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Research Article

Decade of Research on the cGAS-STING Pathway in Cancer: A Bibliometric Analysis (2015 - 2025)

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Abstract

Purpose: *The cGAS–STING pathway is a central component of the innate immune system by detecting cytoplasmic DNA and initiating antitumor immunity. This study aims to identify research trends, prominent themes, and existing knowledge gaps by analyzing the literature on the role of the cGAS-STING pathway in cancer using bibliometric methods.*
Methods: *On May 4, 2025, an extensive search was conducted in the Web of Science Core Collection database using the terms "cGAS-STING Pathway" AND "Cancer." Publications from 2015 to 2025 were analyzed; in terms of annual trend of publications and citations, ınternational collaboration network of countries, highly cited articles, author performance analysis, and the keyword co-occurrence. Network visualizations were generated using VOSviewer software.*
Results: *The search identified 827 relevant articles. Annual publication counts showed a steady increase, peaking in 2024. The People's Republic of China ranked first with 561 publications and 11,946 citations, followed by the United States with 178 publications and 9,957 citations. The majority of articles appeared in high-impact journals, which also published the most highly cited studies in this field. Recent research has increasingly focused on the role and therapeutic potential of the cGAS-STING pathway in cancer treatment.*
Conclusion: *From 2015 to 2025, research on the cGAS–STING pathway in oncology has expanded substantially, with growing emphasis on therapeutic strategies involving innate immunity. These trends reflect heightened scholarly interest in the pathway's function in cancer immunotherapy and underscore its potential as a promising target for future research and drug development.*

Key words*: Bibliometric Analysis, Cancer, cGAS-STING Pathway, Web of Science*

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Introduction

Cancer is a leading cause of death worldwide, accounting for approximately 10 million deaths in 2020, or nearly one in six deaths (1). According to data from the Global Cancer Observatory (GLOBOCAN) of the International Agency for Research on Cancer (IARC), nearly 20 million new cancer cases, including nonmelanoma skin cancers (NMSCs), were reported in 2022, alongside approximately 9.7 million deaths from cancer. Lung cancer was the primary cause of cancer mortality, resulting in an estimated 1.8 million deaths (18.7%), followed by colorectal (9.3%), liver (7.8%), breast (6.9%), and stomach cancers (6.8%) (2). A malignant tumor is a collection of cells characterized by uncontrolled proliferation, invasiveness, and metastatic potential, distinguishing it from normal tissue. Cancer develops as a result of disrupted genomic control, caused either by the aberrant activation of oncogenes or by the functional inactivation (3). For decades, surgery, radiation therapy, and chemotherapy have been the mainstay treatments for cancer. However, these approaches often induce toxicity and collateral damage to healthy tissue. Intratumoral heterogeneity, a primary driver of tumor recurrence and metastasis, represents a significant obstacle to effective cancer treatment (4). The limitations of conventional therapies have created an urgent need for innovative and targeted treatment strategies (5). The cGAS–STING pathway functions as a key cytosolic DNA-sensing mechanism that activates innate immune responses (6). Cyclic GMP–AMP synthase (cGAS) is a cytosolic DNA sensor that triggers innate immune responses against pathogens such as viruses. Activation of cGAS stimulates the adaptor protein STING, which subsequently initiates interferon signaling (7). In addition to defending against a broad spectrum of DNA-containing pathogens, the cGAS-STING pathway also detects tumor-derived DNA and promotes intrinsic antitumor immunity (8).

Both cGAS and STING have been demonstrated to possess additional functions beyond the canonical interferon response. These include non-catalytic roles of cGAS in the regulation of DNA repair, STING-mediated signaling through the NF-κB and MAPK pathways, and the induction of autophagy and lysosome-dependent cell death by STING (9). Activation of the cGAS–STING pathway by self-DNA has also been linked to the development of diverse infectious, autoimmune, and inflammatory conditions. Furthermore, the cGAS–STING pathway acts as a critical link between innate and adaptive immunity,

leading to the facilitation or inhibition of tumorigenesis. Given its involvement in fundamental cellular processes such as autophagy, senescence, and apoptosis, targeting the cGAS–STING pathway holds promise for the development of novel cancer therapies (10).

Bibliometric analysis is a systematic research methodology that applies quantitative and statistical techniques to assess the volume, impact, and evolution of scientific publications. This approach enables researchers to identify past, current, and emerging trends in scholarly output (11). The use of bibliometrics has recently expanded across scientific disciplines owing to ability to provide objective and reliable insights into research landscapes (12). While bibliometric studies have explored the broader STING signaling pathway in oncology, the specific relationship between the cGAS–STING pathway and cancer biology, particularly with respect to its therapeutic applications, remains underexplored.

This study aimed to systematically evaluate the current state of research on the cGAS–STING pathway in cancer and to trace the evolution of scientific interest in its potential as a therapeutic target. A bibliometric analysis was conducted on all relevant articles retrieved from the Web of Science (WoS) Core Collection, using the search string "cGAS–STING" AND cancer applied to article titles and abstracts, covering the period from 2015 to May 2025.

The growing body of literature, particularly in the context of cancer treatment, highlights the persistent limitations of current cancer therapies. Although chemotherapeutic agents remain a cornerstone of many treatment regimens, their use is frequently associated with severe adverse effects and systemic toxicity. Consequently, there is increasing interest in natural compounds and mechanisms of the innate immune system as alternative therapeutic strategies. Intratumoral heterogeneity underlies drug resistance, necessitating the design of targeted therapies or combination regimens tailored to this heterogeneity to maximize efficacy and minimize toxicity (13). Furthermore, the rising importance of gene expression profiles specific to molecular cancer subtypes underscores the need for personalized therapeutic approaches. In this context, the present study not only examines the current research landscape on the cGAS–STING pathway in oncology but also identifies prevailing trends and potential future directions in this domain.

Methods

Data acquisition and search strategy

This study included publications from 2015 to 2025. The start year 2015 was chosen because the first article specifically linking the cGAS–STING pathway to cancer was published in this year. The end date, May 4, 2025, corresponds to the day the literature search was conducted, ensuring that the analysis reflects the most up-to-date data available. Publications that included the keywords "cGAS-STING Pathway" AND "Cancer" in their titles or abstracts were retrieved from the Web of Science (WoS) Core Collection. This initial search yielded 856 records. Only articles and review articles published in English were considered for inclusion. After excluding conference abstracts, early access publications, meeting abstracts, and book chapters, a total of 827 records remained for analysis. Early access articles were omitted to ensure bibliographic consistency, as such publications did not yet possess definitive volume, issue, or page numbers at the time of the research. This approach was implemented to maintain data consistency and citation stability.

The WoS Core Collection was specifically chosen due to its rigorous indexing criteria, extensive disciplinary coverage, and reliable citation monitoring. These characteristics make it an appropriate and sufficient source for identifying high-quality, peer-reviewed publications relevant to the study's objectives.

Duplicate records were removed, and the titles and abstracts of all remaining publications were carefully reviewed to confirm relevance to the cGAS-STING pathway in cancer. Only peer-reviewed articles and reviews were included to ensure data quality.

Data Analysis

Bibliometric analysis was conducted using VOSviewer version 1.6.20. Articles were analyzed according to multiple parameters, including annual number of publications, article type, and research area; citation counts and temporal citation trends; countries with the highest publication output and citation impact; most cited documents and authors with the highest citation counts; and co-occurrence of author keywords. A minimum threshold of two publications was applied uniformly across all analyses. The extracted records were added to the marked list in the WoS database and subsequently exported as a tab-delimited file using the "Export Records" function. Visual network maps were generated to illustrate relationships among the analyzed characteristics.

Visualization settings were adjusted using the default VOSviewer layout (VOS mapping technique), with attraction set to 2 and repulsion to −1. Clustering resolution was set to 1.0 (minimum cluster size = 1, with small clusters merged), and normalization was performed using the association strength method. For co-authorship and keyword networks, node size was proportional to the number of documents (publications), and edge thickness reflected the link strength (co-authorship links or co-occurrences). The network maps were color-coded according to clusters generated by VOSviewer to highlight research themes and collaboration patterns. All maps were exported in PNG format for visualization and interpretation.

Results

The earliest article on the cGAS–STING pathway in cancer research was published in 2015, marking the onset of scholarly attention in this domain. A total of 856 records published between 2015 and May 4, 2025 were identified, of which 827 met the inclusion criteria. Collectively, these publications accumulated 22,190 citations, with an average of 26.83 citations per article. The most cited publication, "*DNA sensing by the cGAS–STING pathway in health and disease*" (2019)(14), received 955 citations, highlighting its foundational role in shaping subsequent research. The top 19 most cited articles are listed in Table 1.

Table 1. The 19 most cited articles on the cGAS–STING pathway in cancer (2015–2025), including authors, publication year, journal, total citations, and main research focus.

Title	Author	Source Title	Year	DOI	Citation
DNA sensing by the cGAS-STING pathway in health and disease	Motwani et al.(14)	Nature Reviews Genetics	2019	10.1038/s41576-019-0151-1	955
Cytoplasmic chromatin triggers inflammation in senescence and cancer	Dou et al.(15)	Nature	2017	10.1038/nature24050	918
Innate immune sensing of cytosolic chromatin fragments through cGAS promotes senescence	Glück et al.(16)	Nature Cell Biology	2017	10.1038/ncb3586	793

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The Cytosolic DNA-Sensing cGAS-STING Pathway in Cancer	Kwon and Bakhoum (7)	Cancer Discovery	2020	10.1158/2159-8290.CD-19-0761	738
Manganese is critical for antitumor immune responses via cGAS-STING and improves the efficacy of clinical immunotherapy	Lv et al.(17)	Cell Research	2020	10.1038/s41422-020-00395-4	592
PARP Inhibitor Efficacy Depends on CD8+ T-cell Recruitment via Intratumoral STING Pathway Activation in BRCA-Deficient Models of Triple-Negative Breast Cancer	Pantelidou et al.(18)	Cancer Discovery	2019	10.1158/2159-8290.CD-18-1218	475
PARPi Triggers the STING-Dependent Immune Response and Enhances the Therapeutic Efficacy of Immune Checkpoint Blockade Independent of BRCAness	Shen et al.(19)	Cancer Research	2019	10.1158/0008-5472.CAN-18-1003	411
cGAS-STING, an important pathway in cancer immunotherapy	Jiang et al.(20)	Journal of Hematology & Oncology	2020	10.1186/s13045-020-00916-z	373
SAMHD1 acts at stalled replication forks to prevent interferon induction	Coquel et al.(21)	Nature	2018	10.1038/s41586-018-0050-1	314
The Cytoplasmic DNA Sensor cGAS Promotes Mitotic Cell Death	Zierhut et al.(22)	Cell	2019	10.1016/j.cell.2019.05.035	288
Exosomes Shuttle TREX1-Sensitive IFN-Stimulatory dsDNA from Irradiated Cancer Cells to DCs	Diamondet al.(23)	Cancer Immunology Research	2018	10.1158/2326-6066.CIR-17-0581	276
Activating cGAS-STING pathway for the optimal effect of cancer immunotherapy	Li et al.(24)	Journal of Hematology & Oncology	2019	10.1186/s13045-019-0721-x	260

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The cGAS-STING pathway and cancer	Samson and Ablasser (25)	Nature Cancer	2022	10.1038/s43018-022-00468-w	257
PARP inhibition enhances tumor cell-intrinsic immunity in ERCC1-deficient non-small cell lung cancer	Chabano et al.(26)	Journal of Clinical Investigation	2019	10.1172/JCI123319	244
cGAS-STING pathway in cancer biotherapy	Wang et al. (6)	Molecular Cancer	2020	10.1186/s12943-020-01247-w	219
Mitochondria-to-nucleus retrograde signaling drives formation of cytoplasmic chromatin and inflammation in senescence	Vizioli et al.(27)	Genes & Development	2020	10.1101/gad.331272.119	219
DNA Damage and Cancer Immunotherapy: A STING in the Tale	Reisländer et al.(28)	Molecular Cell	2020	10.1016/j.molcel.2020.07.026	216
Cisplatin-induced immune modulation in ovarian cancer mouse models with distinct inflammation profiles	Grabosch et al.(29)	Oncogene	2019	10.1038/s41388-018-0581-9	205
cGAS-STING drives the IL-6-dependent survival of chromosomally instable cancers	Hong et al.(30)	Nature	2022	10.1038/s41586-022-04847-2	201

Annual Publication Trends

From the first publication in 2015, the annual number of articles generally showed an upward trend, reaching a maximum of 278 articles in 2024. Interestingly, only six articles were published in 2017, and even fewer (four articles) in 2018. By May 4, 2025, 119 articles had already been published. Citation counts also increased steadily over the years, with 2024 showing the highest citation count (Fig. 1). Although publication and citation counts appear lower in 2025, this is likely due to the year not yet being complete.

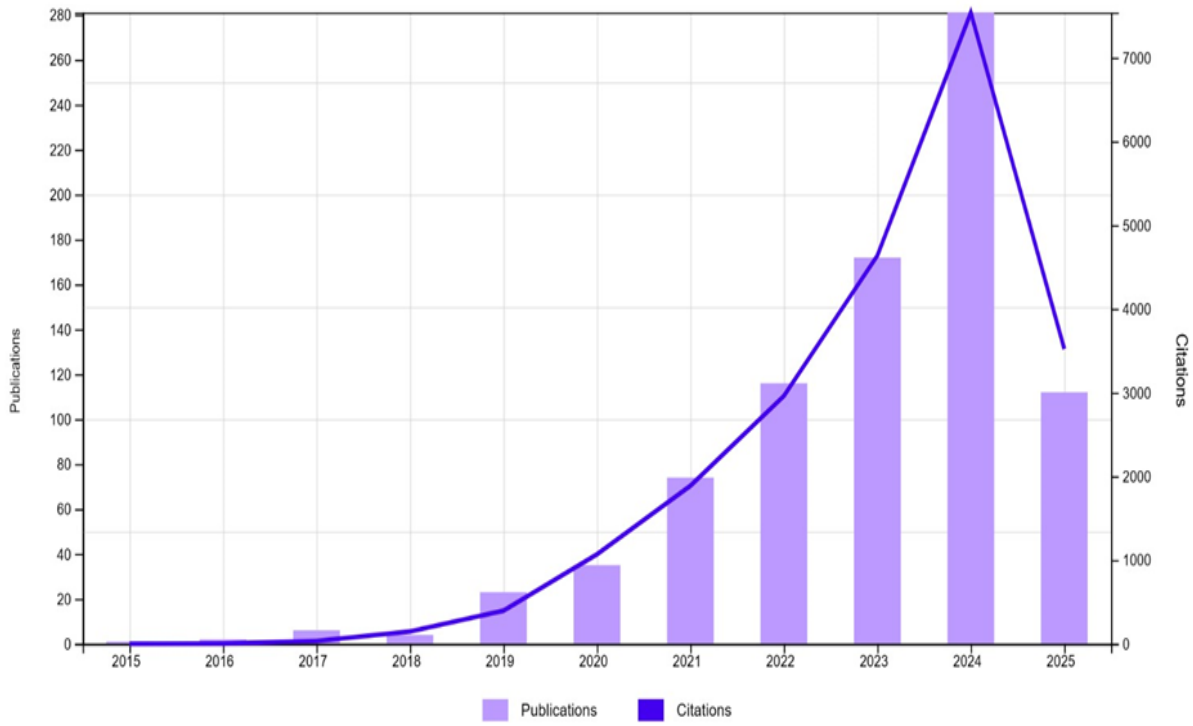

Figure 1. Annual trend of publications and citations.

The figure shows the yearly distribution of publications and citation counts from 2015 to 2025. Publications (lavender bars) and citation counts (dark purple line) exhibit a consistent upward trend, both peaking in 2024 (~280 publications; ~7,000 citations) before a slight decline in 2025. The parallel increase indicates that higher research output was associated with greater citation impact.

Country Contribution

The People's Republic of China (PRC) led with 561 publications and 11,946 citations, followed by the United States of America (USA) with 178 publications and 9,957 citations (Fig. 2).

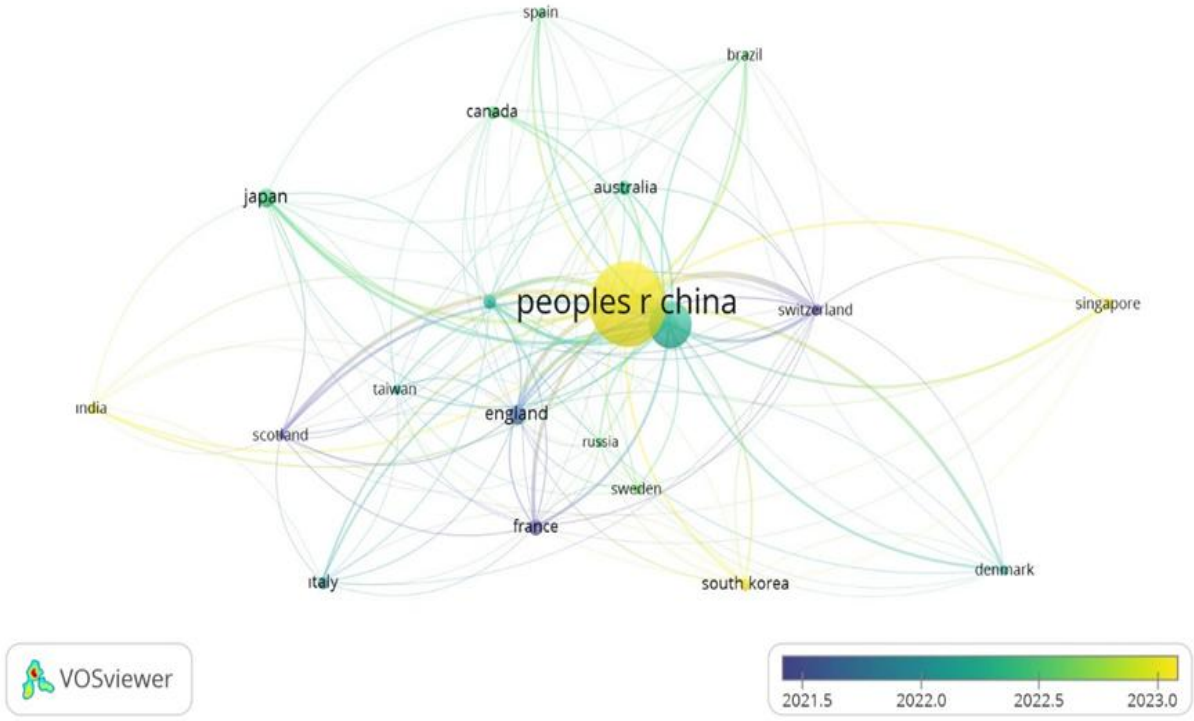

Figure 2. International collaboration network of countries (VOSviewer).

Each node represents a country, with node size indicating publication output. Links represent collaborative relationships, with thicker lines reflecting stronger collaborations. Node colors indicate the average publication year (dark blue = 2021.5 to yellow = 2023.0). The PRC is the largest and most central node, showing strong collaborations with Australia, England, and Switzerland. India, Singapore, and South Korea appear in yellow, suggesting more recent collaborations.

Highly Cited Articles

Filtering for articles with at least two citations yielded 607 publications. Among these, Motwani (2019) (14) had the highest citation count, with 955 citations, followed by Dou (2017) (15) with 918 citations (Fig. 3).

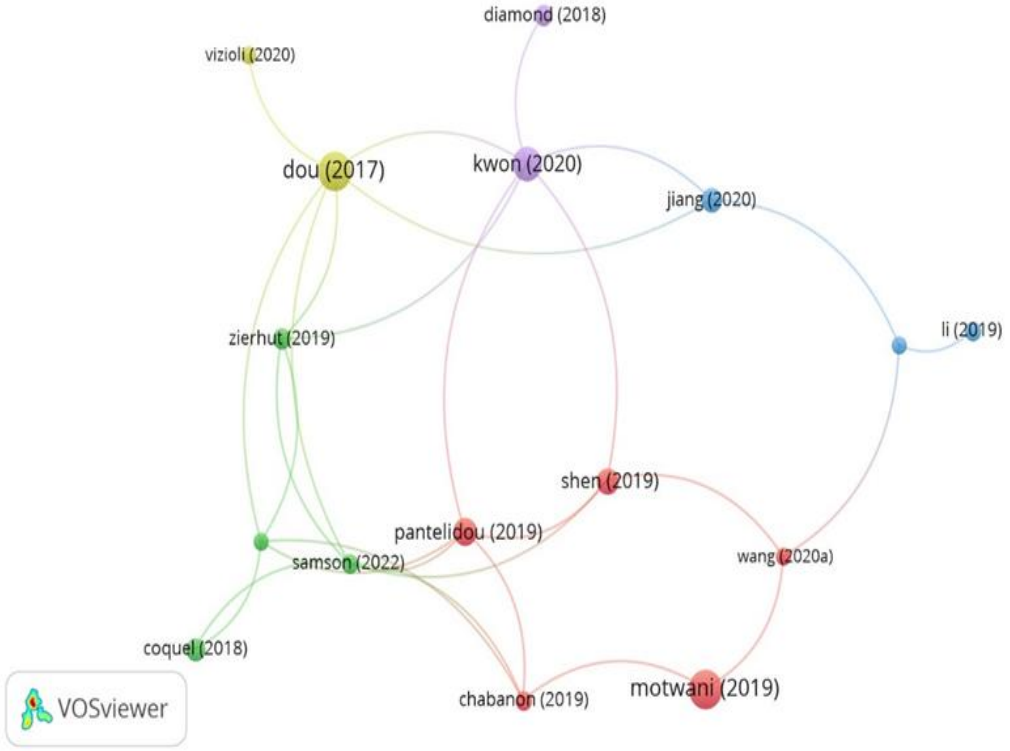

Figure 3. Co-citation network of references (VOSviewer).

Each node represents a cited reference, with node size indicating citation count. Links reflect co-citation relationships, with thicker lines indicating stronger connections. Different colors represent distinct clusters, grouping references that are frequently cited together. Dou (2017) (15) has the largest node, indicating the highest citation frequency; other influential references include Kwon (2020) (7), Motwani (2019) (14), and Shen (2019) (19).

Author Performance Analysis

The authors with the highest citation counts were Peter D. Adams, Shelley I. Berger, Zhixun Dou, and Maria Grazia Vizioli, each accumulating 1,137 citations (Fig. 4).

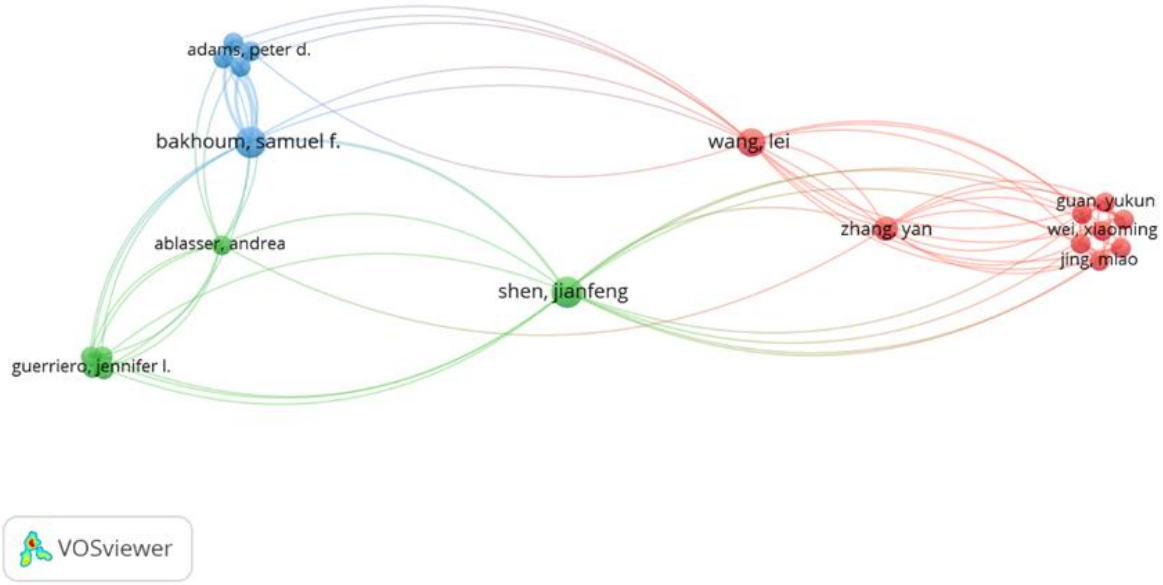

Figure 4. Co-authorship network of authors (VOSviewer).

Each node represents an author, with node size indicating the number of publications. Links represent collaborative relationships, with thicker lines reflecting stronger co-authorship. Different colors denote clusters of closely collaborating authors. Samuel F. Bakhoum, Andrea Ablasser, and Jianfeng Shen are influential within their clusters, whereas Lei Wang, Yan Zhang, and collaborators form another strong cluster, indicating active and frequent collaboration.

Analysis of Research Hotspots

Keyword analysis identified a total of 1,654 unique keywords. Applying a minimum threshold of two occurrences reduced this number to 340 keywords. The most frequently used keywords, in descending order, were cGAS-STING pathway, cGAS-STING, STING, cGAS, and immunotherapy (Fig. 5).

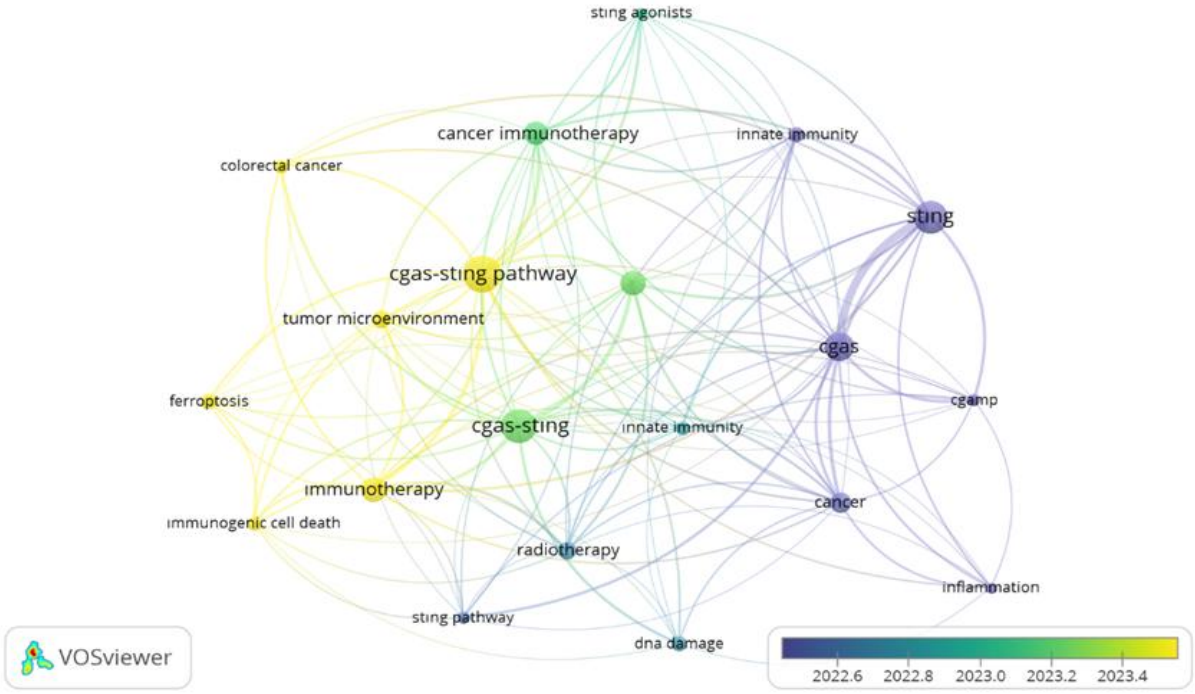

Figure 5. Keyword co-occurrence overlay visualization (VOSviewer).

Each node represents a keyword, with node size indicating frequency of occurrence. Links reflect co-occurrence relationships, with thicker lines indicating stronger associations. Node colors represent the average publication year (dark blue = 2022.6 to yellow = 2023.4). Recent hotspots such as “cGAS–STING pathway,” “tumor microenvironment,” “immunotherapy,” and “ferroptosis” appear in yellow, while earlier terms like “cGAS,” “STING,” and “innate immunity” appear in darker colors.

Discussion

Over the past decade, significant advances have been made in understanding the relationship between nucleic acid sensing and immune gene regulation, particularly the DNA sensor cGAS, its downstream effector STING, and the mechanisms regulating this pathway. Activation of cGAS by self-DNA has emerged as a key factor in inflammation, linking the cGAS-STING pathway to human inflammatory disorders and cancer (14).

In cancer cells, activation of the STING signaling pathway may also promote apoptosis. The effects of cGAMP on cancer are influenced by factors such as the timing and type of tumorigenesis, as well as the specific cell type activated (5).

In this study, reviewing publications from 2015 to May 4, 2025, we observed a substantial increase in the number of articles, peaking in 2024. The apparent decrease in publications in 2025 likely reflects partial-year data collection (Fig. 1). Citation trends showed a similar pattern, also reaching their highest level in 2024. As shown in Table 1, the review article "*DNA sensing by the cGAS-STING pathway in health and disease*" received the highest citation count. The article discussed how cytoplasmic cGAS receptor activation and downstream signaling are coordinated, identifying numerous regulatory mechanisms controlling this pathway, and highlighted studies linking this pathway to the development of various sterile inflammatory conditions as well as its emerging role in cancer. Additionally, the review emphasized the potential use of this pathway in the treatment of inflammatory diseases and the advancement of cancer immunotherapy (14). Other highly cited publications primarily focused on cancer immunotherapy, cancer biotherapy, specific gene functions, and chromosomal research.

Regarding geographical contributions, the PRC ranked first in both publication and citation counts, followed by the USA. Notably, the most frequently cited authors are based in the USA, highlighting strong American research activity in the cGAS–STING pathway. Keyword analysis revealed frequent use of terms such as "cGAS–STING pathway," "immunotherapy," "radiotherapy," "tumor microenvironment," and "DNA damage," indicating a research focus on the pathway's role in cancer treatment.

The majority of the most highly cited publications focus on the cGAS–STING pathway, DNA damage response, and tumor immunity. This studies indicates that gene expression studies are not limited to molecular-level research but are increasingly integrated with clinically relevant processes, such as immune responses and the tumor microenvironment. In particular, the significant role of STING-mediated immune responses in cancer immunotherapy has been emphasized (31). Unlike previous bibliometric analyses covering the broader cGAS–STING pathway, our study focuses specifically on cancer-related publications. This targeted approach, together with an updated dataset from 2015 to 2025, allows us to reveal recent trends in publications, citations, and author contributions that were not

previously reported. Through advanced bibliometric network analyses using VOSviewer and CiteSpace, we identify influential authors, research clusters, and emerging subtopics, highlighting knowledge gaps and opportunities in the current literature.

Figure 1 illustrates the publication and citation trends from 2015 to 2025 related to cGAS–STING and gene expression. A rapid increase in publication counts was observed after 2019, peaking in 2024. Citation counts followed a similar upward trajectory, reaching a peak in 2024. While publication numbers remain high in 2025, citation counts exhibit a decline, which can be attributed to the limited time for newly published articles to accumulate citations. These trends confirm the heightened interest in the cGAS–STING pathway in recent years. The PRC occupies a central position and maintains extensive international collaborations (Fig. 2). It is evident from the dispersed visualizations that the PRC has established robust connections with countries such as Switzerland, the United Kingdom, Canada, and Australia, and that these networks have expanded over time. This development may relate to the PRC's recent emergence as a leader in scientific publication output and its increasing influence within international research networks. According to statistics compiled by the United States National Science Foundation, the PRC surpassed the USA in total scientific publication output for the first time (32). This rise is thought to be driven by rapidly increasing research funding, which has accelerated the expansion of the PRC's scientific and technological workforce (33). Moreover, since 2018, the PRC has produced the largest number of original research articles indexed in the Science Citation Index, surpassing the USA (34). In recent years, countries such as Singapore, Denmark, and South Korea have also become increasingly active in current research, as indicated by nodes with higher yellow coloration. This pattern demonstrates that scientific output is now concentrated not only in traditional centers but also in emerging research economies, reflecting the global spread of collaborative research culture. A recent bibliometric study provides a comprehensive overview of the global distribution and emerging research frontiers in tumor immune escape (35).

The co-citation network presented in Figure 3 illustrates the co-citation relationships and thematic clusters of the twenty most highly cited publications on the cGAS–STING pathway and cancer. This visualization demonstrates that key publications are organized around distinct thematic clusters and provides insight into how research

trends have shifted over time. Central to the network, the study by Dou et al. demonstrated that cytoplasmic chromatin activates the cGAS–STING pathway, leading to both acute inflammation and cancer-associated chronic inflammation (15). The link between the cGAS–STING pathway and antitumor immunity, cancer progression, genomic instability, tumor microenvironment, and pharmacological strategies for cancer therapy has been discussed in a review by Kwon et al. (7). The study by Zierhut and Funabiki, which examined how cGAS activation is regulated by the cell's own DNA and its consequences, provides us with important information (36). Publications in the red cluster, such as those by Motwani et al. and Pantelidou et al., explore the immunotherapeutic potential of the cGAS–STING pathway (14, 18). Overall, the network structure indicates that research initially focused on molecular mechanisms before gradually transitioning toward therapeutic and clinical applications.

Figure 4 depicts the co-authorship network of the twenty most highly cited authors in cGAS–STING and cancer research. The analysis reveals three main clusters, colored blue, red, and green. Node size is proportional to citation counts, and authors such as Samuel F. Bakhoum and Jianfeng Shen occupy bridging positions between clusters. This network clearly demonstrates how key actors and research groups are organized within the field of cGAS–STING cancer research, who holds central roles, and how knowledge is disseminated through interdisciplinary collaborations.

The co-occurrence network of author keywords in Figure 5 illustrates the prominent thematic focuses in cGAS–STING-related cancer research. Terms such as “cGAS–STING pathway” and “cGAS–STING” show strong associations with clinical concepts such as “cancer immunotherapy,” “tumor microenvironment,” and “immunotherapy,” whereas keywords such as “cGAS” and “STING” are associated with fundamental biological processes, including “innate immunity,” “DNA damage,” and “inflammation.” The color scale indicates that research topics have become particularly concentrated in areas such as immunotherapy, tumor microenvironment, and ferroptosis from late 2022 to mid-2023.

In a previous bibliometric analysis, Shi et al. examined studies published between 2013 and 2021 and reported substantial growth in the field, with the USA and PRC as the main contributing countries. They also noted a shift from basic mechanistic studies to therapeutic applications, particularly nanoparticle-based treatments (11). Unlike their broader focus on the

cGAS–STING pathway as a whole, the present study specifically employed the combined keywords “cGAS–STING pathway” AND “cancer” to capture cancer-related publications, thereby generating a more targeted dataset Similarly, Lu et al. analyzed articles published between 2008 and 2022 using the broader terms “STING signaling pathway” AND “cancer” with CiteSpace and identified the USA as the leading country (37). In contrast, our study identified the PRC as the most productive country, a finding likely attributable to our biologically defined focus on cGAS-activated STING, whereas Lu and colleagues’(37) broader STING definition encompassed non-cGAS activation mechanisms. This methodological approach provides the advantage of presenting the current landscape of cGAS–STING research specifically within a cancer context in a more precise, focused, and detailed manner. By incorporating a more recent time frame, cancer-specific search terms, and comprehensive VOSviewer network analyses, this study offers an original, up-to-date, and cancer-centered perspective that complements and extends previous bibliometric investigations.

While previous analyses addressed related areas, the present study is distinguished by its exclusive focus on the cGAS–STING pathway in cancer and by the inclusion of the most current dataset spanning 2015 to 2025. Using advanced visualization techniques, it provides insights into publication trends, influential authors, emerging research directions, and underexplored subtopics. This focused approach advances the field by offering clear guidance for future research trajectories.

Limitations

This study has several limitations. First, it relied solely on the Web of Science Core Collection, which may have excluded relevant publications indexed in other databases such as Scopus or PubMed. Second, the search strategy focused on keywords in titles, abstracts, and author keywords, potentially omitting indirectly related studies. Third, citation counts are time-dependent and do not necessarily reflect the quality or impact of research. Fourth, the dataset included publications only up to early 2025, and visual network analyses may be subject to interpretation bias. Although this study provides a quantitative overview of publication counts, citation patterns, and author contributions, some broader research trends require further exploration.

Conclusion

Our analysis shows that research on the cGAS–STING pathway has increased since 2015, peaking in 2025, with the PRC and USA as leading contributors. However, areas such as combination therapies and tumor microenvironment mechanisms remain underexplored. Future studies focusing on these topics, along with novel approaches like single-cell sequencing and spatial transcriptomics, may deepen understanding of the pathway and enhance therapeutic development. Greater collaboration across immunology, oncology, and bioinformatics is likely to further accelerate drug discovery in this field.

Ethical Approval

As this study was based exclusively on publicly available bibliometric data, ethical approval was not required.

Conflict of Interest

The author declares that there are no conflicts of interest related to this study.

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