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RESEARCH

Research trends and hotspots of laser therapy in hemangioma: a bibliometric and visualization analysis

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Abstract

This bibliometric analysis aimed to analyze global research trends in laser therapy for hemangiomas, a common benign vascular tumor in children from 1977 to 2024. Publications in laser therapy for hemangiomas from 1977 to 2024 were retrieved from the Web of Science Core Collection (WoSCC) database, and only articles published in English were analyzed. Bibliometric and visual analyses were performed using VOSviewer, CiteSpace, and the R package "bibliometrix." A total of 1,028 publications from 66 countries and 4,199 authors were analyzed, showing an annual growth rate of 5.61%. The United States led with 365 articles and 11,713 citations. Major contributors included the University of California System and Harvard Medical School, and key journals were *Lasers in Surgery and Medicine* and *Dermatologic Surgery*. Pulsed dye laser (PDL) was the most studied laser type. Research focused on optimizing treatment safety, effectiveness, and management, especially in children. The rise of propranolol as a keyword highlighted its increasing role in hemangioma therapy, and the keyword like "classification" and "vascular anomalies" underlining the importance of accurate diagnosis and classification. This study highlights the growing importance of laser therapies for hemangiomas. Future research should explore combining propranolol with laser treatments and the role of precise diagnosis in improving treatment outcomes.

Keywords Hemangioma · Laser Therapy · Bibliometric Analysis · Pulsed Dye Laser Therapy

Introduction

Hemangiomas, the most common benign vascular tumors in children, affect approximately 4% to 5% of the pediatric population [1], with higher incidence rates in premature infants, those with low birth weight, and a notable gender bias favoring females [2]. These tumors frequently develop in visible areas such as the head, neck, and trunk, where they can significantly impact aesthetics, functionality, and quality of life [3]. While most hemangiomas resolve spontaneously, some lesions—particularly those that are large, rapidly growing, or located in critical areas—can lead to complications, including ulceration, infection, pain, scarring, and functional impairments, such as vision obstruction or airway compromise [4, 5].

Treatment options for hemangiomas include surgical resection, systemic beta-blockers (e.g., propranolol), corticosteroids, and laser therapy, which are often used in combination depending on lesion characteristics [6]. Among these, laser therapy has become a minimally invasive option with superior cosmetic outcomes, especially for superficial and residual lesions [7, 8]. Beyond hemangiomas, lasers are widely used in dermatology for addressing vascular lesions, scars, and birthmarks[9, 10]. For example, fractional carbon dioxide (CO_2) lasers have demonstrated efficacy in treating hypertrophic burn scars and are often combined with pulsed dye laser (PDL) to improve outcomes in scar management [11, 12]. For hemangiomas specifically, PDL has emerged as the gold standard for treating superficial lesions due to its high safety profile and superior cosmetic results, particularly in pediatric patients [11–13]. PDL selectively targets hemoglobin in blood vessels while sparing surrounding tissues, reducing the risk of adverse effects. In contrast, CO_2

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and argon lasers, though effective in early studies, are now less commonly used due to their higher risks of scarring and less precise targeting capabilities [14, 15]. Despite this, fractional CO_2 lasers remain of interest for treating residual scarring or deeper lesions, highlighting their potential role in more challenging cases.

Despite the growing adoption of laser therapy, significant gaps persist in understanding its long-term efficacy, safety, and the optimal application of different laser modalities. Additionally, research on laser therapy for hemangiomas is fragmented across various disciplines, making it difficult to evaluate trends, collaborations, and emerging priorities systematically. Bibliometric analysis—a method for quantitatively evaluating scholarly literature—offers a powerful tool to bridge these gaps by identifying key research trends, influential studies, and priority areas in the field [16]. While bibliometric studies have explored broader areas of hemangioma research [17], no comprehensive analysis has focused specifically on laser therapy, leaving a critical gap in understanding its research trajectory and clinical implications.

This study aims to fill this gap by conducting a bibliometric analysis of laser therapy for hemangiomas. By examining publication trends, key contributors, and emerging research themes, this study provides insights into the evolution of the field and highlights areas for future investigation. The findings are expected to support clinicians, researchers, and policymakers in advancing the understanding and application of laser therapy for hemangiomas, facilitating more effective and evidence-based treatment strategies.

Materials and methods

Data sources and search strategies

The literature search was conducted using the Web of Science Core Collection (WoSCC) database, which provides extensive coverage of peer-reviewed journals across various disciplines [18]. The search was limited to articles published from January 1, 1977, to May 30, 2024. The search strategy was developed and validated based on prior bibliometric studies and discussions among two researchers to ensure consistency and relevance [17, 19, 20]. The final search formula was as follows: (TS = hemangioma OR TS = hemangioma OR TS = hemangiom* OR TS = angiom* OR TS = chorioangioma OR TS = chorioangiomas) AND (TS = laser or TS = lasers). This search retrieved 1,511 studies (Fig. 1). The inclusion criteria were as follows: (1) indexed in WoSCC, (2) document type was "articles", (3) language was "English". Exclusion criteria included duplicate records (n = 0), non-article types (e.g., conference abstracts, editorials; n = 364), and non-English publications (n = 119). After applying these criteria, 1,028 eligible studies were included for analysis. To mitigate potential inconsistencies arising from database updates, the literature retrieval was conducted on May 30, 2024. All data were collected in a "plain text" format.

Statistical analysis

Relevant data were extracted from bibliographic records, and the indicators encompassed various facets of publications, including annual publication volume, citation frequency, average citation rate, journal names, and journal impact factors (IF). For visualization purposes, three robust bibliometric tools were employed: VOSviewer (version 1.6.20), CiteSpace (version 6.3.R1), and the R package "bibliometrix" (version 4.3.3). VOSviewer, a versatile software tool, played a pivotal role in mapping institutional collaboration, author collaboration, co-authorship, citations, and co-citations [21]. This tool provides detailed insights into the complex networks of collaboration and relationships within academic fields, elucidating the interconnections among authors, institutions, and publications. Additionally, keyword co-occurrence analysis was conducted using VOSviewer to identify emerging trends and research hotspots. In the visualizations, node size represents publication volumes, line thickness indicates the strength of connections, and node color signifies different clusters or time periods. CiteSpace was employed for keyword burst analysis with the following parameters: time slicing from January 1994 to May 2024, with node types designated as keywords. Nodes categorized as keywords were subjected to a threshold (top N per slice) of 5, and pruning was configured to pathfinder plus pruning merged network. These parameters facilitated the generation of a timeline graph of keywords in the research pertaining to laser therapy in hemangiomas.

The IF was obtained from information published in the latest version of Journal Citation Reports (JCR). It is widely accepted that the H-index serves as a reflection of the scientific research impact of a scholar or a country, indicating that a scholar or country has published H papers, each of which has been cited in other publications at least H times. In this study, the H-index was obtained from the WoSCC[22].

Results

An overview of publications in research of Laser therapy for hemangioma

A total of 1,028 eligible publications were ultimately analyzed in the present study, involving 4,199 authors, published in 337 journals, cited 15,017 references from 1977 to 2024, with an annual growth rate of 5.61% and 11.28% of the documents featured international co-authorship. Each document had an average of 4.74 co-authors, showing a

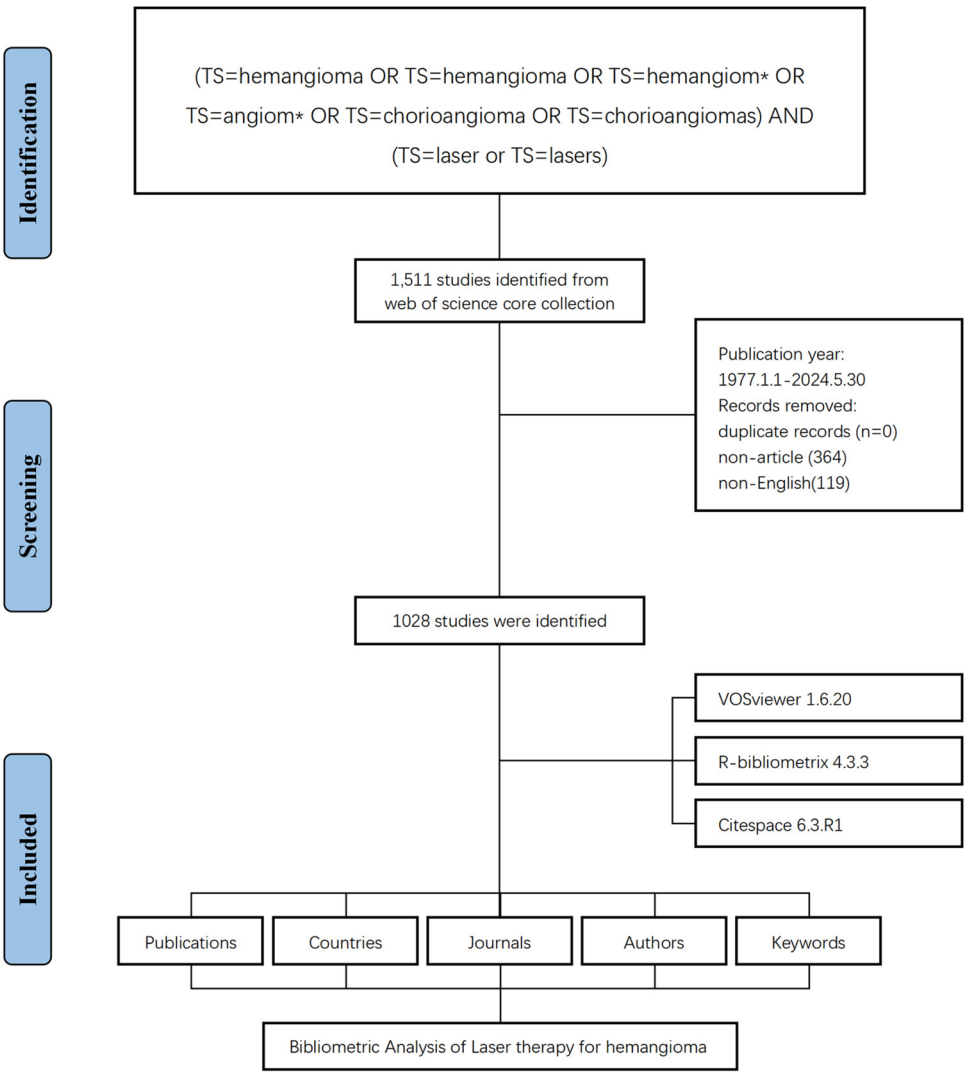


Fig. 1 Flowchart of the Literature Screening Process

trend toward teamwork. The analysis revealed 1,386 distinct keywords, indicating diverse research topics. The documents had an average age of 16.9 years and received an average of 24.74 citations (Fig. 2A). The publication trends of research on laser therapy for hemangiomas has shown fluctuations over the years (ranged from 22 to 45), but hold a high output since 2000 (Fig. 2B), reflecting the growing interest in laser therapy as a minimally invasive treatment modality. The peak in publications observed in recent years demonstrates the increasing recognition of its clinical benefits. This trend highlights the sustained momentum of research in the field, driven by technological advancements and the need for improved therapeutic outcomes.

Analysis of journals

The body of work was disseminated across a diverse array of 337 academic journals. A substantial 354 publications, representing 34.44% of the total, appeared in the top 20 journals, as ranked by their H-index (Table S1). The *Ophthalmology* (IF = 13.7; H-index = 22) was the most influential journal. Notably, *Lasers in Surgery and Medicine* (IF = 2.4; H-index = 20), which ranked second in H-index, led the number of total publications, with 44 entries, suggesting its prominence in the field. *Dermatologic Surgery* (IF = 2.4; H-index = 19) and *Plastic and Reconstructive Surgery* (IF = 3.6; H-index = 18) followed suit, with 30 and 26 records, respectively.

Analysis of the countries

A total of 488 countries or regions contributed in this field. The top 10 most productive countries generated 842 publications, accounting for 81.91% of the global output. The United States led with 365 publications, followed by China (104 articles) and Germany (65 articles) (Fig. 3A). The Multiple Country Publications (MCP) Ratio reveals the extent of international collaborations, with France (0.147) and Spain

Fig. 2 Annual Publication Trends in Laser therapy in hemangioma. **A**. Graphical overview of the total publications. **B**. Detailed trend analysis showing the annual fluctuations in publication volume

(0.148) showing higher levels of multiple-country collaborations compared to China (0.087) and the United States (0.129), which had a higher proportion of single-country publications. When considering citation impact (Table S2), the United States was also the leading country with 11,713 citations and an average of 32.1 citations per paper, followed by Germany (2,270 citations, 34.9 average citations) and France (1,267 citations, 37.1 average citations). China, despite its high publication volume, ranked fourth in total citations (1,085), with a lower average citation rate per article (10.4).

A total of 49 countries involved in international collaborations with a minimum of 2 articles. The global collaborations map highlighted the extensive international coauthorship network, particularly dominated by the United States, which had the highest total link strength (80), followed by Italy (23) and UK (22). And China had the highest collaboration links with the United States. Germany, France, and Canada also showed strong collaborative ties with the United States. In contrast, China, despite its high research output, exhibited fewer collaborative ties (total link strength: 21) (Fig. 3B).

The United States, China, and Germany emerged as the top contributors to the field, collectively accounting for over 60% of the total publications. The dominance of these countries can be attributed to their robust research funding, advanced healthcare infrastructure, and strong academic collaborations. Interestingly, the United States had the highest citation impact, which may reflect its leadership in publishing in high-impact journals and fostering international collaborations. In contrast, countries with fewer publications, such as Brazil and South Korea, demonstrated relatively lower citation impacts, potentially due to limited resources or less global visibility. These differences underline the importance of international cooperation in elevating the global research landscape.

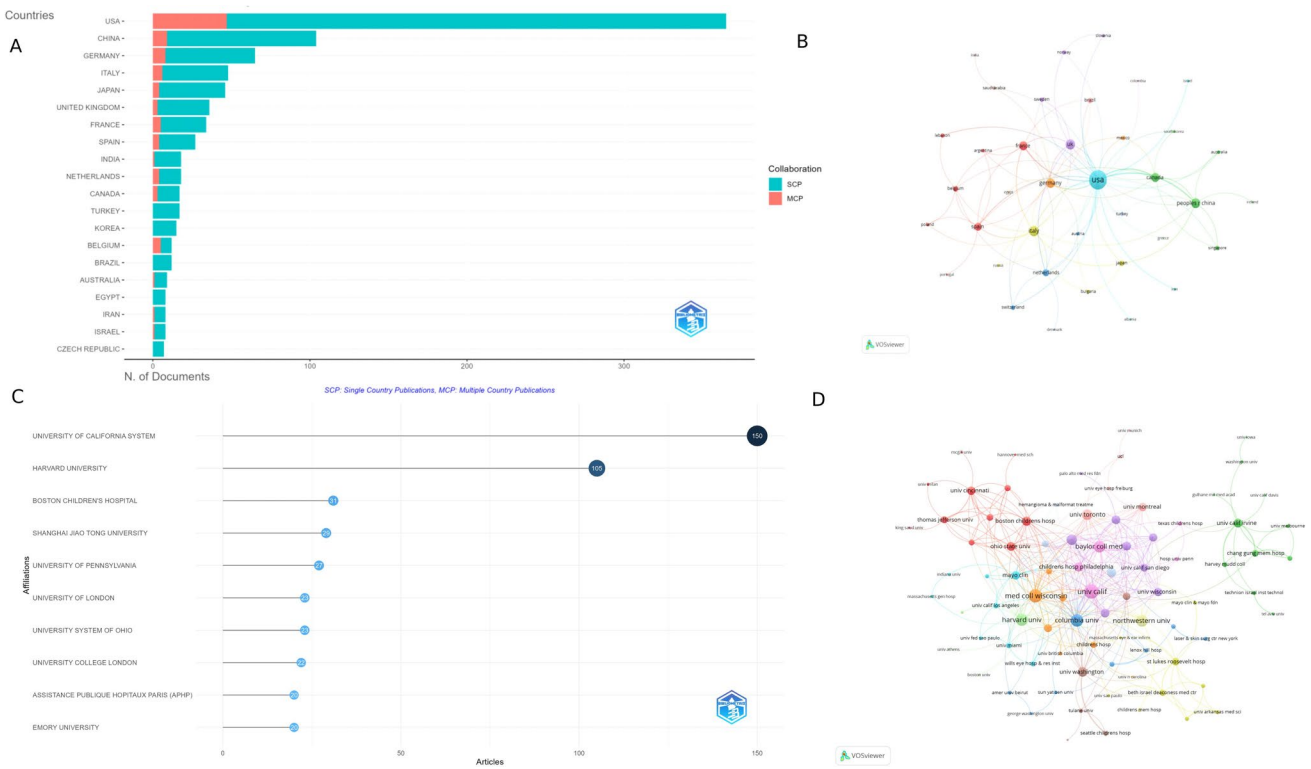


Fig. 3 Global Distribution and Collaboration in Laser therapy in hemangioma. **A**. Corresponding Authors' Publications by Country. Blue bars represent single-country publications (SCP), while red bars indicate multiple-country publications (MCP). **B**. Collaboration Map Among Countries. Each node represents a country, with node size proportional to the total number of publications. Node color indicates clusters of closely collaborating countries. Lines between nodes represent co-authorship relationships, with line thickness reflecting the strength of collaboration. **C**. Ranking of the Top 10 Institutions Based on Article Count. The x-axis represents the number of articles published by the institution, while the y-axis lists the institution names. **D**. Institutional Collaboration Network. Each node represents an institution, with node size reflecting the number of publications. Node color clusters institutions based on their collaborative networks. Lines between nodes represent collaborative ties, with line thickness indicating the strength of collaboration

Analysis of the institutions

Among 2,322 institutions, the top 10 institutions with the highest research output were displayed in Fig. 3C. The University of California System (n = 150) was the leading institution, followed by Harvard Medical School (n = 105) and Boston Children's Hospital (n = 31). The institution collaboration network included 125 institutions involved in international collaborations with a minimum of 3 articles. The University of California, San Francisco (UCSF) has the highest number of collaborations with other countries (47), forming strong partnerships with Harvard University, the Medical College of Wisconsin, and Northwestern University. The Medical College of Wisconsin (39 collaborations) shows close ties with institutions like UCSF, Mayo Clinic, and Indiana University School of Medicine. Columbia University (35 collaborations) is closely connected with other prominent institutions like Ohio State University and Stanford University, indicating a robust network of research collaboration across the field (Fig. 3D).

Analysis of the authors

A total of 4,199 authors contributed to publications in this field, and the top 20 most influential authors were identified according to the H-index (Table S3). Among them, Apfelberg DB was the most highly cited author with an H-index of 11, having published 17 papers since 1979, accumulating 520 citations. One of his representative work was published in *JAMA* at 1981 [23]. Nelson JS, ranked second, has an H-index of 10, with 10 publications starting from 1996 and a total of 342 citations. Additionally, Lash H and Maser MR, both with an H-index of 9, each contributed 10 publications, starting in 1979, and accumulated 396 citations. Their work has greatly influenced the early adoption and refinement of laser technologies in hemangioma treatment.

The co-authorship network included 325 authors had collaborations with a minimum of 2 articles. The finding highlighted the collaborative nature of this research field (Fig. 4). Frieden Ilona J. and Blei Francine, both key figures in the field, are situated centrally within the

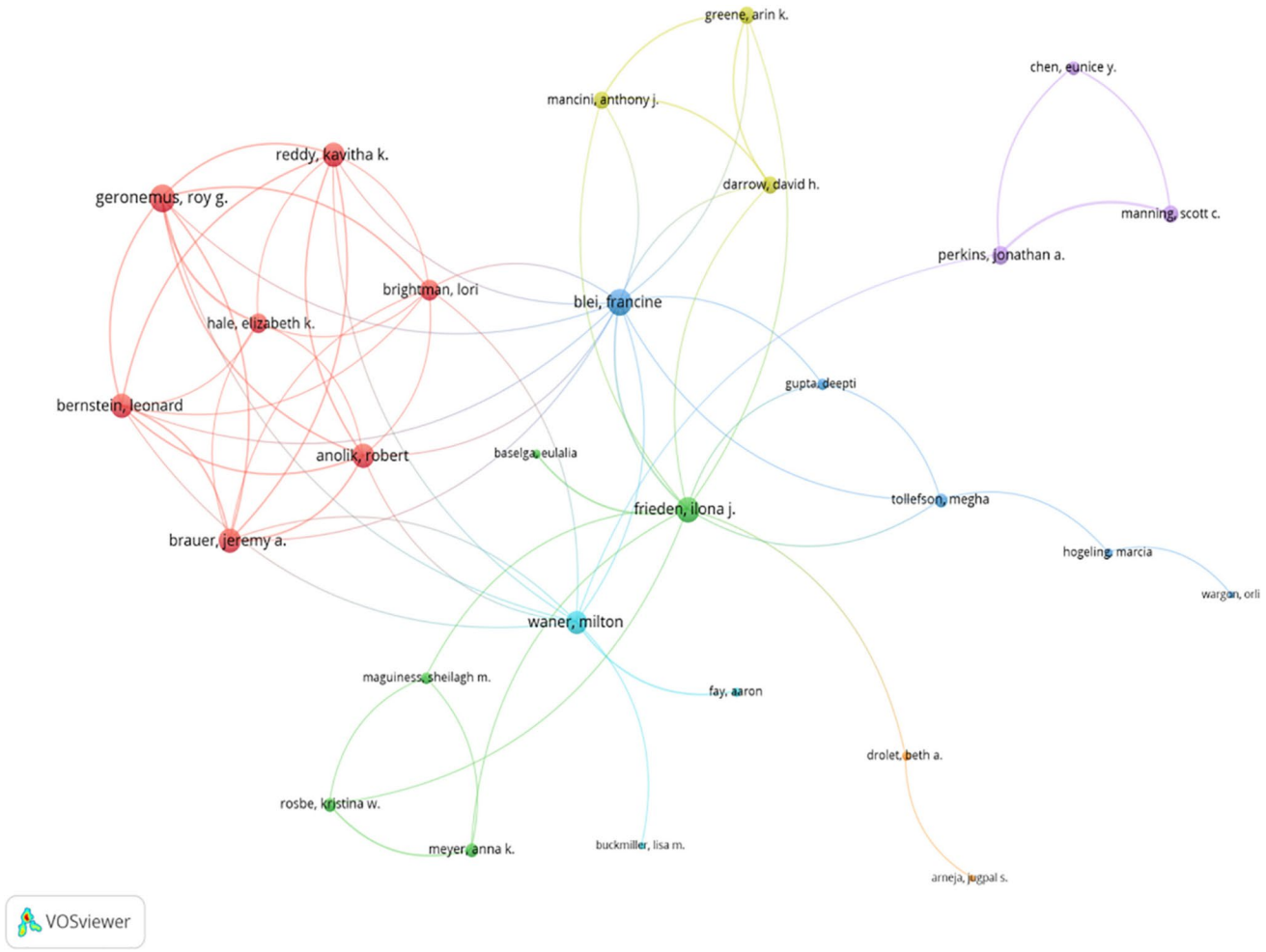


Fig. 4 Author Collaboration Network in Laser Therapy In Hemangioma. Each node represents an author, and the node size is proportional to the number of publications by that author. Node color indicates clusters of closely collaborating authors. Lines between nodes represent co-authorship relationships, with thicker lines indicating stronger collaborative ties

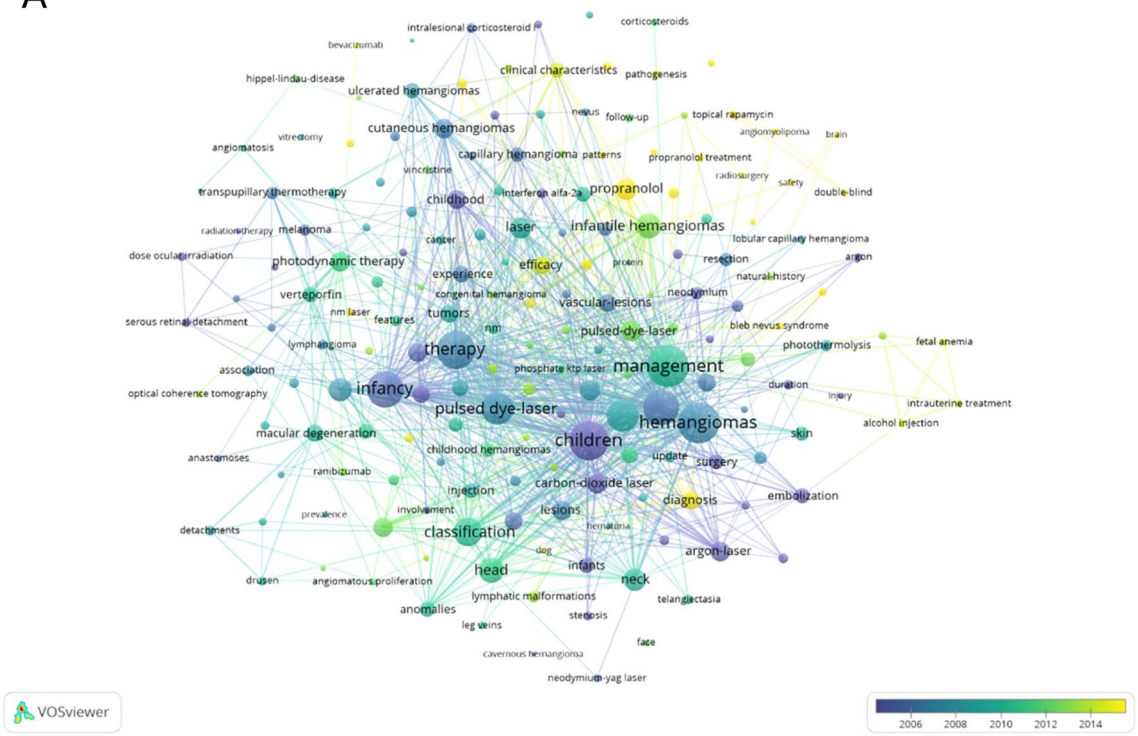
network, indicating extensive collaboration with other prolific authors. Blei F. has connections with multiple authors, such as Meyerson A and Gupta A, contributing to her broad research influence. Waner M, another highly connected author, has strong collaborations with Frieden Ilona J. and Buckmiller Lisa M., further strengthening the research network in pediatric hemangioma treatment. Perkins Jonathan A., with 6 publications since 2009, has established connections with other influential authors, such as Manning SC and Chen EY.

The analysis identified several prolific authors and institutions, with the most influential authors being affiliated with leading research centers in dermatology and vascular surgery. Collaborative networks, visualized using VOSviewer, revealed dense co-authorship clusters within countries but relatively sparse cross-national collaborations, suggesting an opportunity to enhance international research partnerships. Such collaborations could help bridge gaps in knowledge and ensure a more comprehensive understanding of laser therapy efficacy across diverse populations.

Analysis of the keywords

The analysis of keywords offers valuable insights into the research trends and focus areas in the field of laser therapy for hemangiomas. A total of 185 keywords with a minimum of 5 occurrences were identified (Fig. 5 **A** and Table S4)**.** The most frequently occurring keywords, such as "management" (144 occurrences), "hemangiomas" (166 occurrences), "children" (114 occurrences), "therapy" (123 occurrences), and "infancy" (105 occurrences), reflect the primary focus of research on clinical management and treatment strategies in pediatric populations. These keywords are closely linked with terms related to patient demographics and treatment modalities, such as "infantile hemangiomas," "classification," and "vascular malformations." Laser types, including

A



B

Top 20 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	1994 - 2024
argon laser	1994	9.91	1994	1998	
carbon dioxide laser	1994	5.13	1997	2000	
malformations	1998	4.65	1998	2010	
photocoagulation	2000	4.67	2000	2005	
transpupillary thermotherapy	2001	5.92	2001	2004	
lesions	1996	4.79	2001	2008	
laser photocoagulation	1999	4.85	2003	2005	
photodynamic therapy	2003	4.3	2003	2012	
retinal angiomatous proliferation	2006	5.24	2006	2012	
macular degeneration	2002	4.87	2006	2013	
subglottic hemangioma	2007	7.1	2007	2011	
head	1996	4.68	2009	2019	
tumors	2011	5.28	2011	2012	
venous malformation	2013	5.07	2013	2017	
neck	1997	4.37	2013	2016	
propranolol	2012	9.67	2014	2024	
classification	1994	4.57	2017	2022	
vascular anomalies	2011	4.47	2018	2020	
diagnosis	2007	8.27	2019	2021	
vascular malformation	1999	4.9	2019	2020	

Fig. 5 Keyword and Citation Analysis in Laser Therapy for Hemangiomas. **A**. Keyword Co-occurrence Network in Laser therapy in hemangioma. Each node represents a keyword, with node size indicating the frequency of occurrence. Node color indicated average year of publication of keywords. Lines between nodes represent co-occurrence relationships, with thicker edges indicating stronger associations. **B**. Citation Burst Analysis for Keywords in Laser therapy in hemangioma.The top 20 keywords with the strongest citation bursts from 1994 to 2024. The period of each keyword's citation burst is represented by a red bar

"pulsed dye-laser" (85 occurrences), "carbon-dioxide laser" (37 occurrences), and "argon-laser" (32 occurrences), form another significant cluster in the co-occurrence network. The prevalence of these laser types suggests a well-established trend in clinical practice, as evidenced by its strong links with other treatment-related keywords like "photocoagulation" and "propranolol." Additional keywords linked to treatment outcomes, such as "safety," "efficacy," and "follow-up". Terms related to specific anatomical sites, including "head" and "neck," emphasize the frequent localization of hemangiomas in visible and sensitive areas.

The burst analysis of keywords from 1994 to 2024 (Fig. 5B) revealed the evolution of research focus over time. Keywords with the strongest citation bursts reflect periods of heightened academic interest. Notably, "propranolol" (strength = 9.67) exhibited continuous burst, peaking from 2014 to 2024, highlighting the growing importance of propranolol in the treatment of hemangiomas. Similarly, "argon laser" (strength = 9.91) had a significant burst from 1994 to 1998 and the strongest burst strength, underscoring the early adoption of laser technology in treating vascular lesions. Other important bursts include "carbon dioxide laser" (strength = 5.13, 1997–2000) and "photocoagulation" (strength = 4.67, 2000–2005), reflecting critical periods of innovation and clinical application of laser therapies. The recent bursts such as "classification" (strength = 4.57, 2017–2022) and "vascular anomalies" (strength = 4.47, 2018–2020) suggest a growing focus on the accurate categorization and understanding of hemangiomas and related vascular conditions. Additionally, "diagnosis" (strength = 8.27, 2019–2021) and "vascular malformation" (strength = 4.9, 2019–2020) reflect a cross-disciplinary interest in early and accurate diagnosis, which is crucial for effective treatment planning.

Discussion

Key findings

This bibliometric study provided a comprehensive overview of global research trends in laser therapy for hemangioma from 1977 to 2024. A total of 1,028 articles were analyzed, revealing the contributions of 4,199 authors from 337 journals. The United States led both in publication volume and citations, with significant contributions from institutions like the University of California System and Harvard Medical School [17]. The analysis identified propranolol, PDL, argon laser, and carbon dioxide laser as significant focal points in the field, with propranolol emerging as a key hotspot in recent years. Early studies concentrated on laser treatments, such as argon and carbon dioxide lasers, while more recent trends have focused on propranolol therapy, classification of vascular anomalies, and advancements in diagnosis. Key research topics emphasize safety, efficacy, and clinical management of hemangiomas, particularly in pediatric populations.

Research trends in laser therapy for hemangioma

The study identified *Lasers in Surgery and Medicine*, *Dermatologic Surgery,* and *Plastic and Reconstructive Surgery* as the leading journals. *Lasers in Surgery and Medicine* published the most articles, reflecting its central position in this field. The journal's focus on laser technologies and their application in surgery aligns with the high number of hemangioma-related studies [24]. *Dermatologic Surgery* and *Plastic and Reconstructive Surgery* also published a significant number of articles [25]. These journals typically focus on skin-related surgical techniques, reconstruction, and aesthetic outcomes, making them ideal platforms for disseminating research on hemangioma treatment, particularly when considering the cosmetic aspects of laser therapy [26].

The United States led in both publication volume and citation impact, reflecting its robust funding systems, advanced laser technologies, and extensive collaboration networks. Institutions such as the University of California System and Harvard Medical School have played pivotal roles, contributing a significant number of high-quality publications and fostering interdisciplinary collaboration, as evidenced by their high co-authorship counts [27]. The strong citation impact from U.S.-based research suggests a focus on publishing in high-impact journals and active participation in international collaborations, which amplify global visibility and influence. In contrast, China, despite being a leading contributor in publication volume, demonstrated a relatively low average citation rate. This variation may stem from several factors, including language barriers that limit accessibility to non-Chinese-speaking audiences, lower representation in high-impact international journals, and less extensive international collaboration networks compared to Western countries. Enhancing global collaboration and increasing submissions to high-impact journals could help address these disparities. Such citation impact differences highlight the importance of international research partnerships. Countries with lower citation rates could benefit from collaborative efforts that integrate advanced technologies, diverse expertise, and global dissemination strategies. Future bibliometric analyses could delve deeper into regional and institutional factors contributing to these variations, which would further inform strategies to improve global research equity and influence. The analysis of the most influential authors revealed key figures in the field. Apfelberg DB was the most prolific author, focusing on the early adoption of lasers in dermatologic surgery has been foundational,

particularly in demonstrating the efficacy of argon and carbon-dioxide lasers in treating vascular lesions [28].

Research hotspots and frontiers in laser therapy for hemangioma

The keyword co-occurrence analysis revealed significant research hotspots, with terms like "management," "hemangiomas," "children," "therapy," and "infancy" being the most frequently occurring. These keywords indicate that research is heavily focused on the clinical management of hemangiomas, particularly in pediatric populations. Infantile hemangiomas, affecting around 4–5% of children, are more common in preterm and low birth weight infants [29]. The keyword analysis highlighted "Pulsed dye laser therapy" (PDL) as the most frequently mentioned laser (85 occurrences), underscoring its role as the gold standard for treating superficial vascular lesions, particularly in pediatric patients. PDL's mechanism of action relies on the principle of selective photothermolysis, which targets hemoglobin within blood vessels, minimizing collateral damage to surrounding tissues and reducing the risk of scarring. These characteristics make PDL particularly effective for treating infantile hemangiomas, which often appear in visible areas like the face and neck, where cosmetic outcomes are a key consideration [30, 31].

The shift from earlier laser types, such as CO_2 and argon lasers, to PDL reflects advancements in both laser technology and clinical understanding. Although laser modalities like fractional CO_2 lasers have demonstrated efficacy in dermatology for conditions like burn scars and alopecia, their role in hemangioma treatment has diminished due to their higher risks of adverse effects and less precise targeting capabilities [11, 12]. Early studies demonstrated the efficacy of CO_2 and argon lasers in ablating vascular lesions, but these lasers were associated with higher risks of adverse effects, such as scarring, hyperpigmentation, and damage to surrounding tissues [14, 15]. For example, CO_2 lasers, while effective for deeper or more extensive lesions due to their precise ablation capabilities, were limited by their potential for scarring, making them less suitable for delicate or visible areas [14]. Similarly, argon lasers, once widely used for vascular lesions, were shown to have a higher incidence of adverse effects and less precise targeting capabilities compared to PDL [30]. Research comparing these modalities, such as the work by Apfelberg et al. [23], consistently demonstrated the superiority of PDL in both safety and cosmetic outcomes. This body of evidence led to a paradigm shift in treatment protocols, with PDL becoming the preferred modality for managing superficial hemangiomas, particularly in pediatric populations. The transition to PDL also coincided with advancements in laser technology, including the development of longer pulse durations and improved cooling systems, which further enhanced its safety and efficacy. Cooling systems, such as dynamic cooling devices, protect the epidermis during laser treatment, reducing the risk of burns and discomfort, which is especially important in pediatric patients [32]. These technological improvements, coupled with clinical evidence supporting PDL's efficacy, established its dominance in the treatment landscape and influenced clinical guidelines for hemangioma management.

Interestingly, other laser types, such as Nd:YAG lasers, were not strongly represented in the keyword analysis, despite their documented utility in treating deeper vascular lesions [33]. Nd:YAG lasers are capable of penetrating deeper into the dermis due to their longer wavelength, making them suitable for mixed or deep hemangiomas that are less responsive to PDL alone. However, the limited representation of Nd:YAG lasers in the keyword analysis may reflect either their relatively niche application in hemangioma treatment or insufficient reporting in the literature. For example, Hoffman et al. [27] demonstrated the efficacy of Nd:YAG lasers in specific cases, such as combined hemangiomas, but these findings have not been widely replicated or incorporated into mainstream treatment protocols. This underrepresentation highlights a potential limitation of the current research landscape and suggests the need for more comprehensive studies to evaluate the complementary roles of Nd:YAG lasers in combination with PDL.

The emergence of "propranolol" as a significant keyword reflects its transformative impact on hemangioma management and represents a paradigm shift in therapeutic priorities. Before propranolol's introduction, treatment options for hemangiomas were limited to surgical excision, systemic corticosteroids, and laser therapy, each of which carried significant risks or limitations. Corticosteroids, once the mainstay of systemic therapy, were associated with considerable adverse effects, including growth suppression, hypertension, and immune suppression, particularly in pediatric population [34, 35]. Surgical excision of hemangiomas, while effective in some cases, was invasive, carried risks of scarring, and was often unsuitable for large or sensitive lesions in cosmetically critical areas [36]. These limitations created a demand for safer, less invasive, and more effective treatment modalities. Propranolol, a non-selective beta-blocker, dramatically altered the treatment landscape after Léauté-Labrèze et al. [7]. serendipitously discovered its efficacy in 2008. Its mechanism of action, which includes vasoconstriction, inhibition of angiogenesis, and induction of apoptosis in endothelial cells, directly targets the underlying biological processes of hemangioma proliferation [23]. This targeted mechanism, combined with its favorable safety profile, positioned propranolol as the first-line treatment for many infantile hemangiomas. Its widespread adoption reduced the reliance on more invasive procedures, particularly in cases

where systemic therapy alone was sufficient to control lesion growth and promote involution [30].

Keywords related to treatment outcomes, such as "safety," "efficacy," and "follow-up," indicate a growing focus on ensuring the long-term safety and effectiveness of laser therapies [37, 38]. This emphasis is particularly relevant to pediatric populations, where the potential for adverse effects is of greater concern due to the delicate nature of developing skin and the need for minimally invasive approaches. The dominance of PDL in recent years reflects its ability to balance safety and efficacy, making it a preferred choice for managing superficial hemangiomas. PDL's selective targeting of hemoglobin minimizes collateral damage, while its improved cooling systems further enhance safety, especially for pediatric patients [39].

Recent bursts for terms such as "classification" (2017–2022) and "vascular anomalies" (2018–2020) suggest a growing emphasis on accurately categorizing and diagnosing hemangiomas and other vascular anomalies. This trend reflects the increasing complexity of vascular conditions and the need for more nuanced treatment protocols. Accurate classification is critical, as it allows clinicians to tailor therapies—whether pharmacological, surgical, or laser-based—to the specific type and severity of the lesion [40]. The burst of "diagnosis" from 2019 to 2021 also emphasizes the importance of early and precise identification of hemangiomas, which is essential for timely intervention and optimizing therapeutic outcomes [41]. As diagnostic techniques, such as imaging and molecular testing, continue to improve, future research may also explore the genetic and biological pathways underpinning hemangioma development, leading to more personalized treatment approaches. With the increasing use of newer laser technologies and the expanded use of propranolol, there is a need for ongoing research into the potential side effects and long-term outcomes of these therapies [42]. As treatments evolve, ensuring that they are not only effective but also safe over the long term will be a priority, particularly for young children who may be more vulnerable to complications.

Limitations

This study has several limitations that should be acknowledged. First, the reliance on citation counts as a metric for research impact may not fully capture an article's clinical relevance or practical influence. Citation metrics can be influenced by factors such as journal visibility, accessibility, and regional disparities, potentially disadvantaging certain regions or languages. Additionally, the exclusion of non-English publications introduces a language bias, which may have led to the omission of significant research from non-English-speaking nations. Second, the analysis was limited to the WoSCC database, which, while comprehensive, may not include all relevant literature on laser therapy for hemangiomas. This could result in an incomplete representation of the global research landscape. Finally, the search strategy was developed based on a cited reference and refined through discussions among two researchers in the team. While this approach ensured consistency, it may have introduced subjective bias in the selection of search terms, potentially affecting the comprehensiveness of the study. Future studies could address these limitations by incorporating multiple databases, including non-English publications, and employing more standardized or collaborative methods for search strategy development.

Conclusion

This study highlights the evolving field of laser therapy for hemangiomas, with PDL dominating due to their safety and efficacy, particularly in pediatric populations. While earlier reliance on carbon dioxide and argon lasers has declined, propranolol has emerged as a transformative therapy, creating opportunities for combined treatment approaches. Future research should focus on developing standardized protocols for propranolol-laser combination therapies, optimizing timing and dosing, and investigating outcomes across diverse patient demographics. Additionally, advancements in diagnostic techniques and classification systems for vascular anomalies will be essential for refining treatment strategies and personalizing care. These efforts will help enhance therapeutic outcomes and broaden the clinical applications of laser therapy.

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