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ORIGINAL RESEARCH

Chemotherapy-Induced Bone Marrow Suppression: A Bibliometrics Analysis

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Objective: This study seeks to investigate the key research hotspots and evolving trends in chemotherapy-induced bone marrow suppression over the past two decades by employing bibliometric visualization analysis, thereby providing a robust theoretical and empirical foundation for advancements in both scientific understanding and clinical practice.

Methods: Utilizing the Web of Science Core Database, a total of 6,110 documents were retrieved and analyzed using CiteSpace and VOSviewer software. This analysis traces and evaluates the current research status, key advancements, and development trajectories of chemotherapy-induced bone marrow suppression research from 2004 to 2023.

Results: The analysis included 6,110 documents, revealing a significant upward trend in research volume. The United States (1,688 papers) and China (1,528 papers) are the leading contributors, with *Cancer Chemotherapy and Pharmacology* being the most prolific journal. Keyword burst detection identified key research focuses, including nasopharyngeal carcinoma, immunotherapy, and agents such as nivolumab and pembrolizumab. These findings indicate promising directions for further exploration, such as immunotherapy for nasopharyngeal carcinoma and innovative strategies for managing bone marrow suppression with specific drugs.

Conclusion: Future research may concentrate on immune checkpoint inhibitors and nasopharyngeal carcinoma. Additionally, new treatment such as the natural compound curcumin has demonstrated protective effects during chemotherapy, effectively alleviating side effects. Nutritional support strategies significantly enhance patients' quality of life during treatment, while integrative approaches that combine traditional Chinese medicine with modern medical practices reveal the potential for synergistic effects. Together, these strategies could improve clinical outcomes and effectively address the challenges posed by chemotherapy-induced bone marrow suppression.

Keywords: chemotherapy-induced bone marrow suppression, bibliometric analyses, visualization, citespace, VOSviewer

Introduction

In the field of tumor treatment, chemotherapy, as one of the main methods, plays an important role by inhibiting or killing rapidly dividing cancer cells. However, while killing cancer cells, chemotherapeutic agents also cause varying degrees of damage to normal tissue cells, and bone marrow cells are particularly sensitive to chemotherapeutic agents, leading to myelosuppression, a common toxic side effect.[1] Myelosuppression not only triggers leukopenia, neutropenia, thrombocytopenia, and lowered hemoglobin levels, but also exacerbates the risk of infections, fever, anemia, and immune weakness, severely hindering the successful implementation of chemotherapy regimens.[2] Given the increasing incidence of tumors, effective management of the adverse effects of chemotherapy, especially myelosuppression, has become an important topic in clinical research and practice. Myelosuppression not only directly affects the quality of life of patients, but also poses a significant threat to the continuity of treatment and patient prognosis; therefore, it is urgent to explore strategies to prevent and control myelosuppression, optimize chemotherapy regimens, and improve the treatment experience and survival of patients.

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In this research context, tumor-associated macrophages (TAMs) play a key role in the immunosuppressive solid tumor microenvironment, but engineering TAMs in situ for enhanced tumor immunotherapy remains a major challenge. The study reports an innovative nano-delivery strategy, STNSP@ELE, which utilizes two-dimensional sterene-based nanosheets and the anticancer drug β-elemene, and is able to polarize M2-like TAMs to M1-like phenotypes and enhance anti-tumor responses. In vivo studies demonstrated that the treatment significantly increased the intratumoral M1/M2-like TAMs ratio, elevated T lymphocyte and dendritic cell counts, increased immune-stimulating cytokine expression, and reprogrammed the immune-suppressive tumor microenvironment.[3] In addition, impact injuries are the main type of craniocerebral trauma, and existing helmets have insufficient blast protection. Based on the prototype of Iron Man helmet, the study used finite element model to establish shock wave-helmet-head fluid-solid coupling model, and simulated to analyze the helmet protection performance. The results show that the ACH helmet cannot reduce brain injury, the full-face helmet protection performance is better, and the optimization of helmet shape and thickness can reduce brain injury.[4] Meanwhile, PCSK9 binds to hepatic LDLR leading to elevated plasma LDL-C levels, which is an innovative target for the treatment of hypercholesterolemia and atherosclerosis. The small molecule inhibitor E28362 was found to dose-dependently increase LDLR protein levels in cells and enhance LDL uptake without significant toxicity. Animal studies have shown that E28362 reduces plasma lipid levels and attenuates atherosclerotic lesions, making it a promising lead compound for the treatment of hyperlipidemia and atherosclerosis.[5] Finally, bone metastasis is a common phenomenon in primary malignant tumors with poor prognosis. The emergence of nanotechnology opens up a new era in the management and prevention of bone metastasis, with advances in smart nanosystems to stimulate vascular regeneration, promote bone regeneration, and eliminate tumor cells, and innovations in bone-targeted nanoplatforms that provide new approaches to diagnostics for the treatment of bone metastasis.[6]

In the field of cancer treatment, a variety of treatment methods are constantly explored and developed. DNAzyme (DZ), which cleaves RNA, has great potential in the application of RNA interference, and is superior to siRNA, but it is limited by the requirement of metal cofactor activation and the lack of effective co-delivery system. The metal-organic framework coated with manganese dioxide nanosheets designed in this study can realize the co-delivery of DZ and doxorubicin, which can be used in cancer chemotherapy-gene combination therapy. Both in vitro and in vivo studies have confirmed its good anti-tumor effect, but doxorubicin, as a chemotherapy drug, may have certain toxic effects on normal cells.[7] Phototherapy is widely used in the treatment of cervical cancer and other diseases because of its high selectivity, few side effects and strong controllability. By constructing specific nanoparticles, the photosensitizer can be effectively loaded and delivered to the tumor, which can be released in the tumor microenvironment responsively, and play a synergistic role of photodynamic therapy and photothermal therapy. The local high temperature caused by photothermal therapy can enhance chemodynamic therapy, but the effect of phototherapy may be affected by factors such as hypoxia in the tumor microenvironment.[8] Super enhancer has also attracted much attention in cancer research, which is closely related to the occurrence, development and prognosis of cancer. The related research is mostly concentrated in the United States, China and other countries, involving oncology, cell biology and other fields. Many research institutions and authors are involved, and most of the research is supported by relevant institutions. The key words show that SEs plays a role in cell recognition, gene transcription and its relationship with transcription factors is a research hotspot.[9]

In this study, the bibliometrics method was used to comprehensively analyze the relevant literature of bone marrow suppression after chemotherapy, clearly presenting the overall picture of the research in this field, accurately identifying the core advantages and emerging topics, pointing out the direction for future research, providing important reference for researchers, clinicians and decision makers, and helping to promote the development of bone marrow suppression after chemotherapy to a deeper level and a wider field.

Data and Methods

Data Sources and Search Methods

The Web of Science Core Collection (WoSCC) database served as the data source for this study. We set the search formula: TS=(chemotherapy OR antineoplastic agent) AND TS=(myelosuppression OR Leukopenia OR Thrombopenia OR agranulocytopenia OR haemoglobinopenia). Utilizing the refinement features of the WoSCC database, the following

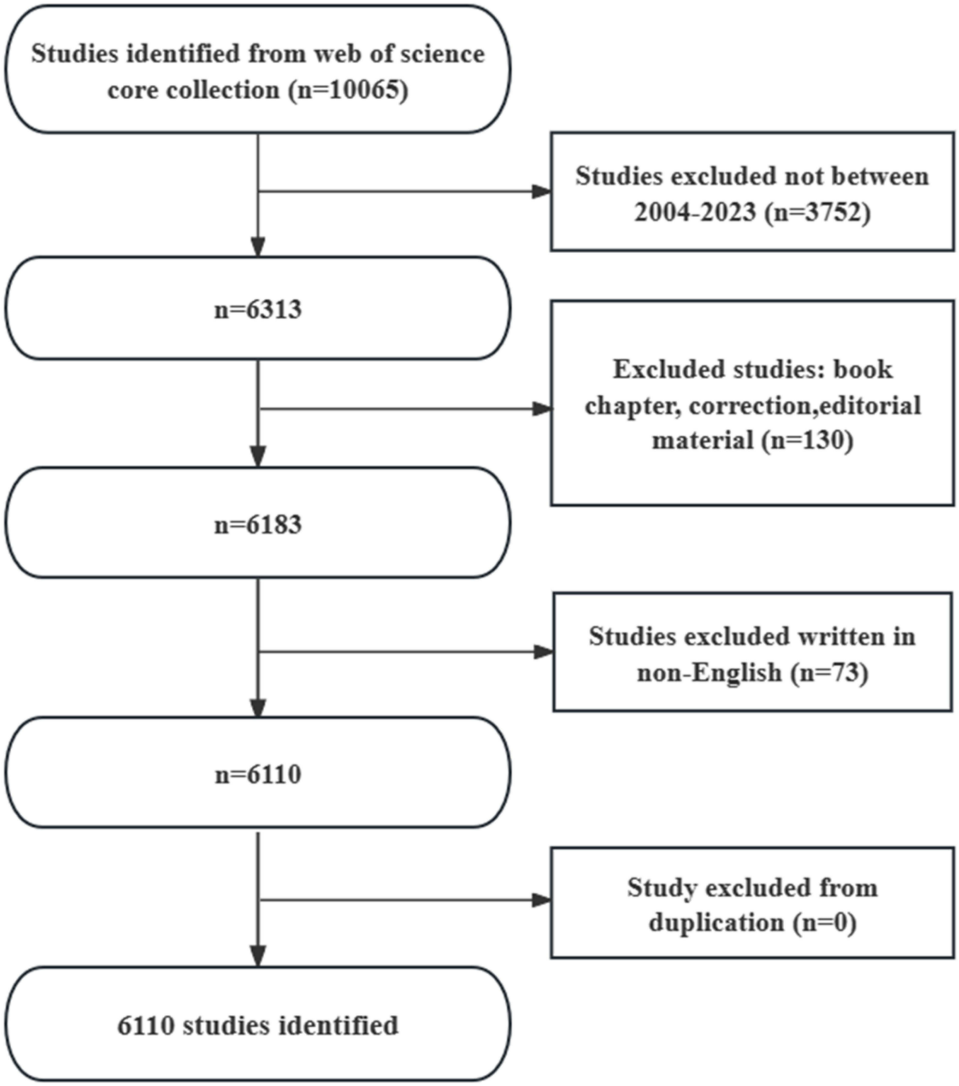

Figure 1 Literature search flowchart. The flowchart presents the process of screening and selecting studies from the Web of Science core collection for a research review or meta-analysis. Initially, 10,065 studies were identified. Subsequently, studies not published between 2004 and 2023 were excluded (n=3,752), leaving 6,313 studies. Further exclusions were made for book chapters, corrections, and editorial material (n=130), resulting in 6,183 studies. Studies written in non-English languages were then excluded (n=73), leaving 6,110 studies. Finally, no studies were excluded due to duplication (n=0), resulting in a total of 6,110 studies being identified for further analysis or review.

search parameters were established: Index: SCI-E; Language: English; Document Types: Articles, Review Articles; Search Period: January 1, 2004, to December 31, 2023. As shown in Figure 1, a total of 6,110 documents were ultimately included.

Research Method

When carrying out bibliometrics research, we first retrieve high-quality documents related to specific topics through the Web of Science Core Collection (WoSCC). In order to ensure the integrity and timeliness of the data, we download 500 papers in batches, and each batch of documents is named "download_*n" (where n is the serial number), so as to facilitate subsequent classification and tracing. After downloading, export these raw data to the local database to prepare for software analysis. In terms of analysis software, this study adopts three professional tools: GraphPad Prism, Vosviewer and CiteSpace. Among them, GraphPad Prism is a professional data analysis and visualization software. Based on its powerful statistical analysis engine and drawing module, it is used to visualize the number of publications and citation trends of documents, and the complex data is transformed into an intuitive

chart form through the built-in statistical chart generation algorithm, and the relationship curve between them is fitted by nonlinear regression analysis, thus revealing the potential association mode. Its nonlinear regression model base can accurately fit the complex data relationship according to the principle of least square method. VOSviewer is a tool specially used for scientific literature analysis and visualization. Its core principle is based on the co-occurrence analysis theory, which extracts the information of authors, institutions, countries/regions in the literature and constructs a co-occurrence matrix. By calculating the co-occurrence frequency and correlation between these elements, a special layout algorithm (such as Vos algorithm) is used to map high-dimensional data to a two-dimensional plane, and the cooperative relationship is displayed in the form of an intuitive network diagram. Through the co-occurrence analysis of information such as literature authors, institutions and countries/regions, the network diagram of cooperation relationship is drawn to help identify key cooperation nodes and cooperation modes in the research field. CiteSpace is developed on the basis of information visualization theory, and mainly uses the construction method of scientific knowledge map to analyze the literature data. By mining and processing the information such as keywords and references in the literature, the LLR algorithm is used to cluster the keywords. This algorithm compares the frequency differences of keywords in different literature collections, calculates their log-likelihood ratios, and thus determines the correlation and clustering structure between keywords. Clustering keywords by log-likelihood ratio algorithm can effectively identify different topics and research directions in the research field, and further analyze the time series changes of keywords, so as to accurately locate the emergence and development track of emerging terms and provide strong support for the dynamic grasp of the frontier in the research field.

Results

From January 1, 2004, to December 31, 2023, the WoSCC database recorded a total of 6,110 articles pertaining to post-chemotherapy bone marrow suppression. This included 5,474 (94.31%) research articles and 636 reviews (5.69%). A total of 96 countries and regions contributed alongside 6,677 institutions and involved 32,946 authors.

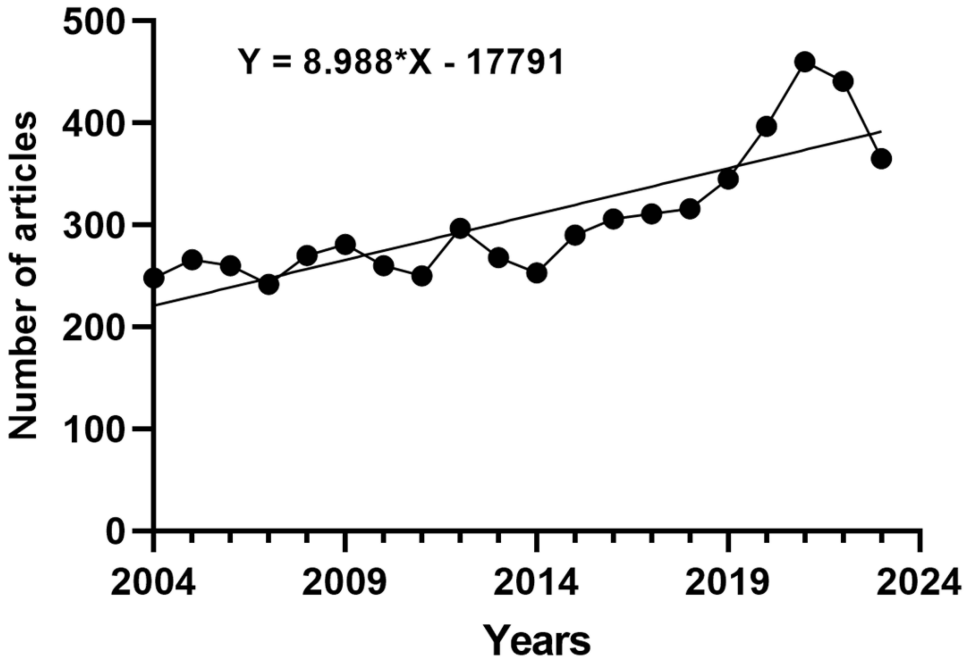

Figure 2 Annual publication quantity change chart. This line graph illustrates the trend of the number of articles published between 2004 and 2024. The x-axis represents the years from 2004 to 2024, and the y-axis shows the number of articles, ranging from 0 to 500. A linear trend line is plotted with the equation \(Y = 8.988X - 17,791 \), indicating a steady increase in the number of articles over the years. The data points show some fluctuations but generally follow the upward trend of the line. The graph effectively demonstrates the growth in article publications within the given time frame.

Publication Quantity Analysis

In general, the annual publication of research papers has exhibited a gradual increase since 2004 (see Figure 2). We identified three distinct phases: 2004–2015: Characterized by slow growth, with fewer than 300 papers published annually, indicating that the field did not attract significant interest from researchers. 2016–2019: Marked by a gradual increase in publication volume, reflecting a growing visibility of the field. Post-2020: Witnessed a rapid surge in publication numbers, peaking in 2022, suggesting a heightened focus on this area of research.

Distribution of Publications by Country and Region

The literature on chemotherapy-induced bone marrow suppression encompasses contributions from 91 countries and regions, among which the United States, China and Japan were the countries with the greatest number of publications (see Figure 3a). China emerged as the most active country in publishing, significantly surpassing other countries since 2019 (see Figure 3b). Among the top ten countries by publication quantity, the United States and China accounted for 52.64% of total publications, significantly more than other countries. Japan, Germany and Italy followed (see Table 1). Papers from the United States have been cited 94,565 times, with a citation-to-publication ratio of 56.02, indicating generally high-quality publications. China ranks sixth in publication quantity (1,528 papers) and third in citation counts (22,130), though its citation-to-publication ratio (14.48) is lower. An analysis of the cooperation among countries and regions, as illustrated in Figure 4, reveals that the United States occupies a pivotal position within the cooperation

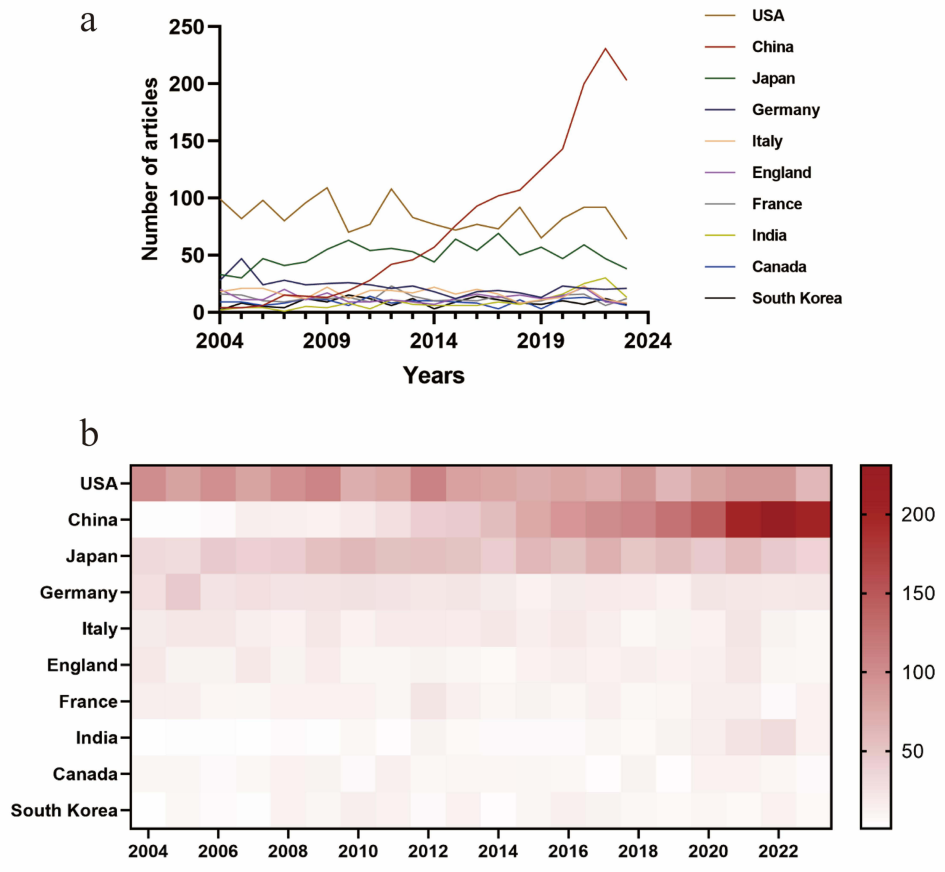

Figure 3 (**a**) Country annual publication quantity change chart. This line graph displays the annual publication output of articles from various countries between 2004 and 2024. Each line represents a different country, with the number of articles on the y-axis and the years on the x-axis. The graph shows fluctuations and trends in publication quantities over time for countries including the USA, China, Japan, Germany, Italy, England, France, India, Canada, and South Korea. (**b**) Country annual publication quantity heatmap. This heatmap visualizes the annual publication quantities of articles by country from 2004 to 2022. The color intensity (ranging from light to dark red) corresponds to the number of publications, with darker shades indicating higher volumes. The heatmap provides a clear visual comparison of publication trends across countries, highlighting the dominance of the USA and China in terms of publication output, especially in more recent years.

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Table 1 Country Publication Quantity

Rank	Country/Region	Article Counts	Centrality	Percentage (%)	Citation	Citation per Publication
1	USA	1688	0.12	27.63	94,565	56.02
2	CHINA	1528	0.1	25.01	22,130	14.48
3	JAPAN	1005	0.06	16.45	26,414	26.28
4	GERMANY	451	0.07	7.38	29,789	66.05
5	ITALY	324	0.03	5.30	22,680	70.00
6	ENGLAND	256	0.1	4.19	23,927	93.46
7	FRANCE	245	0.09	4.01	18,499	75.51
8	CANADA	178	0.06	2.91	16,703	93.84
9	INDIA	178	0.01	2.91	3116	17.51
10	SOUTH KOREA	173	0.08	2.83	5289	30.57

diagram. This suggests its significant influence in the international collaboration network, particularly with close partnerships involving China, the United Kingdom, Germany, and Italy. Furthermore, it is evident from the chart that China, Japan, South Korea, and India are situated on the right side of the diagram, which may reflect distinct characteristics of regional cooperation.

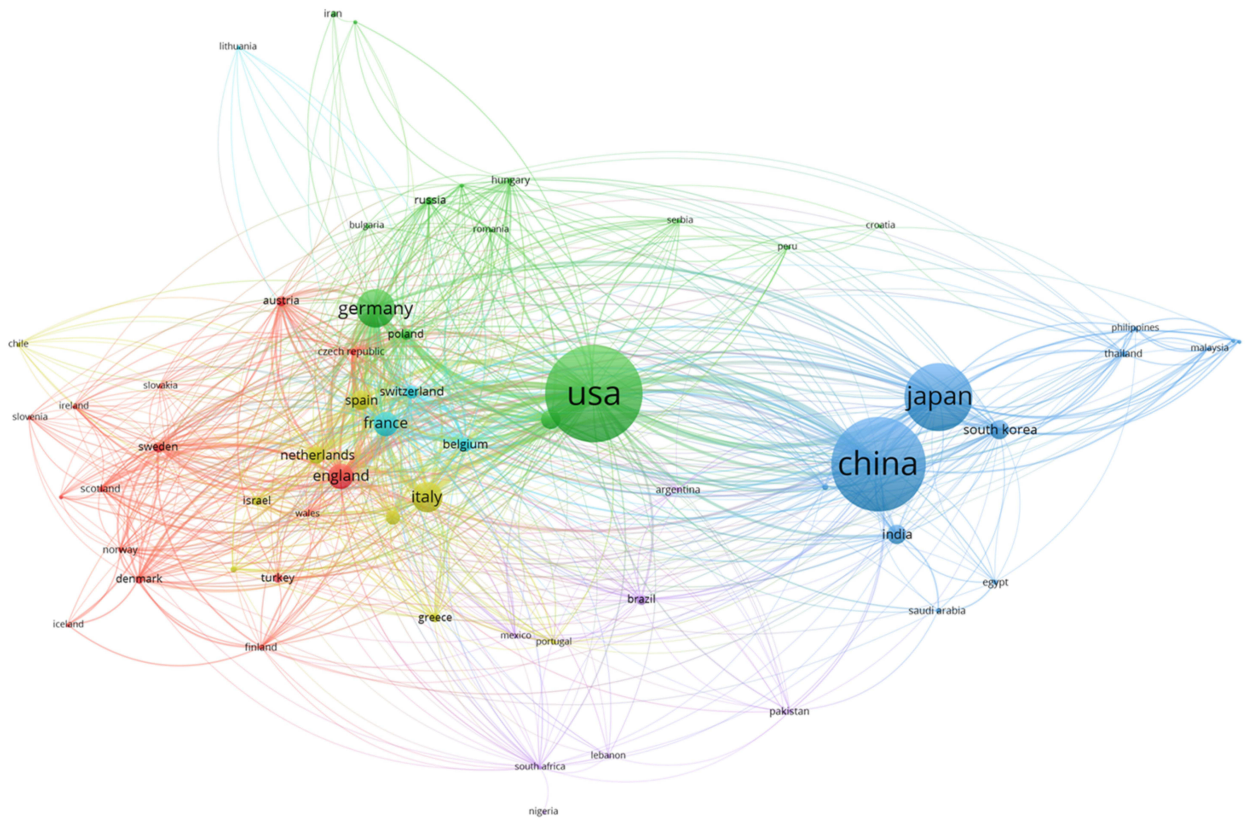

Figure 4 Country cooperation network. This network diagram illustrates the collaborative relationships among countries in research or publication activities. Each node represents a country, with the size of the node potentially indicating the volume or impact of its collaborations. The lines (edges) connecting the nodes signify collaborative partnerships, with different colors possibly representing varying types or strengths of collaboration. Notably, countries like the USA, China, and Japan appear as central hubs, indicating their prominent roles in international collaborations. The dense network of connections highlights the interconnected nature of global research efforts, with the USA showing extensive links to European countries and China demonstrating strong ties with neighboring Asian nations.

Table 2 Journal Publication Quantity

Rank	Journal	Article Counts	Percentage (6110)	IF	Quartile in Category
1	Cancer Chemotherapy and Pharmacology	216	3.54%	3.0	Q3
2	Journal of Clinical Oncology	150	2.45%	45.4	Q1
3	Clinical Cancer Research	123	2.01%	11.5	Q1
4	Annals of Oncology	108	1.77%	50.5	Q1
5	Investigational New Drugs	108	1.77%	3.4	Q3
6	Cancer	106	1.73%	6.2	Q1
7	Anticancer Research	89	1.46%	2.0	Q4
8	Bmc Cancer	81	1.33%	3.8	Q2
9	Medicine	81	1.33%	1.6	Q3
10	Frontiers in Oncology	79	1.29%	4.7	Q2

Journal Publication Analysis

Using the analysis retrieval function of the Web of Science Core Database, we examined the sources of cited journals. Among the top ten journals publishing research on chemotherapy-induced bone marrow suppression, *Cancer Chemotherapy and Pharmacology* leads with 216 papers (3.54%), followed by the *Journal of Clinical Oncology* with 150 papers (2.45%), *Clinical Cancer Research* with 123 papers (2.01%), *Annals of Oncology* with 108 papers (1.77%), and *Investigational New Drugs*, also with 108 papers (1.77%). Notably, *Annals of Oncology* boasts the highest impact factor (IF) at 50.5 (see Table 2). As illustrated in Figure 5a, the journal *Cancer Chemotherapy and Pharmacology* demonstrates significant influence and importance within its domain, as evidenced by its positioning on the publication density chart and the size of its font label.

Using CiteSpace software, we analyzed co-cited journals to identify the most active and influential publications in the field of chemotherapy-induced bone marrow suppression research. The co-citation network diagram was employed to investigate the inter-citation relationships among academic literature. The size of each node corresponded to the citation frequency of journals, while the strength of connections reflected citation intensity. It was observed that the most co-cited journal was the *Journal of Clinical Oncology* (4,421 citations), followed by *The New England Journal of Medicine* (2,939 citations) and *Annals of Oncology* (2,438 citations). Among the top ten co-cited journals, The *Lancet* was cited 1,740 times and has the highest impact factor (IF) at 168.9. Notably, 60% of the co-cited journals fall within the Q1/Q2 category (see Table 3 and Figure 5b).

This study performed a dual overlay analysis using CiteSpace software to explore the connections between cited and citing journals in the research field (see Figure 6). The colored trajectories illustrate citation links, with citing journals positioned on the left and cited journals on the right. The results reveal four main colored citation pathways. Research in the fields of medicine, clinical studies, and nursing predominantly references journals related to molecular biology, genetics, and health. Additionally, research within the domain of molecular biology and immunology is primarily reported in journals focused on molecular biology, genetics, and health as well as reference materials pertinent to nursing and medicine.

Author Collaboration Analysis

Among all authors who have contributed to the literature on chemotherapy-induced bone marrow suppression, Table 4 presents the top 10 authors based on their publication volume. Collectively, these leading authors have published a total of 200 papers, which constitutes 3.27% of all publications in this domain. The author boku, narikazu has authored the highest number of research papers at 23, followed closely by zhang, yu (22), wang, xin (21), wang, yan (21), and dygai,

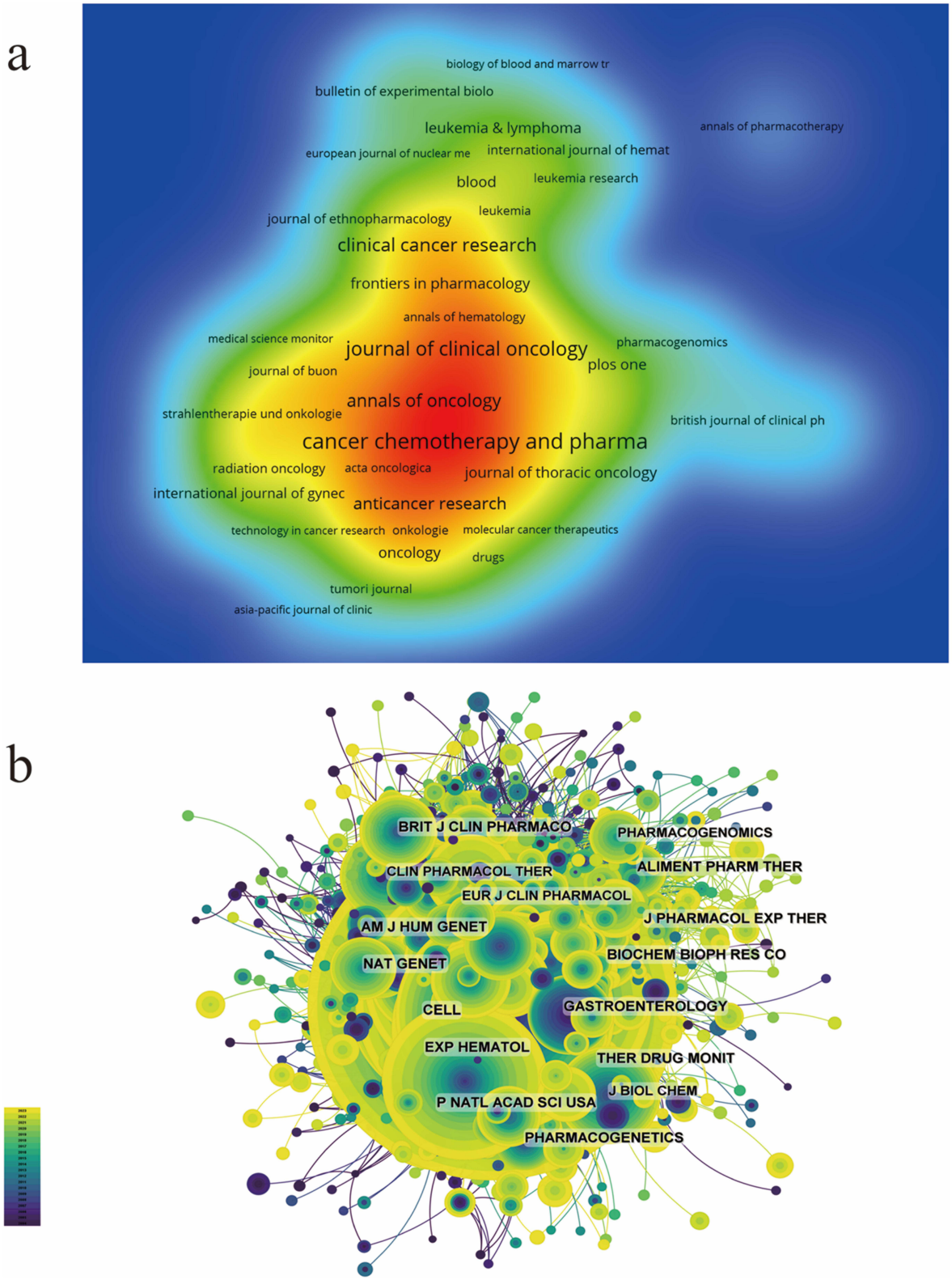

Figure 5 (**a**) Journal publication density. This density map visualizes the distribution of journal publications across different fields or topics. The concentration of journals in specific areas indicates higher publication activity or specialization within those domains. The gradient from blue to yellow may represent varying levels of publication density, with darker colors indicating more intensive publication clusters. **(b)** Journal co-citation network. This network diagram illustrates the co-citation relationships among journals. Nodes represent journals, with their size potentially indicating the frequency of citation or influence. Edges (lines) connect journals that are frequently cited together, reflecting their academic or thematic interrelatedness.

Table 3 Journal Co-Cited

Rank	Cited Journal	Co-Citation	IF (2022)	Quartile in Category
1	Journal of Clinical Oncology	4421	45.4	Q1
2	The New England Journal of Medicine	2939	158.5	Q1
3	Annals of Oncology	2438	50.5	Q1
4	Clinical Cancer Research	1953	11.5	Q1
5	The Lancet	1740	168.9	Q1
6	British Journal of Cancer	1695	8.8	Q1
7	European Journal of Cancer	1692	8.4	Q1
8	Cancer Research	1681	11.2	Q1
9	Cancer (American Cancer Society)	1616	6.2	Q1
10	Blood	1536	20.3	Q1

a.m (20). Further analysis reveals that five of the top ten authors are affiliated with institutions in China, three hail from Japan, while the remaining two represent the United States and Russia respectively. CiteSpace software was employed to visualize the collaborative network among these authors (see Figure 7). In this visualization, nodes correspond to individual authors; larger nodes indicate a greater number of published works. Lines connecting nodes signify collaboration between authors within shared literature; thicker lines denote more frequent co-authorships and closer cooperation among those involved. For instance, one prominent team includes boku narikazu alongside kato ken and hironaka shuichi as core members.

Keyword Analysis

By analyzing keywords, one can gain insights into the current status and developmental trajectory of a field. Utilizing VOSviewer for keyword co-occurrence analysis, the results reveal that the most frequently used keywords are “trial” (754), followed by “cancer” (667), “survival” (602), “combination” (528), and “toxicity” (see Table 5 and Figures 8 and 9).

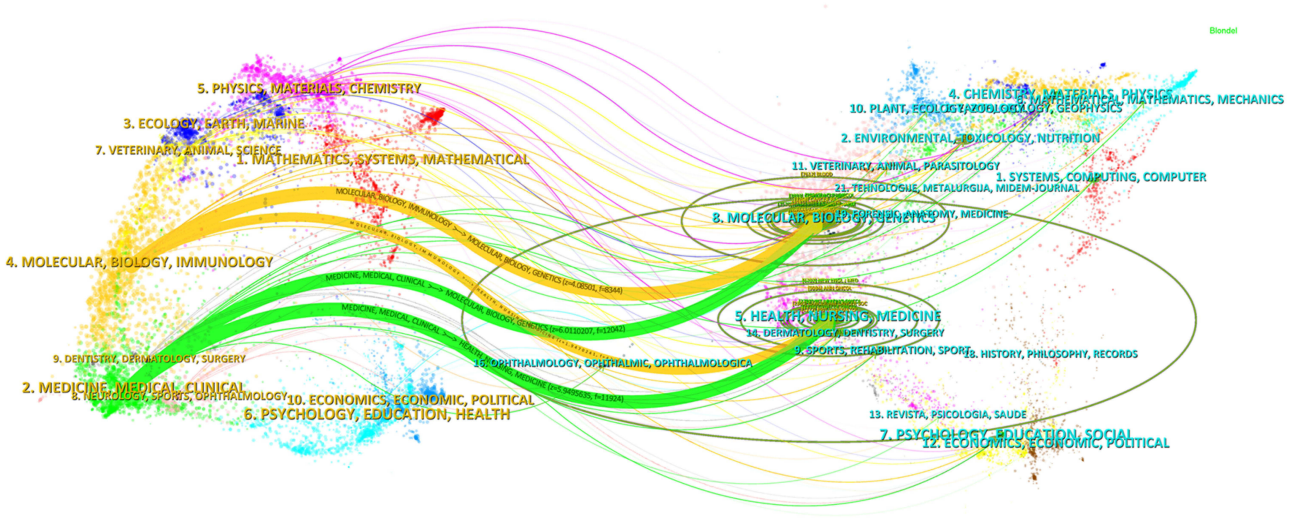

Figure 6 Journal dual overlay. This dual-overlay diagram integrates two dimensions of information: journal distribution across research fields and citation relationships between journals. Each colored arc or line connects journals within the same field or those with strong citation linkages, illustrating the interdisciplinary connections and citation flows across various domains. The density and overlap of lines highlight the interconnectedness of research areas, while distinct color coding helps differentiate between fields such as biology, chemistry, engineering, and social sciences.

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Table 4 Authors' Publications and Co-Cited Lists

Rank	Author	Count	Location	Rank	Co-Cited Author	Citation
1	boku, narikazu	23	Japan	1	jemal a	522
2	zhang, yu	22	China	2	therasse p	462
3	wang, xin	21	China	3	eisenhauer ea	309
4	wang, yan	21	China	4	kaplan el	275
5	dygai, a. m.	20	Russia	5	cheson bd	266
6	hainsworth, john d.	19	USA	6	van cutseme	203
7	okusaka, takuji	19	Japan	7	ajani ja	177
8	zhang, li	19	China	8	cunningham d	164
9	doki, yuichiro	18	Japan	9	simon r	164
10	li, wei	18	China	10	lyman gh	142

Highlighted words represent the current research hotspots in this field and suggest potential future research directions. From 2004 to 2023, a total of 844 highlighted terms emerged, with Figure 10 showcasing the top 50 strongest highlighted words. Between 2013 and 2020, research focused primarily on "bone marrow transplantation", "infusion", and "randomized trial". In the following years, research hotspots shifted to "chemoradiation", "mutation", and "mice", with immunotherapy garnering significant attention from scholars. Since 2017, the focus has centered on "immunotherapy", "maintenance therapy", "double-blind", "case report", and "systematic review". This evolution in disease types, research populations, and directions underscores that chemotherapy-induced bone marrow suppression and its implications continue to be a significant area of interest for many researchers.

Discussion

Over the past two decades, research in the field of chemotherapy-induced myelosuppression has shown a continuous upward trend, particularly since 2019, with an annual growth rate of approximately 115%. This suggests that the field is in a phase of rapid growth and holds substantial potential for further development. The sustained increase in research on chemotherapy-induced myelosuppression is primarily driven by the rising global incidence of cancer. Current studies in this field focus on optimizing chemotherapy and mitigating its side effects. Researchers are actively exploring new drugs

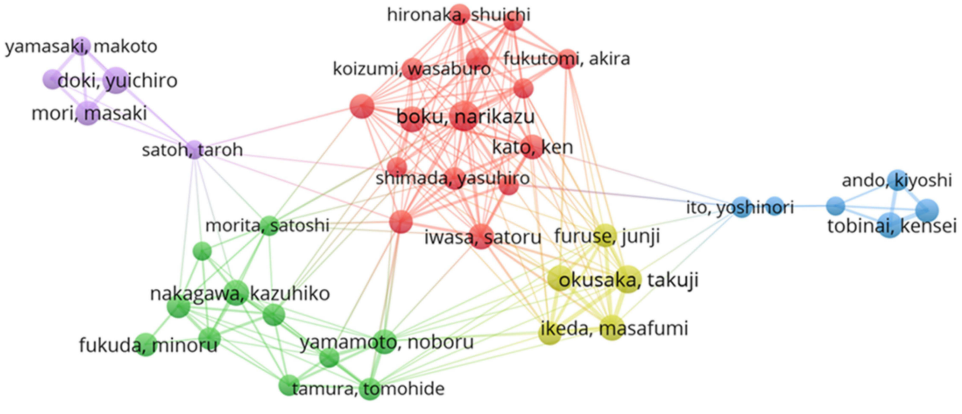

Figure 7 Author collaboration network diagram. This network diagram visualizes the collaborative relationships among authors in a specific research field. Each node represents an author, with node size potentially indicating the number of publications or the strength of their collaborative ties. The lines (edges) connecting the nodes signify co-authorship or research partnerships. Different colors may represent distinct research groups or clusters within the field.

Table 5 High-Frequency Keywords

Rank	Keyword	Counts	Rank	Keyword	Counts
1	trial	754	11	carcinoma	368
2	cancer	667	12	cyclophosphamide	363
3	survival	602	13	fluorouracil	344
4	combination	528	14	multicenter	301
5	toxicity	491	15	pharmacokinetics	301
6	efficacy	454	16	doxorubicin	297
7	myelosuppression	422	17	safety	263
8	radiotherapy	398	18	randomized-trial	251
9	carboplatin	395	19	chemoradiotherapy	248
10	phase-ii	392	20	open-label	240

and treatment strategies, while emphasizing basic research, clinical trials, and multidisciplinary collaboration to improve patients' quality of life. As research progresses, the future promises to deliver safer and more effective chemotherapy regimens for patients.

Globally, there has been extensive exploration in the area of chemotherapy-induced myelosuppression, with the United States standing out for its significant research output. US researchers have contributed 27.63% of all publications in this field, a testament to the country's substantial research investment, its strong interdisciplinary collaboration

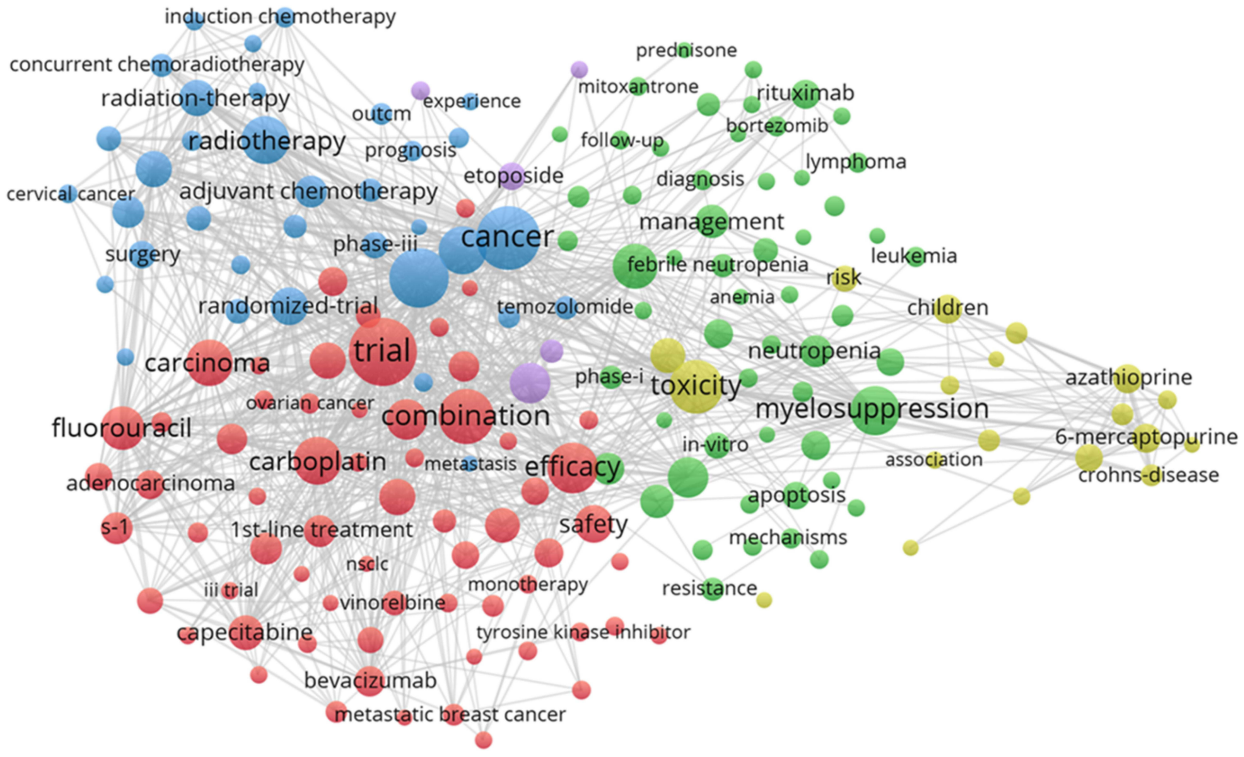

Figure 8 High-frequency keyword network diagram. This network diagram visualizes the relationships and co-occurrences of high-frequency keywords related to cancer research. Each node represents a keyword, with node size potentially indicating the frequency of its appearance in the literature. The lines (edges) connecting the nodes signify co-occurrence or associative relationships between keywords. Different colors may represent distinct clusters or themes within the research domain.

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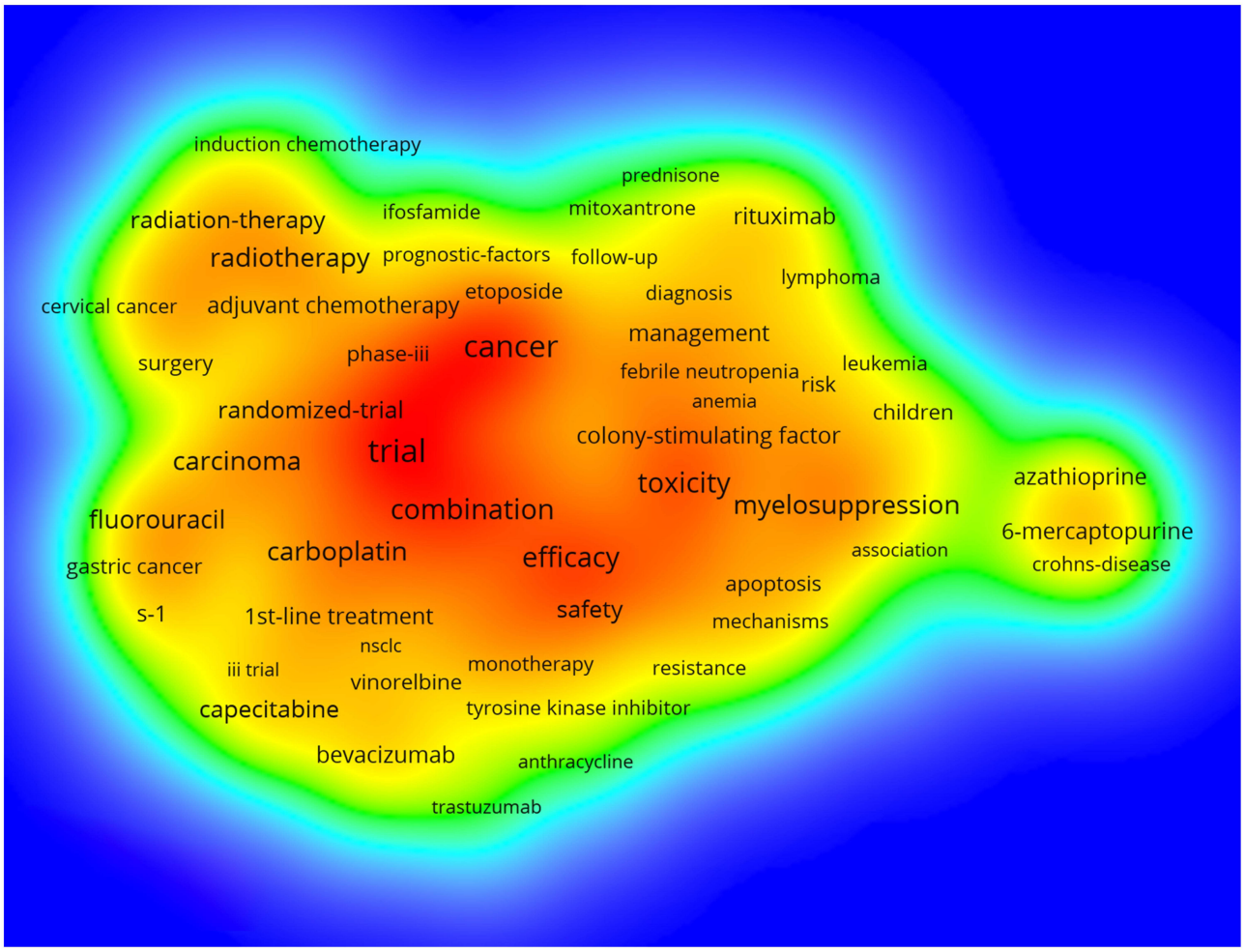

Figure 9 Keyword density. The color gradient, ranging from blue to red, indicates the density of keyword occurrences, with warmer colors (red/yellow) representing higher frequency or centrality of terms. Keywords such as "cancer", "radiotherapy", and "efficacy" appear prominently in high-density regions, reflecting their significance in the field. Surrounding areas with cooler colors (green/blue) show less frequent but related terms, such as "febrile neutropenia" or "colony-stimulating factor", which may represent niche or emerging research topics.

capabilities, its rich clinical resources, and the robust support from policies, funding, international exchanges, and scientific cooperation. Additionally, the presence of outstanding scientific talent and a thriving research culture contribute to this leading role. For instance, the National Institutes of Health (NIH) has established a dedicated fund for Cancer Center Support Grants, which allocates substantial resources for research on myelosuppression following chemotherapy. The Memorial Sloan Kettering Cancer Center, for example, treats a significant number of cancer patients undergoing chemotherapy each year, thereby providing an extensive clinical sample for investigating myelosuppression post-chemotherapy.

According to the analysis, the journals *Cancer Chemotherapy and Pharmacology* and *Journal of Clinical Oncology* have the highest publication and citation rates in this field. *Cancer Chemotherapy and Pharmacology* focuses on cancer treatment drugs and chemotherapy pharmacology. Its high publication volume reflects its role as a crucial platform for disseminating research results in the niche area of chemotherapy-induced myelosuppression, as well as a hub for the latest research advancements and innovative ideas. Meanwhile, *Journal of Clinical Oncology*, as a top-tier oncology journal, publishes high-quality, impactful studies that are widely cited. This indicates its significant academic contribution and value in guiding research on chemotherapy-induced myelosuppression and related areas.

Citation pathways reveal the exchange and integration of knowledge across various disciplines, reflecting the growing trend of interdisciplinary research that fosters innovation and application of knowledge. This is particularly significant in

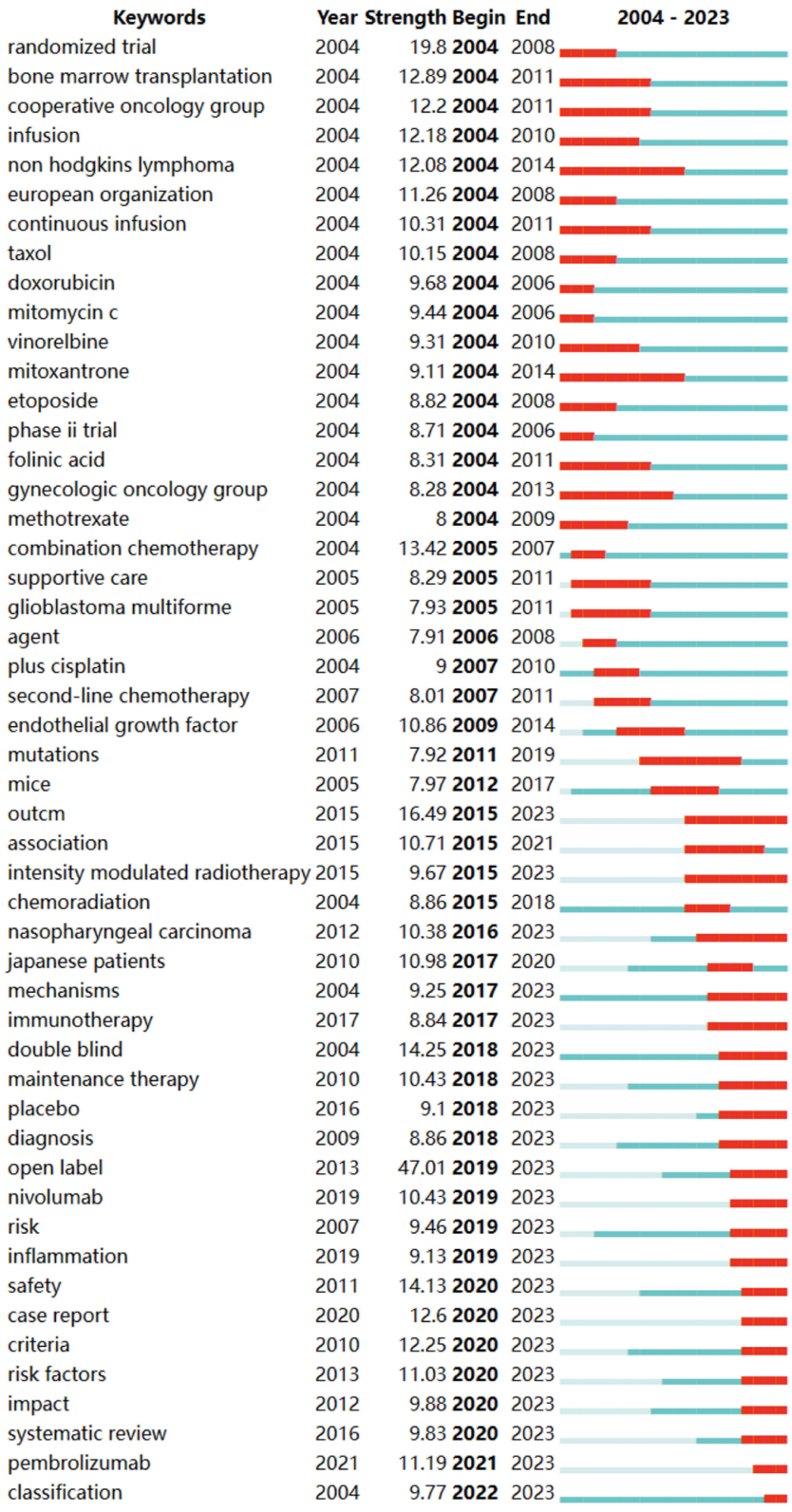

Figure 10 Keyword highlighting. This chart identifies the top 50 keywords with the strongest citation bursts between 2004 and 2024. Each row lists a keyword, its citation strength, and the time period during which the citation burst occurred. The horizontal bars visualize the duration of the citation burst, with red segments indicating periods of heightened citation activity. This figure helps pinpoint trending topics and key concepts that have driven academic discourse in the field during the specified period.

advancing research and treatment of complex diseases such as chemotherapy-induced myelosuppression. Journals in the Medicine/Medical/Clinical field are widely cited by journals in the Molecular/Biology/Genetics and Health/Nursing/Medicine fields, highlighting the substantial impact of clinical medical research on foundational studies in molecular biology, genetics, and health care. Clinical observations and practical experiences provide empirical evidence that enhances the understanding of disease mechanisms in molecular biology and genetics. Similarly, research published in journals from the Molecular/Biology/Immunology field is heavily cited by both Molecular/Biology/Genetics and Health/Nursing/Medicine journals. This underscores the close relationship between immunology and the fields of molecular biology, genetics, health care, and clinical medicine. Advances in immunology not only drive exploration into the molecular mechanisms of diseases but also directly influence the development and optimization of clinical treatment strategies.

One of the most prolific authors in this field, Boku Narikazu from Japan, has made significant contributions, especially in the clinical research of gastrointestinal tumors. An analysis of his ten most-cited articles reveals that his work focuses primarily on exploring treatments for cancers such as gastric, pancreatic, colorectal, and esophageal cancer. His research includes the design and execution of multicenter, randomized Phase III clinical trials, such as comparing different chemotherapy regimens for pancreatic cancer[10] and gastric cancer.[11] He has also contributed to the development of treatment guidelines for colorectal cancer in Japan[12] and investigated chemotherapy and radiotherapy protocols for gastric and esophageal cancers.[13,14] Boku's research spans a broad range of topics, from comparing and optimizing immunotherapy and chemotherapy regimens to the development of treatment guidelines, making significant advancements in the treatment of gastrointestinal tumors and improving patient outcomes.

Through keyword analysis, we can quickly gain insights into the research focus and emerging trends in the field of chemotherapy-induced myelosuppression. By utilizing VOSviewer for co-occurrence analysis, the results clearly highlight the research hotspots in this area. The keyword "trial" emerges as the most prominent, signifying that clinical trials play a central role in driving the optimization of treatment regimens and the validation of new therapies. This suggests that an increasing number of large-scale, multi-center clinical trials may be conducted in the future, encompassing a more diverse patient population, thereby rendering the results more universally applicable. Consequently, physicians will be able to optimize and accurately select chemotherapy regimens based on the findings from these tests. The frequent appearance of "cancer" underscores the primary disease context, focusing on the impact of chemotherapy on bone marrow function in cancer treatment. This suggests that future research will increasingly emphasize the relationship between specific cancers and bone marrow suppression, as well as investigate the connections between cancer pathogenesis and bone marrow suppression. Physicians may be able to predict and manage bone marrow suppression based on cancer types and other relevant factors, with research findings serving to inform clinical pharmacotherapy. The high frequency of the keyword "survival" reflects the research community's strong emphasis on improving patient survival rates, demonstrating a human-centered approach and goal-oriented focus in clinical research. In future studies, greater focus will be directed towards evaluating management strategies through the lens of overall survival, investigating the correlation between myelosuppression and cancer recurrence, and physicians should consider the implications of myelosuppression on survival rates when formulating treatment plans. Proactive measures to prevent and manage myelosuppression are essential. Overall, these keywords not only represent the current research focus on chemotherapy-induced myelosuppression but also point toward future directions. These include further optimization of clinical practice, innovative treatment strategies, and a continued focus on improving patient quality of life and long-term outcomes. As a result, the field is expected to evolve toward more precise, safer, and more effective approaches.

The detection of emerging keywords such as nasopharyngeal carcinoma, immunotherapy, nivolumab (Opdivo), and pembrolizumab (Keytruda) highlights the upcoming research trends in the field of chemotherapy-induced myelosuppression. Immunotherapy, particularly immune checkpoint inhibitors (ICIs) like Opdivo and Keytruda, is expected to become a major focus. Researchers are likely to explore the effects of immunotherapy on managing myelosuppression and its underlying mechanisms, as well as the interaction between immunotherapy and bone marrow suppression. Opdivo and Keytruda function by specifically binding to and blocking the PD-1 (programmed death-1) receptor, disrupting the interaction between PD-1 and its ligand PD-L1 (programmed death-ligand 1). This blockade reactivates T cells and enhances their ability to attack cancer cells, playing a critical role in treating various cancers. Studies have demonstrated

that the combination of ICIs and chemotherapy shows significant advantages in treating cancers like non-small cell lung cancer and ovarian cancer. This combination not only significantly improves the major pathological response rate but also prolongs patient survival.[15,16] However, this therapeutic strategy increases the risk of myelosuppression, which highlights the importance of supportive care in patient management. Supportive care plays a crucial role in controlling chemotherapy-induced myelosuppression and addressing the potential multisystem toxicities, including pulmonary toxicity, that can be triggered by immune checkpoint inhibitors[17,18] Notably, case reports have indicated that combining chemotherapy with immunotherapy, such as pembrolizumab, may lead to pancytopenia, underscoring the urgency of closely monitoring and intervening in myelosuppression during combination therapy.[19] To effectively manage chemotherapy-induced myelosuppression, a range of strategies has been proposed and applied. These include early detection of myelosuppression symptoms, rational drug dose adjustments, timely use of growth factors, and platelet transfusion when necessary. These measures collectively aim to reduce the side effects of immunotherapy and ensure patient safety.[20] Research further confirms that appropriate management of myelosuppression not only helps to prevent chemotherapy-related side effects but also maintains the efficacy of immunotherapy. This ensures that while maximizing the therapeutic benefits, patient safety is safeguarded.[21]

Nasopharyngeal carcinoma (NPC), as a specific disease entity, is highlighted in research for its unique characteristics in terms of bone marrow suppression following chemotherapy. This includes disease-specific treatment strategies, prognostic factors, and evaluations of patient quality of life. The current primary treatment modality for NPC patients is the combination of chemotherapy and radiotherapy, known as concurrent chemoradiotherapy (CCRT). For patients with locally advanced NPC, CCRT significantly improves progression-free survival (PFS) compared to radiotherapy alone, demonstrating its superiority in controlling disease progression.[22–24] Furthermore, for patients with stage IV NPC, the use of induction chemotherapy followed by CCRT has been shown to improve survival rates more effectively than CCRT alone, highlighting the importance of optimizing chemotherapy sequencing.[25] Research into genetic polymorphisms has uncovered individual differences in responses to chemotherapy and radiotherapy, providing a theoretical foundation for personalized treatment strategies.[26] It is noteworthy that curcumin has been found to have the potential to prevent chemotherapy side effects, including the reduction of bone marrow suppression, offering a degree of protection for chemotherapy patients.[27] Additionally, home enteral nutrition support has shown positive effects in preventing bone marrow suppression after CCRT in NPC patients, emphasizing the role of nutritional management in improving patient quality of life.[28] Moreover, Yan Shu injection, a compound traditional Chinese medicine, when used in conjunction with CCRT, has exhibited a synergistic effect in patients with stage III NPC, potentially helping to alleviate side effects, including bone marrow suppression.[29]

Conclusion

Utilizing bibliometric analysis, this study provides an innovative multidimensional examination of research related to myelosuppression after chemotherapy, comprehensively elucidating cutting-edge directions in the field and thoroughly investigating the interrelationships between different treatment modalities. This study not only complements existing research frameworks, strategies, and relationships, but also provides enhanced prospective guidance for clinical practice, particularly in the management of myelosuppression. The results of the study demonstrate that US researchers are leaders in the field of post-chemotherapy myelosuppression, and that Cancer Chemotherapy and Pharmacology is a key communication platform, which provides valuable collaboration and learning opportunities for researchers worldwide. Future research will focus on the core themes of nasopharyngeal cancer and immunotherapy, particularly revealing cutting-edge approaches such as immunotherapeutic interventions in nasopharyngeal cancer treatment. This advancement is expected to facilitate personalized treatment plans tailored to individual patient differences to address myelosuppression with greater precision. It also encourages clinicians to actively explore integrative treatment modalities that combine immunotherapy with traditional Chinese medicine to provide more comprehensive treatment options for patients with myelosuppression. In addition, focusing on specific pharmacological agents in the management of myelosuppression will steer drug research and development towards precision and safety, thereby contributing to the development of more scientific clinical drug guidelines to accurately determine the timing, dosage, and duration of medication, thereby more effectively mitigating chemotherapy-induced myelosuppression and improving the quality of life of patients.

Data Sharing Statement

All data are presented on the proof. For further data information, please contact the correspondence author.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study.

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