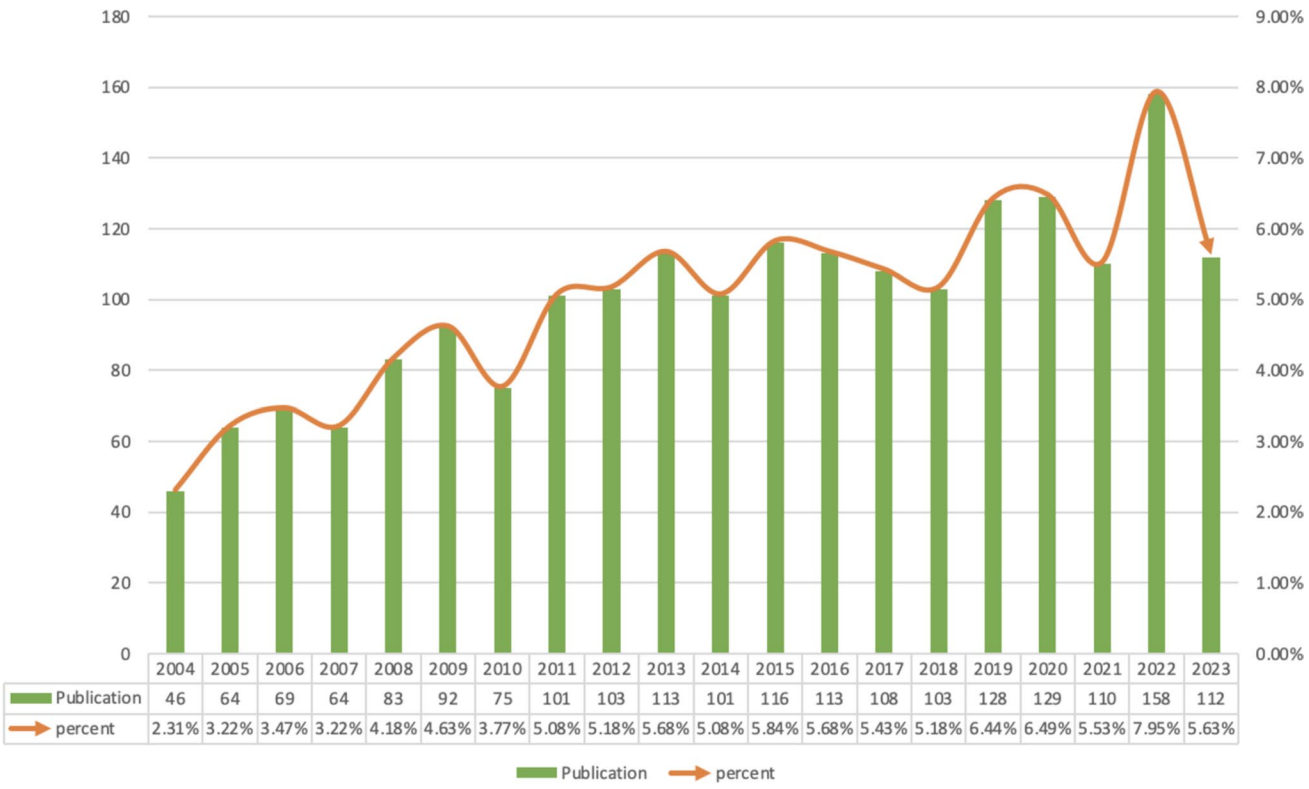


Fig. 2 Annual publications of PA

Table 1 Top 10 countries and institutions on the research of PA

Rank	Country	Counts	Institution	Counts
1	USA (North America)	756 (38.03%)	German Cancer Research Center (Germany)	74(3.72%)
2	Germany (Europe)	251 (12.63%)	Washington University in St. Louis (Canada)	71(3.57%)
3	England (Europe)	135 (6.79%)	St. Jude Children's Research Hospital (USA)	59(2.97%)
4	Japan (Asia)	135 (6.79%)	University of California, San Francisco (USA)	58(2.92%)
5	Canada (North America)	124 (6.24%)	Johns Hopkins University (USA)	51(2.57%)
6	Italy (Europe)	117 (5.89%)	Mayo Clinic (USA)	41(2.06%)
7	China (Asia)	112 (5.63%)	Heidelberg University (Germany)	40(2.01%)
8	France (Europe)	104 (5.23%)	University of Toronto (Canada)	39(1.81%)
9	India (Asia)	98 (4.93%)	Hospital for Sick Children (Canada)	36(1.81%)
10	Switzerland (Europe)	58 (2.92%)	University of Bonn (Germany)	31(1.56%)

Neurosurgery-pediatrics, *Pediatric blood & cancer, Journal of Neuro-oncology, and Neuro-oncology.* Additionally, Fig. 5B reveals positive co-citation relationships between *Acta Neuropathologica* and *Cancer Research*, as well as active collaborations of *Journal of Clinical Oncology* with *Neuro-oncology*.

Moreover, Bradford's law was employed to evaluate the scholarly influence of journals, and the resulting map generated using "bibliometrix" aids in identifying journals with substantial impact [33]. The core journals highlighted in Fig. 5C align consistently with the findings presented in Table 2, derived from VOSviewer analysis.

Authors and co-cited authors

A total of 10,023 researchers and 25,959 co-cited authors made contributions to the 1988 publications in the field of PA from 2004 to 2023. Within the top 10 authors, Gutmann, D.H. holds the highest number of publications ($n = 40$), followed closely by Rodriguez, F.J. ($n = 35$). On the other hand, Louis, D.N. emerges as the most frequently

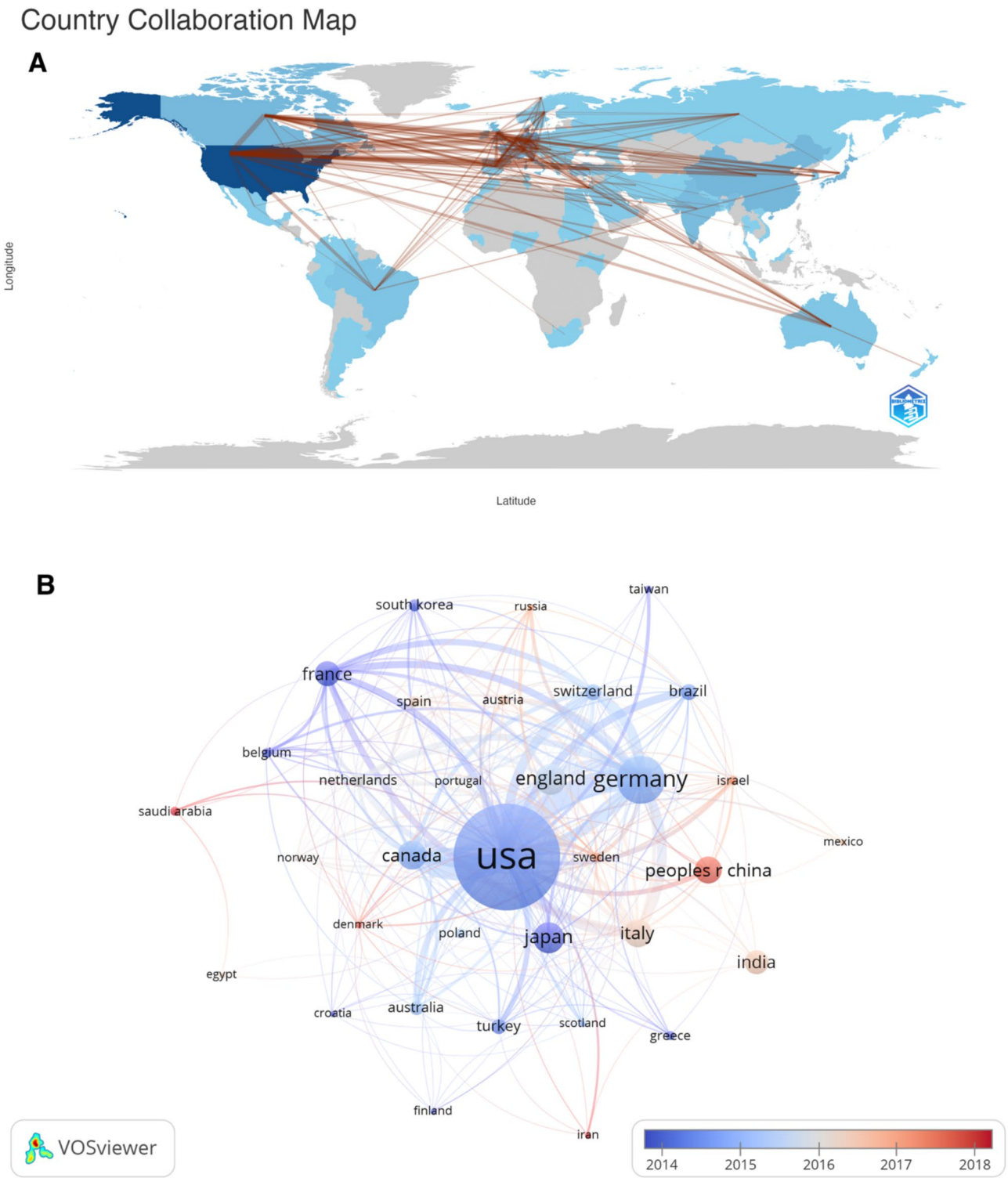


Fig. 3 The geographic distribution of global publications (**A**) and visualization of countries (**B**) on the research of PA

co-cited author, followed by Jones, D.T.W. (Table 3). Co-cited authors are those simultaneously referenced in two or more papers, forming interconnections within the scholarly network [34].

Subsequently, we conducted a co-authorship analysis of authors and co-cited authors using VOSviewer, containing those with a minimum of 13 publications and 100 co-citations. Rodriguez, F.J. demonstrated a total link strength

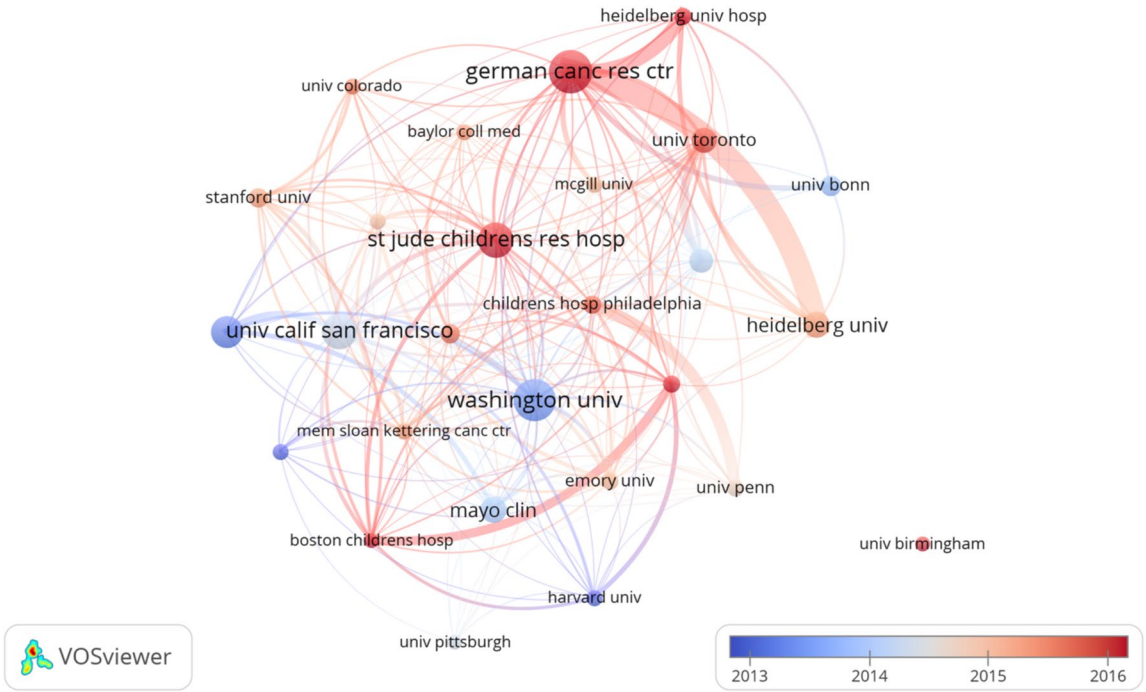


Fig. 4 The visualization of institutions on the research of PA

Table 2 Top 10 journals and Top 10 co-cited journals on the research of PA

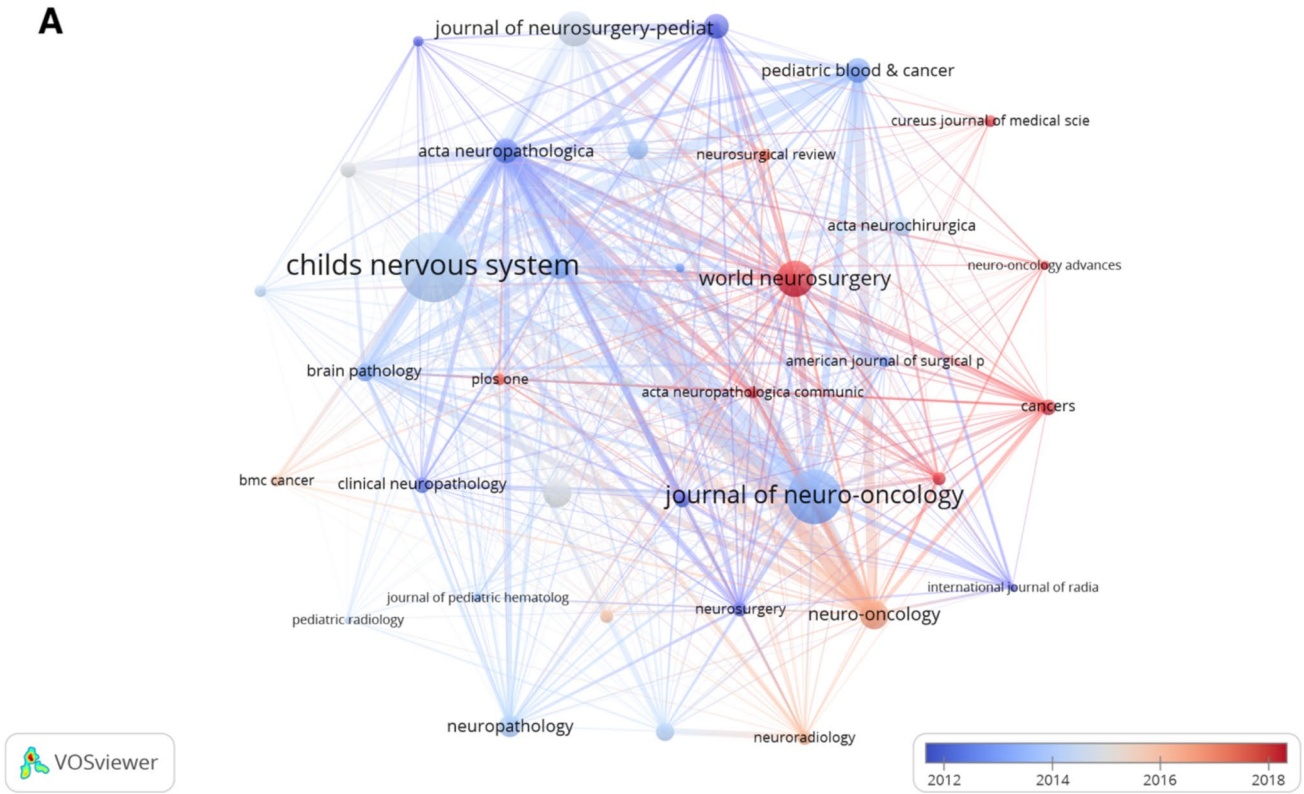
Rank	Journal	Count	IF	Q	Co-cited Journal	Co-citation	IF	Q
1	*Child's Nervous System*	133(6.69%)	1.3	Q3	*Acta Neuropathologica*	3296	9.3	Q1
2	*Journal of Neuro-oncology*	99(4.98%)	3.2	Q2	*Journal of Neurosurgery*	3068	3.5	Q1
3	*World Neurosurgery*	61(3.07%)	1.9	Q2	*Neuro-oncology*	2420	16.4	Q1
4	*Journal of Neurosurgery-pediatrics*	57(2.87%)	2.1	Q2	*Journal of Neuro-oncology*	2211	3.2	Q2
5	*Neuro-oncology*	46(2.31%)	16.4	Q1	*Journal of Clinical Oncology*	2069	37.4	Q1
6	*Journal of Clinical Neuroscience*	45(2.26%)	1.9	Q4	*Child's Nervous System*	2044	1.3	Q3
7	*Journal of Neuropathology and Experimental neurology*	39(1.96%)	3.2	Q2	*Neurosurgery*	1994	3.9	Q1
8	*Journal of Neurosurgery*	39(1.96%)	3.5	Q1	*Cancer Research*	1775	12.5	Q1
9	*Acta Neuropathologica*	38(1.91%)	9.3	Q1	*Journal of Neuropathology and Experimental Neurology*	1642	3.2	Q2
10	*Pediatric blood & cancer*	38(1.91%)	2.4	Q1	*American Journal of Neuroradiology*	1160	3.1	Q1

of 1030, indicating significant collaborative ties within the scholarly community. Figure 6A displays the strongest connection observed between Gutmann, D.H. and Rodriguez, F.J., highlighting their close collaboration. Additionally, Fig. 6B indicates a notable partnership between Louis, D.N. and Jones, D.T.W. It's worth noting that the top 2 co-cited authors also exhibit robust collaborative ties.

The application of Lotka's law (conducted by "bibliometrix") to gauge author productivity unveiled that approximately 95% of manuscripts originated from authors with just one published document, while around 3% were attributed to authors with two published documents. This analysis underscores the prevalent trend in this field, illustrating that the majority of authors demonstrate low productivity, while a small subset contributes significantly to the volume of publications [35] (Fig. 6C).

Co-cited references

Over the past two decades, the domain of PA has amassed 37,318 co-cited references. Among the top 10 co-cited



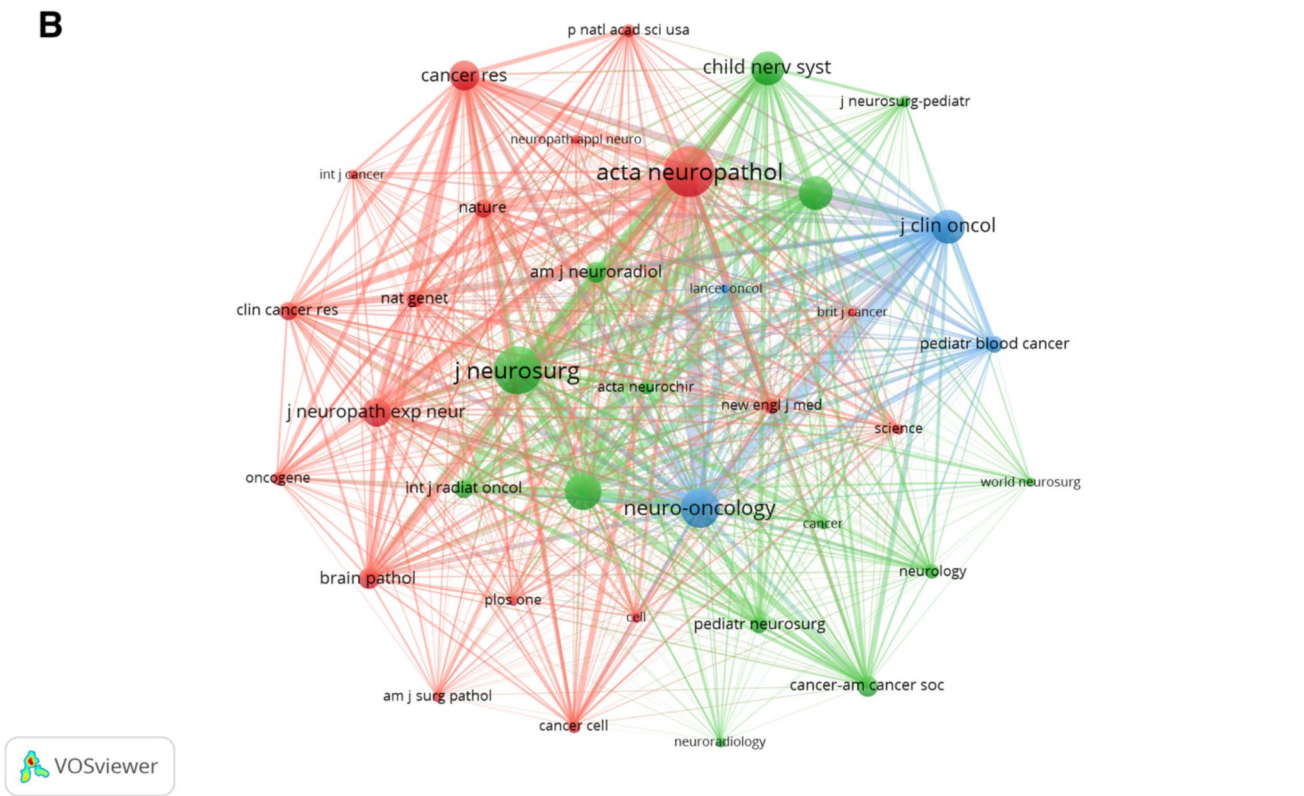


Fig. 5 The visualization of journals (**A**), co-cited journals (**B**), and the map of core sources by Bradford's Law (**C**) on the research of PA

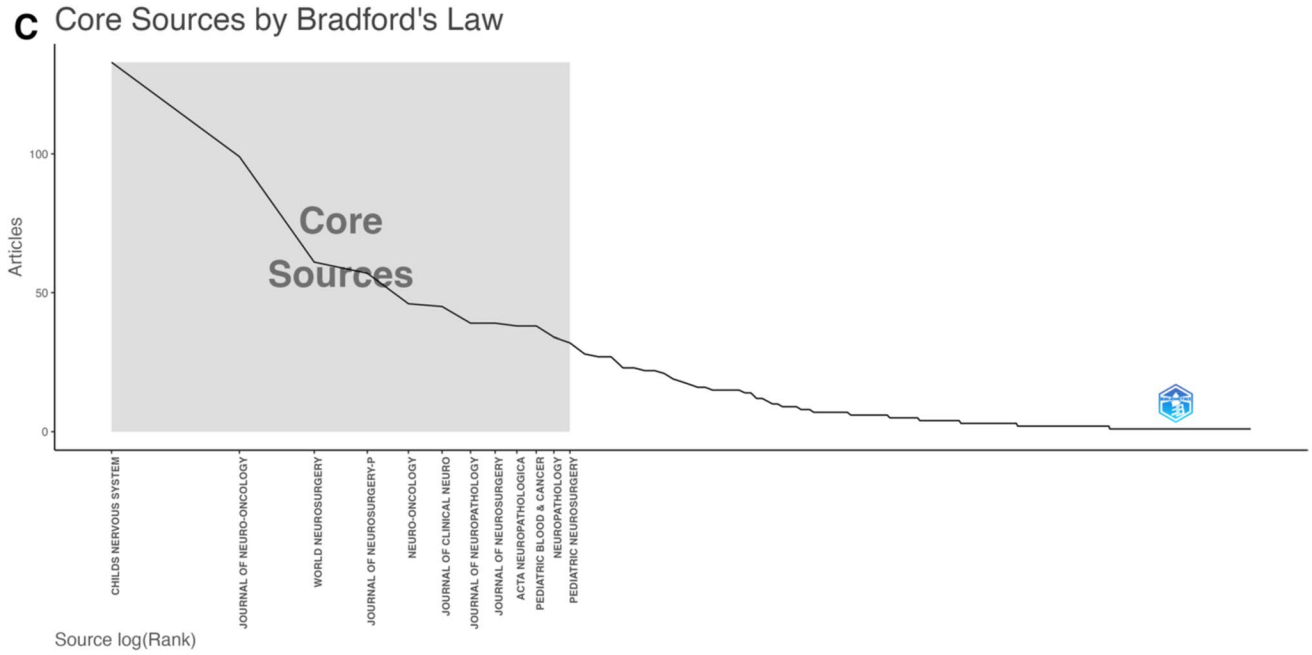


Fig. 5 (continued)

Table 3 Top 10 authors and co-cited authors on the research of PA

Rank	Authors	Count	Co-Cited Authors	Co-citations
1	Gutmann, D.H	40	Louis, D.N	839
2	Rodriguez, F.J	35	Jones, D.T.W	702
3	Jones, D.T.W	22	Packer, R.J	332
4	Pietsch, T	22	Pollack, I.F	328
5	Tihan, T	22	Ostrom, Q.T	267
6	Eberhart, C.G	20	Rodriguez, F.J	249
7	Perry, A	20	Sievert, A.J	204
8	Pfister, S.M	19	Korshunov, A	203
9	Korshunov, A	18	Listernick, R	201
10	Hawkins, C	16	Gutmann, D.H	195

references (Table 4), Jones, D.T.W. and Louis, D.N. contributed two papers each. Notably, four of these top 10 references were published in *Acta Neuropathologica* (IF = 9.3 Q1). Subsequently, a co-citation analysis of references was visualized using VOSviewer, considering co-cited references with a minimum of 70 citations. Figure 7 highlights an active co-citation relationship between "Jones, D.T.W., 2008, *Cancer Res*" and "Schindler, G., 2011, *Acta Neuropathol*" (in the upper right of the former point).

Hotspots and research trends

In the exploration of research fields, keywords serve as crucial indicators of hotspots and directional trends. Table 5 presents the top 20 keywords based on co-occurrence frequency. We conducted cluster analysis after filtering keywords with more than or equal to 30 occurrences by using VOSviewer. As displayed in Fig. 8A, we obtained six clusters representing six research directions. (1) The keywords in the red cluster consist of children, brain tumors, low-grade glioma, neurofibromatosis type 1 (NF1), chemotherapy, radiotherapy, surgery, prognosis, outcome. (2) The keywords in the green cluster consist of pediatric brain tumor, adult, cerebellum, ependymoma, medulloblastoma, pilocytic astrocytoma, and pilomyxoid astrocytoma. (3) The keywords in the blue cluster consist of pediatric, brain, brain tumor, tumor, oncology, and MRI. (4) The keywords in the yellow cluster consist of pilocytic, astrocytoma, glioblastoma, glioma, oligdendroglioma, and immunohistochemistry. (5) The keywords in the purple cluster consist of BRAF and ganglioglioma. (6) The keyword in the cyan cluster is neurofibromatosis.

Trend topic analysis was conducted to examine emerging topics and their trajectories over time, as shown in Fig. 8B. The results indicate a notable rise in high-frequency keywords from 2013 onward, identifying key trend topics in the field, including pilocytic astrocytoma, pilomyxoid astrocytoma, BRAF, and differentiation from other gliomas.

Discussion

General information

This study systematically analyzed 1988 publications from 83 countries on pilocytic astrocytoma (PA) over the past

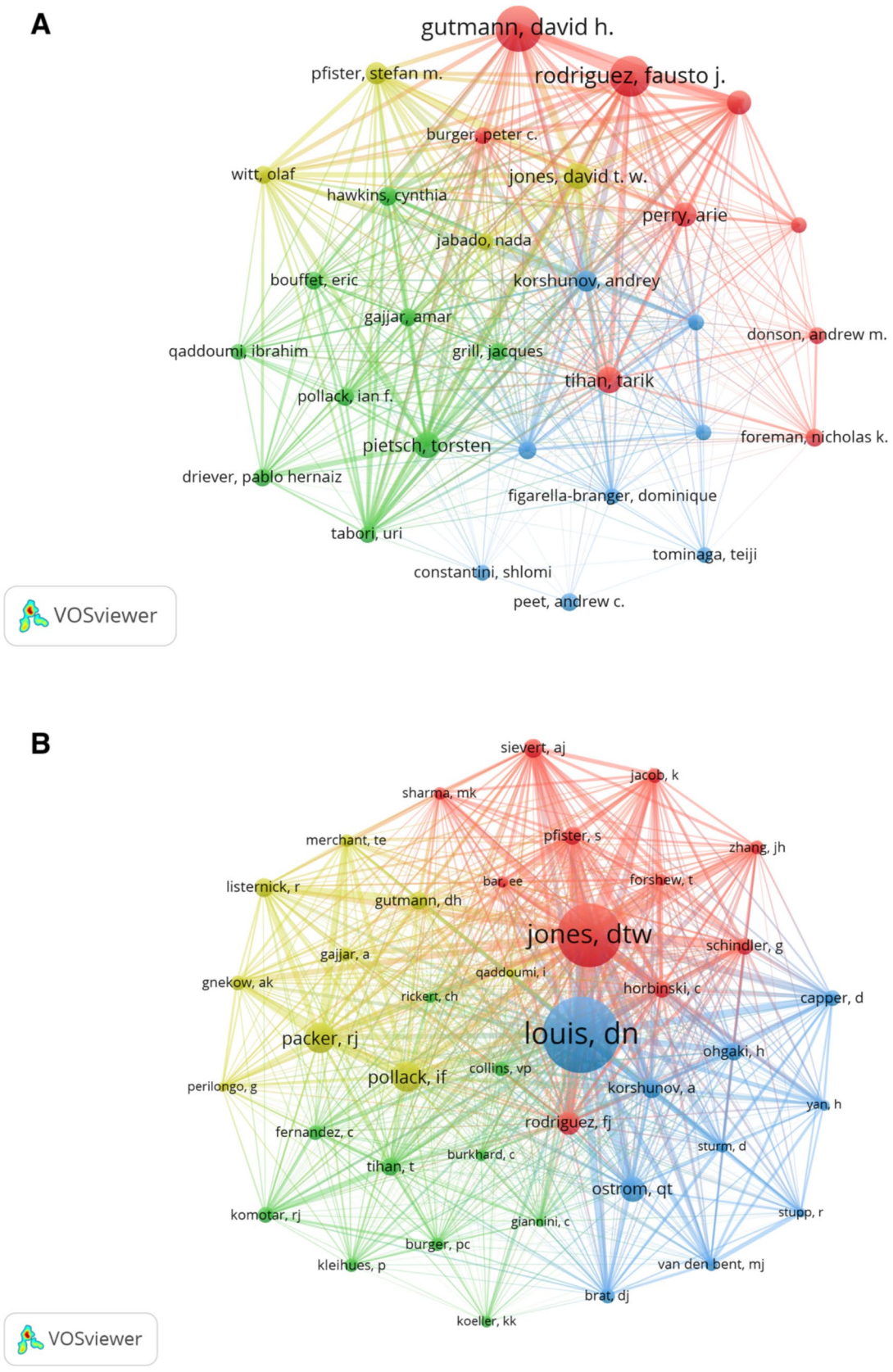


Fig. 6 The visualization of authors (**A**), co-cited authors (**B**), and the map of author productivity through Lotka's Law (**C**) on the research of PA

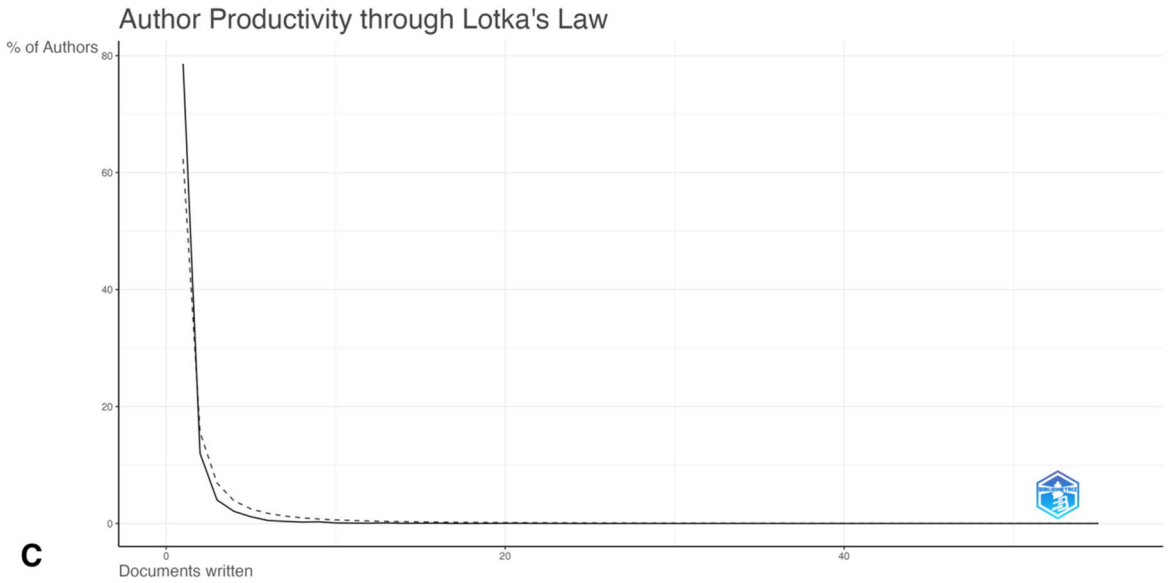


Fig. 6 (continued)

two decades. The annual output of publications exhibited a fluctuating yet predominantly upward trend, with 2022 marking the peak in literature volume. The USA and Germany have emerged as the leading contributors, surpassing

Table 4 Top 10 co-cited references on the research of PA

Rank	Article Title	Citations	Published Year	Journal	Author
1	Tandem duplication producing a novel oncogenic BRAF fusion gene defines the majority of pilocytic astrocytomas [36]	239	2008	*Cancer Research* (IF = 12.5 Q1)	Jones, D.T.W
2	The 2016 World Health Organization Classification of Tumors of the Central Nervous System: a summary [37]	216	2016	*Acta Neuropathologica* (IF = 9.3 Q1)	Louis, D.N
3	The 2007 WHO classification of tumours of the central nervous system [38]	207	2007	*Acta Neuropathologica* (IF = 9.3 Q1)	Louis, D.N
4	Analysis of BRAF V600E mutation in 1,320 nervous system tumors reveals high mutation frequencies in pleomorphic xanthoastrocytoma, ganglioglioma and extra-cerebellar pilocytic astrocytoma [39]	186	2011	*Acta Neuropathologica* (IF = 9.3 Q1)	Schindler, G
5	BRAF gene duplication constitutes a mechanism of MAPK pathway activation in low-grade astrocytomas [40]	168	2008	*Journal of Clinical Investigation* (IF = 13.3 Q1)	Pfister, S
6	Recurrent somatic alterations of FGFR1 and NTRK2 in pilocytic astrocytoma [41]	165	2013	*Nature Genetics* (IF = 31.7 Q1)	Jones, D.T.W
7	Whole-genome sequencing identifies genetic alterations in pediatric low-grade gliomas [42]	147	2013	*Nature Genetics* (IF = 31.7 Q1)	Zhang, JH
8	Pilocytic astrocytoma: pathology, molecular mechanisms and markers [4]	141	2015	*Acta Neuropathologica* (IF = 9.3 Q1)	Collins, V.P
9	Pilocytic astrocytomas in children: prognostic factors–a retrospective study of 80 cases [11]	137	2003	*Neurosurgery* (IF = 3.9 Q1)	Fernandez, C
10	Pediatric astrocytomas with monomorphous pilomyxoid features and a less favorable outcome [43]	137	1999	*Journal of Neuropathology and Experimental Neurology* (IF = 3.2 Q2)	Tihan, T

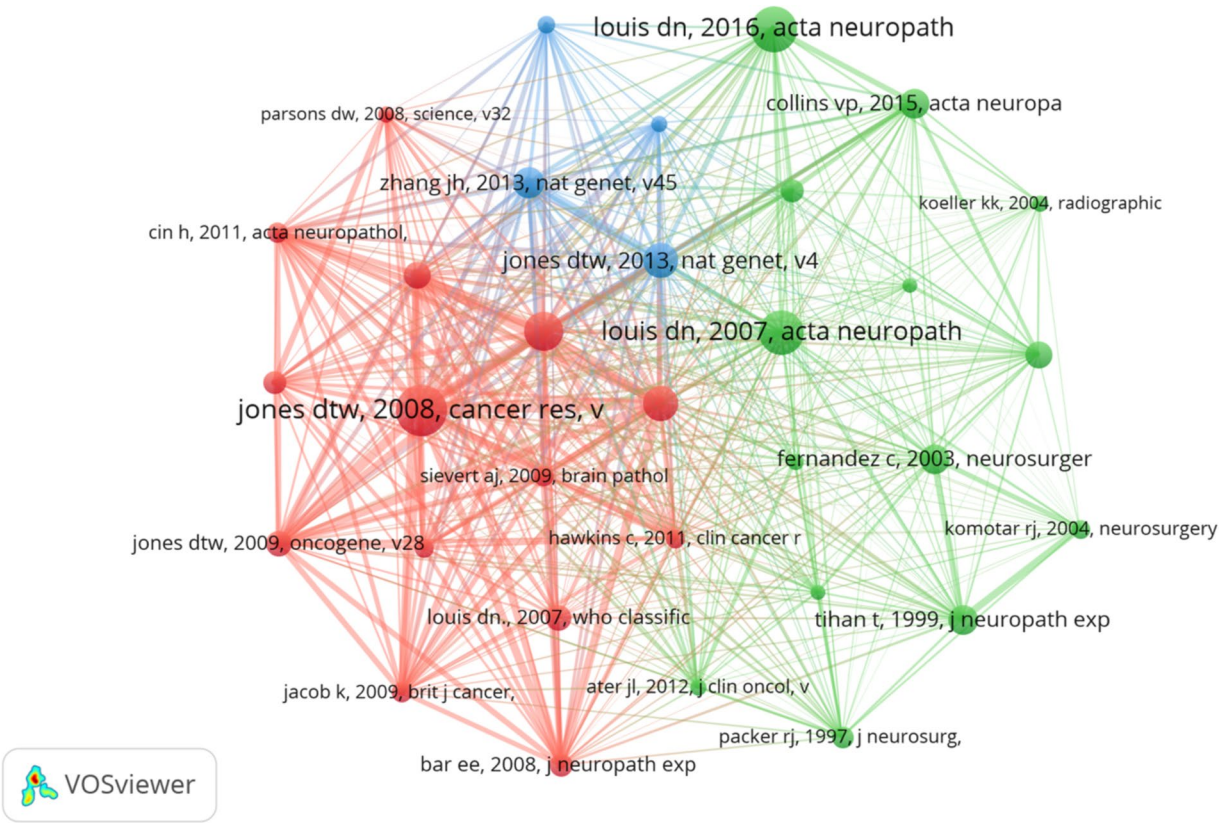


Fig. 7 The co-citation analysis of references on the research of PA

Table 5 Top 20 author keywords on the research of PA

Rank	Keywords	Occurrences	Rank	Keywords	Occurrences
1	pilocytic astrocytoma	393	11	pilomyxoid astrocytoma	132
2	glioma	286	12	ependymoma	121
3	astrocytoma	262	13	immunohisochemistry	109
4	brain tumor	214	14	chemotherapy	107
5	pediatric	196	15	oncology	102
6	braf	174	16	magnetic resonance imaging	97
7	glioblastoma	156	17	oligodendroglioma	97
8	low grade glioma	143	18	prognosis	94
9	children	142	19	brain tumors	92
10	medulloblastoma	139	20	mri	86

other countries in publication count. The USA garnered the highest citation count and exhibited the most robust link strength. In addition, among the top 10 institutions with the most published papers, four were situated in the USA, three in Germany, and three in Canada. In terms of journals, the most productive journals and co-cited journals were *Child's Nervous System* and *Acta Neuropathologica*. *Neuro-oncology* (IF = 16.4) and *Journal of Clinical Oncology* (IF = 37.4) were identified as the journals with the greatest impact factor in journals and co-cited journals. Notably, three of the top ten co-cited journals had impact factors surpassing ten, offering robust support for PA studies. Regarding authors, Gutmann, D.H. ($n = 40$) and Rodriguez, F.J. ($n = 35$) emerged as the most productive authors, while Louis, D.N. ($n = 839$) and Jones, D.T.W. ($n = 702$) accrued the highest co-citations, signifying their prominent role in PA research. The top 10 co-cited references predominantly explored

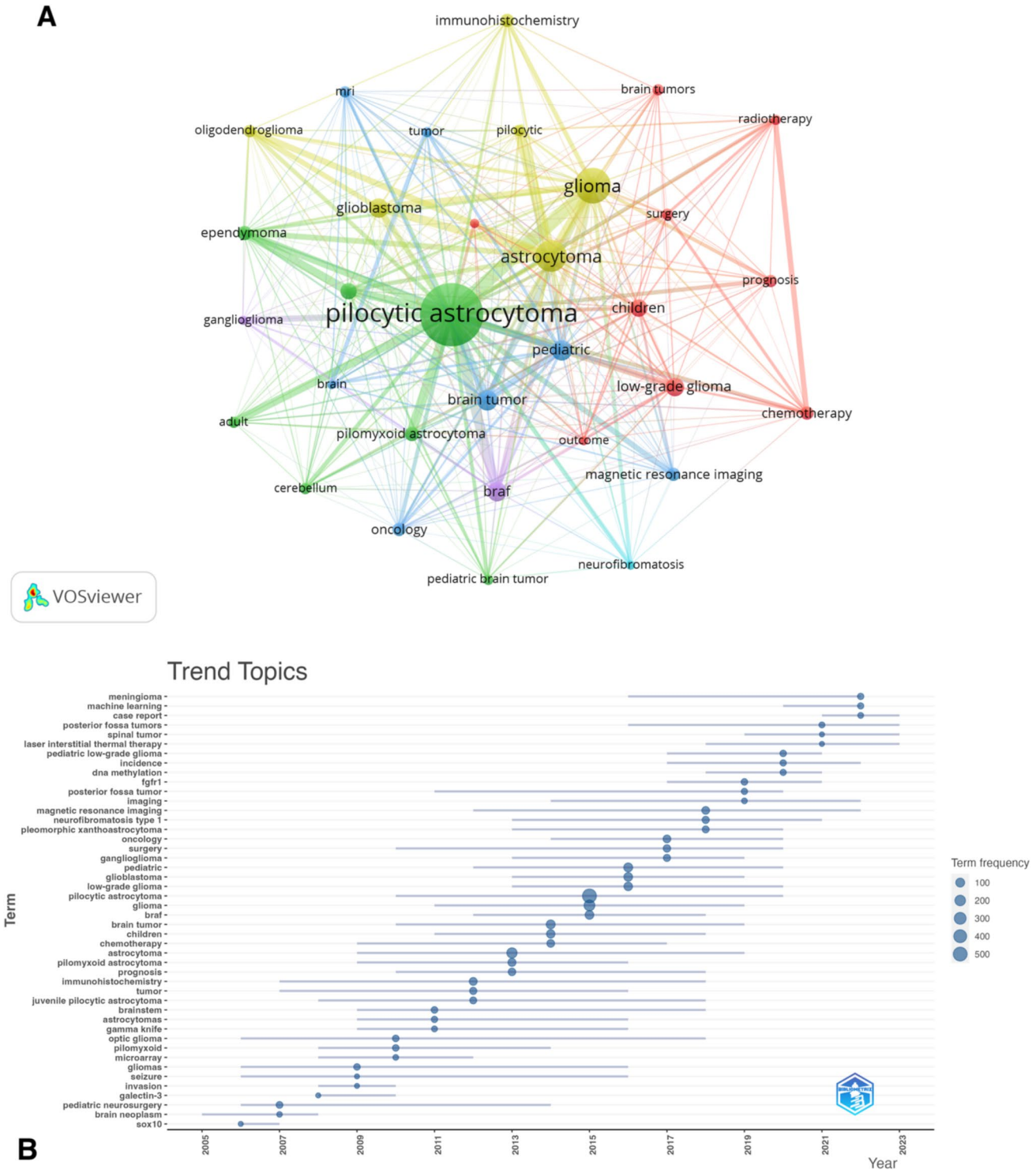


Fig. 8 The co-occurrence analysis of keywords-Plus and trend topics on the research of PA

molecular mechanisms of PA, with nine published in first-quartile (Q1) journals.

Utilizing VOSviewer and "bibliometrix", we analyzed keyword clusters and the trend topics for PA. The co-occurrence of author keywords in PA delineated xx research directions: (1) comprehensive therapy for PA with or without NF1, encompassing chemotherapy, radiotherapy, and surgery. (2) Differential diagnosis of PA, particularly distinguishing it from cerebellar tumors such as ependymoma and medulloblastoma, and from pilomyxoid

astrocytoma in pathology. (3) Differentiation from other astrocytic tumors, such as glioblastoma and oligodendroglioma, utilizing immunohistochemistry. (4) Differentiation from gangliogioma with *BRAF* mutation. (5) Clinical and genetic correlations with NF1. This detailed analysis sheds light on hotspots and frontiers in this domain.

Hotspots and frontiers

Molecular mechanisms

In 2008, multiple studies identified a common trait in PAs: a focal duplication of 2.5 Mb at 7q34. This duplication led to a tandem fusion gene between *KIAA1549* and *BRAF*, swiftly recognized as a transforming event [36, 44, 45]. This fusion resulted in the loss of the *BRAF* N-terminal autoregulatory domain, activating its kinase domain [36, 40]. The fusions between *KIAA1549* and *BRAF* emerged as the most prevalent genetic alterations in PAs [36, 45], particularly involving *KIAA1549* exon 16 and *BRAF* exon 9 as the most frequent fusion events [46]. Other genetic alterations of PAs encompass other *BRAF/RAF1* fusions, *BRAF V600E* mutation, *KRAS* mutation, *FGFR1* mutation, *FGFR1-ITD*/fusion, *NTRK* fusions, and germline *NF1* mutation. Interestingly, the spectrum of *MAPK* (mitogen-activated protein kinase) pathway alterations differs among anatomical locations. The *KIAA1549:BRAF* fusion predominantly occurs in the cerebellum, while *BRAF V600E* mutation and *NTRK* family fusions are more prevalent in supratentorial PAs. *FGFR1* alterations are frequently found in midline PAs [4]. However, the underlying basis for this intriguing relationship between the site/cell of origin and specific molecular alterations remains unclear.

Neurofibromatosis type 1 (NF1) arises from an NF1 gene mutation, encoding neurofibromin, a pivotal protein involved in RAS-RAF signaling within the *MAPK* and *mTOR* pathways [47]. Neurofibromin loss heightens RAS activity, stimulating the *MEK-ERK* (*MAPK*) and *PI3K-Akt-mTOR* (mammalian target of rapamycin) pathways [48, 49]. Additionally, mechanisms related to the tumor microenvironment and angiogenesis have been implicated in NF1 [47, 50]. PAs associated with NF1 are typically located in the optic pathway [51–55] and exhibit a more favorable prognosis compared to sporadic PAs [56]. The understanding of the molecular mechanisms underlying NF1 provides valuable insights into the dysregulation of signaling pathways, contributing to the development and progression of PAs associated with this genetic condition.

Adults generally exhibit a poorer prognosis when considering factors such as tumor location, size, extension, surgical approach, and other mortality causes, suggesting divergent clinical courses between adult and pediatric PA patients, possibly due to distinct biological backgrounds [7, 8]. APA cases commonly exhibit fewer *BRAF* alterations but more frequent *FGFR* alterations than pediatric cases. Notably, *KIAA1549-BRAF* fusion shows an inverse correlation with age, while *FGFR1* mutation associates with older age [57–59]. The presence of *KIAA1549-BRAF* fusion in APA does not significantly impact outcomes [58]. In terms of possible mechanisms, Mair et al. demonstrated a higher occurrence of *PI3K/AKT* pathway alterations in an adult patient cohort, correlating with anaplastic features and heightened clinical aggressiveness [8]. Moreover, the activation of *MAPK/ERK/mTOR* signaling appears pivotal in APAs, potentially driving aggressive tumor behavior [57]. This underscores the importance of considering age-related molecular differences in understanding and managing the clinical behavior of PAs.

Pilomyxoid astrocytoma (PMA)

Pilomyxoid astrocytoma (PMA) was recognized as a variant of PA in the 2016 WHO classification scheme [37]. However, the 2021 WHO classification omitted PMA from its listing [60]. PMAs typically arise in the hypothalamic/chiasmatic region, leading to symptoms such as visual disturbances, hormonal imbalances, and growth delays [4, 9, 61]. Pathologically, they exhibit distinct histological characteristics, including a myxoid background, a high density of bipolar cells, and an absence of Rosenthal fibers. Radiologically, distinguishing between PMAs and PAs can be challenging due to their similar appearances. However, specific factors such as tumor location, texture homogeneity, contrast enhancement, presence of cysts, meningeal spread rate [61, 62], arterial spin labeling (ASL) imaging [63], apparent diffusion coefficient (ADC) values, and T2 signal intensity aid in differentiation [64]. PMAs, often found in very young children and challenging-to-access regions, present a worse prognosis compared to PAs, potentially due to difficulties in achieving radical surgical intervention [4, 10]. This highlights the importance of accurate differentiation between PAs and PMAs for effective clinical management and prognosis assessment.

Differential diagnosis

Based on the purple and green keyword clusters and existing knowledge, two focal areas warrant attention: (1) Differential diagnosis among low- and high-grade gliomas, encompassing ganglioglioma (GG), pleomorphic xanthoastrocytoma (PXA), oligodendroglioma (OG), and glioblastoma (GMB); (2) Differential diagnosis of posterior fossa tumors, specifically PA, medulloblastoma, and ependymoma.

Ganglioglioma (GG) represents a mixed glial-neuronal tumor, comprising neoplastic glial elements and dysplastic ganglion cells. Both the *KIAA1549-BRAF* fusion gene

and *BRAF V600E* mutation are prevalent in PA and GG; Nevertheless, the former is more frequent in PA [65], while the latter is more common in GG [39]. Typically, GGs, categorized as WHO grade I neoplasms, predominantly occur throughout the central neuraxis, with over 70% localized to the temporal lobe in the supratentorial compartment. In contrast, PAs are infrequent in the posterior fossa (brain stem and cerebellum) and spinal cord [66]. Research by De-jun She et al. revealed that conventional MRI, DWI, and DSC-PWI aid in differentiating infratentorial GG from PA, with DWI offering optimal sensitivity [67].

Pleomorphic xanthoastrocytoma (PXA), classified as WHO grade II, exhibits poorer outcomes compared to PA and oligodendroglioma, particularly in younger patients. However, even higher-grade PXA patients display significantly better overall survival rates in comparison to glioblastoma [68]. Schindler et al. reported a higher occurrence of *BRAF V600E* mutations in PXA (42/64; 66%), contrasting with a less common rate in PA (9/97; 9%) [39]. Radiologically, PXA is more prevalent in the temporal (83, 39%) and frontal lobes (41, 19%), with fewer instances in the cerebellum (2, 1%) [68].

Oligodendroglioma (OG), classified as WHO grade II, presents as multiple or single complete cystic or cystic-solid nodules, posing challenges in differentiation from cystic astrocytomas like PA. Radiologically, OGs typically display mixed density and slight heterogeneous enhancement, in contrast to the typical appearance of PA in the cerebellum as an expansive, cystic mass with a mural enhancing nodule. Molecularly, oligodendrogliomas are characterized by *IDH1-R132H* and *1p19q* loss, distinguishing features of this tumor [65]. Utilizing gradient boosted trees and texture features from enhanced T1WI could serve as an additional diagnostic tool to enhance accuracy in distinguishing PA from cystic OG [69].

Glioblastoma (GBM): Diffusion-weighted imaging (DWI) and perfusion-weighted imaging (PWI) aid in distinguishing PA with aggressive characteristics from high-grade brain tumors. However, these imaging modalities might not be routinely obtained in some initial work settings [70]. Dong et al. developed a decision tree model in 2019, offering potential assistance in distinguishing between PA and GMB [71].

Posterior fossa tumors (PFTs): Recent research has increasingly utilized radiomics and machine learning techniques to distinguish prevalent posterior fossa tumors such as PA, medulloblastoma, and ependymoma [72–75]. Additionally, apparent diffusion coefficient (ADC) measurements [76–78] and diffusion-weighted imaging (DWI) studies [72, 79] have shown promise in differentiating these tumors in the posterior fossa.

Therapy

As per the National Comprehensive Cancer Network (NCCN) guidelines, resection stands as the primary treatment for PA. Patients with total resection typically do not require further treatment. In cases of incomplete resection in adults, the NCCN recommends options like observation, radiotherapy (RT) for progression or neurologic symptoms, and BRAF/MEK inhibition for tumors harboring BRAFV600E mutation [5]. Similar adjuvant therapy options exist for children, with chemotherapy being preferred in young children to avoid potential radiation toxicity [80]. Currently, there is no established consensus for managing patients with incompletely resected, progressive, or recurrent PA. Chemotherapy (CMT), radiotherapy (RT), and targeted therapy (TT) are considered beneficial for improving their prognosis. According to a substantial retrospective study (n = 485) by Parsons et al. there's a trend where children tend to receive CMT more often and are less likely to undergo RT. Conversely, older patients are more inclined toward RT. Among children, those under 5 years old are the least likely to receive RT, followed by children aged 5 to 10 [80]. This emphasizes the importance of individualized treatment approaches based on age and tumor characteristics.

Cisplatin-based chemotherapy, typically combined with Vincristine, demonstrates efficacy in controlling PA, particularly in the optic pathway and brainstem, thereby delaying the necessity for early radiotherapy [80–83]. Intra-arterial chemotherapy is also considered for managing progressive or unresectable PAs [84]. Advanced radiation techniques like conformal RT [85], stereotactic radiosurgery (SRS) [86–91], and proton therapy [92] aim to minimize radiation exposure to normal brain tissue, potentially reducing RT-related side effects. However, further clinical validation is necessary to ascertain the effectiveness of these newer RT modalities. It's important to recognize pseudoprogression, a common occurrence in PAs, to avoid prematurely subjecting children to additional treatment regimens [93].

In targeted therapy, MEK inhibitors like selumetinib and trametinib present effective strategies against pediatric low-grade gliomas (pLGG) harboring *BRAF* fusion. Trametinib, compared to chemotherapy, shows potential to improve vision in optic pathway gliomas [94]. Targeted therapy notably reduces inpatient stays, clinic visits, and the need for intravenous access in comparison to standard chemotherapy [95]. However, discontinuation of targeted therapy for pLGG often results in disease progression/recurrence shortly afterward [94]. The long-term effects of targeted therapies remain uncertain.

In summary, we believe that chemotherapy is anticipated to persist as the primary treatment option for patients with incompletely resected, recurrent, and progressive PAs.

Limitation

The study exclusively utilized the Web of Science Core Collection database (WoSCC), omitting other databases, potentially leading to a level of selection bias. However, because of differing citation indexes and metadata structures, the integration of multiple databases into a comprehensive bibliometric analysis is hard to achieve at present [96]. Moreover, the scope of this study was confined to English-language articles, possibly excluding pertinent literature in other languages. Furthermore, this bibliometric analysis was conducted on November 20th, 2023. Therefore, publications in 2023 were not included due to insufficient data.

Conclusion

This study offers a comprehensive bibliometric analysis and visualization of the PA research domain. We analyzed relevant literature on the topic from 2004 to 2023 in the Web of Science Core Collection (WoSCC), employing VOSviewer and "bibliometrix". Our bibliometric analysis and visualization encompassed countries, institutions, journals, authors, references, keywords, and research trends and hotspots. The most prominent research topics in the field of PA were found to be: (1) Molecular mechanisms; (2) Associations among PA, neurofibromatosis (NF), and pilomyxoid astrocytoma (PMA); (3) Differential diagnosis; (4) Comparative analysis between pediatric and adult pilocytic astrocytoma (APA); (5) Therapeutic approaches covering surgery, chemotherapy (CMT), radiotherapy (RT), and targeted therapy (TT). Overall, these insights serve as a valuable resource for researchers and practitioners seeking to explore new directions in PA research. Compared to the top 100 most cited publications on PA through bibliometric analysis by Bauman et al. in 2022, we analyzed the field in a more comprehensive structure, encompassing countries/institutions/journals/authors/keywords/trend topics. In the detection of hotspots and frontiers, we systematically reviewed the domain on the basis of a wider range of literature, keywords occurences and trend topics.

Abbreviations *PA*: Pilocytic astrocytoma; *PAs*: Pilocytic astrocytomas; *pLGG*: Pediatric low-grade gliomas; *APA*: Adult pilocytic astrocytoma; *PMA*: Pilomyxoid astrocytoma; *NF*: Neurofibromatosis; *GG*: Ganglioglioma; *PXA*: Pleomorphic xanthoastrocytoma; *OG*: Oligodendroglioma; *GMB*: Glioblastoma; *PFTs*: Posterior fossa tumors; *EOR*: Extent of resection; *WoSCC*: Web of Science Core Collection; *CBTRUS*: Central Brain Tumor Registry of the United States; *NCCN*: National Comprehensive Cancer Network; *PFS*: Progression-Free Survival; *OS*: Overall Survival; *EFS*: Event-Free Survival; *MAPK*: Mitogen-activated protein kinase; *mTOR*: Mammalian target of rapamycin; *ASL*: Arterial spin labeling; *ADC*: Apparent diffusion coefficient; *DWI*: Diffusion-weighted imaging; *CMT*: Chemotherapy; *RT*: Radiotherapy; *SRS*: Stereotactic radiosurgery; *TT*: Targeted therapy

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