Pain Physician 2025; 28:S157-S168 • ISSN 1533-3159

Bibliometric Study

Radiofrequency Ablation for Musculoskeletal Pain: A Bibliometric Analysis of Global Research Trends (2000–2024)

Şahide Eda Artuç, MD and Gizem Kılınç Kamacı, MD

From: Gaziler Physical Therapy and Rehabilitation Research and Training Hospital, University of Health Sciences, Ankara, Türkiye

Address Correspondence:
Şahide Eda Artuç, MD
SBÜ Ankara Gaziler Fizik Tedavi Ve Rehabilitasyon Eğitim Ve Araştırma Hastanesi, Üniversiteler Mahallesi, 6002. Cadde, No:3/1, 06800, Bilkent Çankaya / Ankara
E-mail: edartuc@gmail.com

Disclaimer: This study is a bibliometric analysis based on previously published literature and does not involve human patients or animal subjects. Therefore, ethical approval was not required. The authors received no financial support for the research, authorship, and/or publication of this article. The authors have no acknowledgments to declare. The data that support the findings of this study are available from the corresponding author upon reasonable request. All data were obtained from the Web of Science Core Collection database and processed using bibliometric software tools. There was no external funding in the preparation of this article.

Conflict of interest: Each author certifies that he or she, or a member of his or her immediate family, has no commercial association (i.e., consultancies, stock ownership, equity interest, patent/licensing arrangements, etc.) that might pose a conflict of interest in connection with the submitted article.

Article received:08-06-2025
Revised article received: 09-16-2025

Background: Radiofrequency ablation (RFA) is a minimally invasive technique increasingly utilized in the treatment of musculoskeletal pain, particularly when pharmacological or rehabilitative approaches prove insufficient. However, the thematic evolution and research development of RFA over the past 2 decades have not been explored adequately.

Objective: To conduct a comprehensive bibliometric analysis of the global literature on RFA for musculoskeletal pain, identifying publication trends, research focuses, leading contributors, and thematic transitions between 2000 and 2024.

Study Design: Bibliometric analysis.

Setting: Data were retrieved from the Web of Science Core Collection (WoSCC).

Methods: A total of 736 English-language articles published between January 1, 2000, and December 31, 2024, were included. Bibliometric tools such as VOSviewer, CiteSpace, and Biblioshiny were used to analyze annual publication trends, co-authorship networks, country/institutional productivity, keyword co-occurrences, co-citation patterns, and citation bursts.

Results: A marked increase in publication volume was observed after 2010, with the peak occurring in 2023. The United States led in both publication output and international collaboration. The Johns Hopkins School of Medicine, University of Wisconsin, and University of Utah were among the most productive institutions. Steven P. Cohen and Laxmaiah Manchikanti emerged as the most influential authors, centrally positioned within international co-authorship networks. Meanwhile, Pain Physician, Pain Medicine, and Regional Anesthesia and Pain Medicine were identified as the journals that exerted the greatest impact. Co-citation analysis revealed a thematic shift from early spinal facet interventions and diagnostic blocks toward peripheral applications, especially genicular nerve ablation, and consensus-based clinical practices. Keyword co-occurrence and citation burst analyses identified 3 chronological research themes: firstly, early spinal interventions (2000-2010), secondly, the diagnostic standardization era (2010-2017), and thirdly, expansion into peripheral, imaging-guided, and multidisciplinary applications (2017-2024).

Limitations: The analysis was limited to English-language articles indexed in the WoSCC. Conference proceedings, book chapters, and articles from other databases were excluded. Therefore, some relevant studies might not have been captured.

Conclusion: This bibliometric analysis demonstrates a steady growth in RFA-related publications globally. While spinal interventions remain the primary focus, an interest in peripheral applications has seen a notable increase. The expansion of RFA reflects both technological advancements and evolving clinical demands. Future studies should focus on long-term outcomes, clinical adoption, and the evidence-based optimization of treatment algorithms across spinal and peripheral indications.

Accepted for publication: 11-24-2025

Free full article: www.painphysicianjournal.com

Key words: Radiofrequency ablation, musculoskeletal pain, bibliometric analysis, CiteSpace, VOSviewer, Bibliometrix

Pain Physician 2025: 28:S157-S168

Musculoskeletal pain refers to acute or chronic pain arising from bones, muscles, ligaments, tendons, and nerves (1). The condition is one of the leading causes of disability worldwide and poses a significant medical and socioeconomic burden (2,3). According to the World Health Organization (WHO), 20-33% of the global population suffers from chronic musculoskeletal pain, affecting approximately 1.75 billion people (4). Manifestations of this condition range from localized low back, neck, and knee pain to neuropathic pain syndromes (5). They are associated with increased medication use, impaired daily functioning, high rates of sick leave and disability, and reduced quality of life (2,6). Although conventional treatments such as pharmacological therapy, physical rehabilitation, and surgery remain standard options for managing chronic pain, they may be insufficient for this purpose (7). Consequently, radiofrequency ablation (RFA), a minimally invasive pain management technique, has gained increasing attention (8).

RFA modulates neural structures through thermal energy, interrupting pain transmission. The first reported use of this procedure for pain management dates back to 1931, when Kirschner applied that form of ablation to the Gasserian ganglion for trigeminal neuralgia (9). After the development of commercial RF generators in the 1950s, RFA entered broader clinical use (10). In the 1990s, pulsed and cooled RFA techniques emerged, and related publications began increasing in the early 2000s (11,12). Initially applied to spinal syndromes such as facet joint–related low back pain, RFA has since expanded to peripheral indications like knee osteoarthritis and sacroiliac joint pain. Growing evidence supporting the efficacy and safety of RFA has contributed to a substantial rise in publications over the past 2 decades (2,9,12-15).

Bibliometric analysis is a statistical method used to evaluate research output and trends in a specific field (16,17). Although studies on RFA have increased, no comprehensive bibliometric analysis has mapped its development. This study aims to address that gap by examining publication trends, major research themes, and emerging clinical applications.

Methods

Data Source and Search Strategy

In this study, the Web of Science Core Collection (WoSCC) was used to retrieve data, since it was a well-established and trusted database indexing peer-reviewed scientific literature across a wide range of disciplines. WoSCC is particularly suitable for tracking research trends in areas such as medicine, biology, engineering, and the social sciences. This study aimed to identify publications on the use of RFA techniques in the treatment of musculoskeletal pain. The literature search was completed on July 10, 2025. To ensure a comprehensive scan of the literature, a topic search (TS) strategy was applied, targeting terms within article titles, abstracts, and keywords. The search formula used was:

TS = (("radiofrequency" OR "radiofrequency ablation" OR "radiofrequency neurotomy" OR "RF neurotomy" OR "RF denervation" OR "RFA" OR "conventional radiofrequency" OR "pulsed radiofrequency" OR "cooled radiofrequency") AND ("low back pain" OR "lumbar pain" OR "knee pain" OR "hip pain" OR "shoulder pain" OR "sacroiliac pain" OR "facet joint pain" OR "cervical pain" OR "thoracic pain" OR "musculoskeletal pain" OR "myofascial pain" OR "osteoarthritis")).

To reflect contemporary research trends, the search was limited to publications between January 2000 and December 2024. Additional eligibility criteria included:

- Focus: studies involving the use of RFA for musculoskeletal pain management
- Publication type: original articles and review papers
- Language: English only
- WoSCC categories: orthopedics, rheumatology, anesthesiology, clinical neurology, neurosciences, physical medicine and rehabilitation, and general internal medicine

After records were retrieved from WoSCC, each publication was reviewed manually, and studies that did not meet the inclusion criteria were excluded. Following the screening and exclusion procedures, 736 articles were included in the final analysis. The full screening and selection process is summarized in Fig. 1.

Because the data were obtained from a publicly accessible database and did not involve human patients or personal data, no approval from a board of ethics was required for this study.

Bibliometric Analysis Methods

In this bibliometric study designed to analyze the literature on RFA applications for musculoskeletal pain, 3 programs were employed: CiteSpace (18) (v6.3.R1), VOSviewer (19), and Biblioshiny (20), the Web interface of the R-based Bibliometrix package. Biblioshiny was used to examine annual publication trends and analyze productivity distributions by country, institution, and author. VOSviewer was utilized to construct keyword co-occurrence networks and author collaboration networks. CiteSpace was employed to identify thematic clusters and detect "citation bursts" among keywords and cited references.

Our analysis focused on the following objectives:

- To examine the current research hot spots and trends in the use of RFA for the treatment of musculoskeletal pain, based on the existing literature and keyword clusters.
- To evaluate temporal changes in the distribution of spinal applications as compared to peripheral applications over the years.
- To identify leading authors and prominent research domains and to analyze patterns of collaboration among countries, institutions, and researchers.

Results

Annual Publication Trends

The number of publications on RFA for musculoskeletal pain showed a general upward trend between 2000 and 2011, followed by a fluctuating pattern from 2011 to 2016. Despite this variability, a marked increase was observed over the past decade, with the number of publications peaking in 2023. This trend reflects the growing clinical and academic interest in RFA as a method of interventional pain management (Fig. 2A).

Subgroup analysis based on clinical focus revealed that, since 2007, publications related to spinal applications of RFA have consistently outnumbered those in other categories. Studies on the use of RFA to target peripheral joints, such as the knee and shoulder, began to show an upward trend after 2017. In contrast, publications addressing general musculoskeletal pain approaches have remained relatively few throughout the entire period. This distribution suggests a sustained interest in spinal interventions using RFA and a growing clinical focus on anatomically targeted procedures involving joints (Fig. 2B).

Fig. 2C provides a summary of the dataset's core bibliometric features, including document count, author metrics, international collaboration, and citation statistics.

Key word Co-occurrence Analysis

Key word co-occurrence analysis revealed a dense and interconnected network. The most promi-

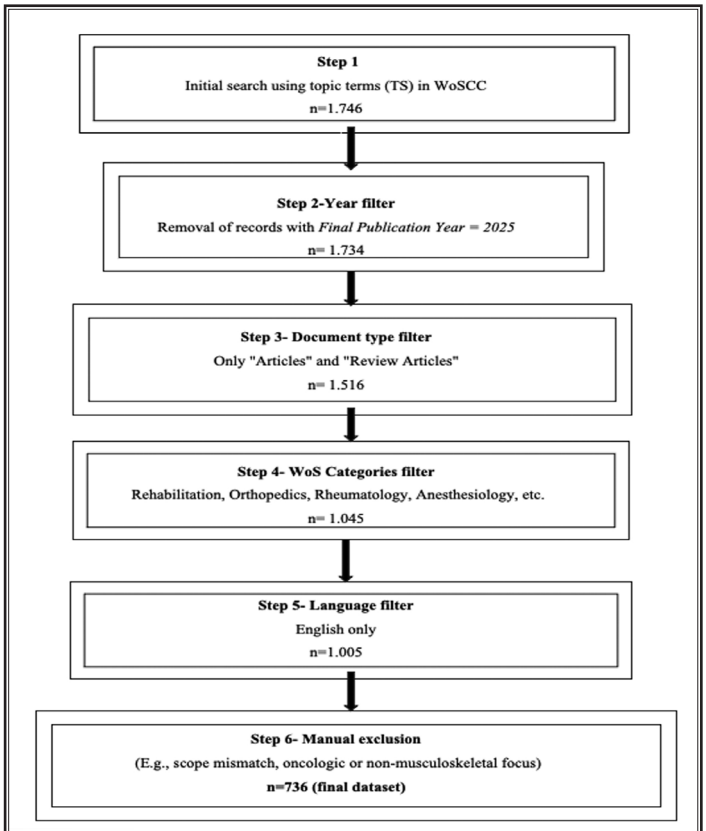

Fig. 1. *Flowchart summarizing the inclusion and exclusion steps applied to the initial search results.*

nent terms were "radiofrequency ablation," "low back pain," and "facet joint," indicating the central role of spinal applications in the field (Fig. 3A). The cluster visualization, generated by CiteSpace, further emphasized thematic domains such as "genicular nerve ablation," "medial branch blocks," "facet joint intervention," and "basivertebral nerve ablation" (Fig. 3B).

Citation burst analysis provided insights into temporal research trends (Fig. 3C). In the early 2000s, citation bursts of terms such as "low back pain" (2000-2007), "zygapophysial joint" (2004–2010), and "intradiscal electrothermal therapy" (2005-2011) highlighted a clinical focus on spinal interventions.

Table 1 presents the 20 most influential conceptual keywords identified through citation burst detection. The burst strength reflects the intensity of citation growth during the specified period. Procedural or generic terms were excluded to enhance interpretability. Key words such as "low back pain" and "intradiscal electrothermal therapy" exhibited early bursts tied to spinal applications, while more recent bursts in "knee pain" and "genicular nerve" suggest a thematic shift toward peripheral interventions and multidisciplinary integration.

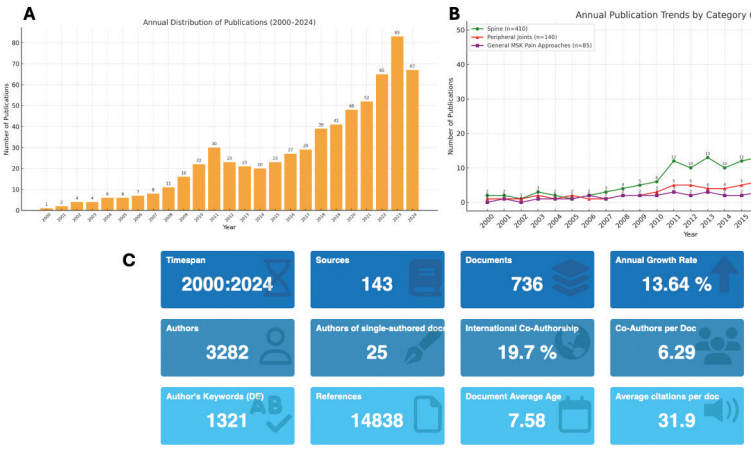

Fig. 2. *Annual publication trends:*
(A) Annual number of publications on radiofrequency ablation (RFA) for musculoskeletal pain between 2000 and 2024.
(B) Annual publication trends categorized by clinical focus: spine (green), peripheral joints (red), and general musculoskeletal pain approaches (purple).
(C) Summary of dataset characteristics, including total documents, authorship metrics, collaboration indicators, citation statistics, and time span.

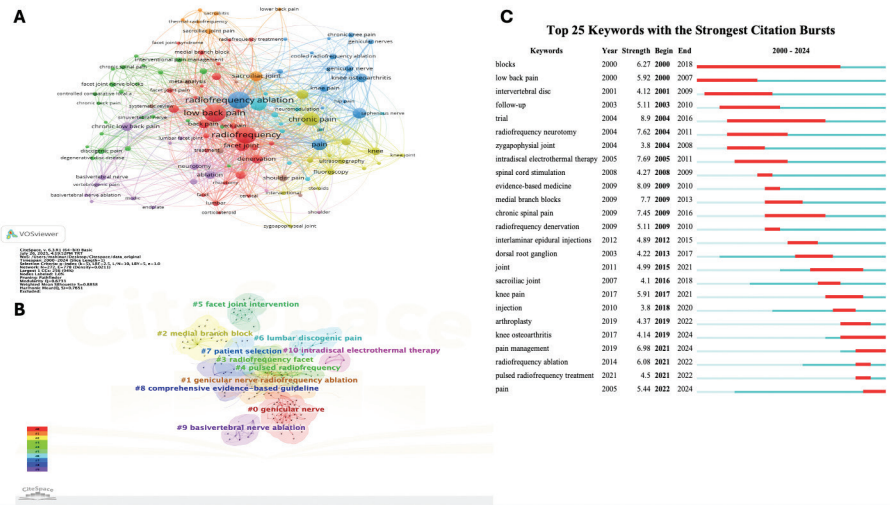

Fig. 3. *Visualization of key word co-occurrence and citation bursts in the RFA literature (2000-2024).*
(A) Network visualization map of key word co-occurrence, showing the most frequent and interconnected terms in the field of RFA.
(B) Clustered network of thematic key word groups, highlighting conceptual domains such as spinal procedures (e.g., medial branch blocks, intradiscal electrothermal therapy) and peripheral interventions (e.g., genicular nerve ablation).
(C) Top citation bursts detected by CiteSpace, illustrating the most rapidly emerging topics over specific time periods.

From 2008 onward, citation bursts in terms such as "evidence-based medicine" (2008-2012) and "medial branch blocks" (2009-2013) indicate a growing emphasis on diagnostic precision and standardization in interventional pain management. These research trends closely parallel the publication of influential clinical guidelines and randomized controlled trials during this period.

In the more recent period of 2017-2024, a thematic shift is evident. Key words such as "knee pain" (2017-2021), "osteoarthritis" (2018-2024), "chronic knee pain" (2019-2022), and "genicular nerve" (2022-2024) reflect the growing interest in genicular and extraspinal applications of radiofrequency ablation.

Notably, the term "pain management" showed a strong burst between 2021 and 2024. This phenomenon reflects a broader conceptual framing of RFA as part of multidisciplinary pain care, rather than a strictly anatomical intervention.

Table 1. *Top 20 key words with the strongest citation bursts (2000-2024).*

Key Word	Burst Strength	Begin Year	End Year
low back pain	5.75	2000	2007
radiofrequency neurotomy	5.61	2004	2009
zygapophysial joint	4.18	2004	2010
intradiscal electrothermal therapy	7.64	2005	2011
evidence-based medicine	8.76	2008	2012
discogenic pain	4.32	2008	2012
medial branch blocks	8.82	2009	2013
chronic spinal pain	7.34	2009	2016
radiofrequency denervation	4.82	2009	2010
percutaneous radiofrequency neurotomy	5.21	2010	2013
interlaminar epidural injections	4.82	2012	2015
radicular pain	3.92	2014	2017
sacroiliac joint	3.96	2016	2018
knee pain	6.85	2017	2021
osteoarthritis	5.94	2018	2024
chronic knee pain	4.83	2019	2022
radiofrequency ablation	6.84	2021	2022
pain management	6.15	2021	2024
pulsed radiofrequency treatment	3.97	2021	2022
genicular nerve	4.73	2022	2024

Burst detection was conducted using CiteSpace (v6.3.R1). Procedural or nonconceptual terms were excluded for clarity.

Analysis of Authors

The co-authorship network (Fig. 4A) revealed distinct clusters of prolific researchers active in the field of RFA for musculoskeletal pain. Notably, authors such as Steven P. Cohen, Laxmaiah Manchikanti, and Jan Van Zundert emerged as central figures, characterized by both high publication output and extensive collaborative networks.

According to H-index values calculated locally with Biblioshiny (Fig. 4B), Cohen and Manchikanti stood out

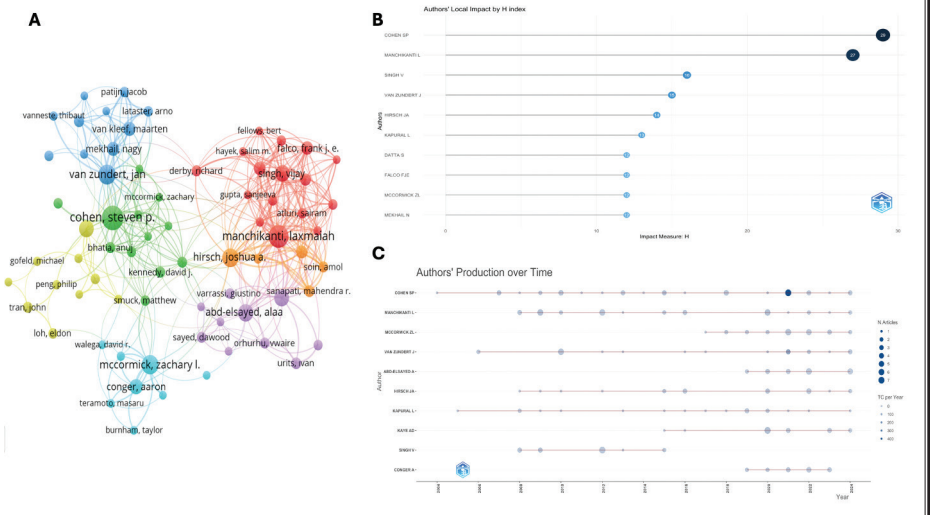

Fig. 4. *Author-level analysis based on co-authorship, impact, and productivity over time. (A) Co-authorship network map, depicting collaborative clusters among prolific researchers in the field of RFA for musculoskeletal pain. (B) Most influential authors ranked by local H-index, reflecting scientific productivity and impact within the dataset. (C) Temporal evolution of author productivity. The diameter of the dots represents the number of publications per year, and color intensity indicates the frequency of annual citations.*

as the most influential contributors, with H-indices of 29 and 27, respectively. They were followed by Singh, Van Zundert, and Hirsch, indicating a small group of highly cited leaders in the field.

Fig. 4C illustrates the temporal distribution of author productivity. The diameter of each dot represents the annual number of publications, while the color intensity corresponds to the total number of citations received that year. Cohen and Manchikanti maintained consistently high levels of scholarly output and citation impact across the entire study period. In contrast, McCormick demonstrated increasing productivity and citation influence, particularly in more recent years.

Overall, the analysis underscores the dominant role of a core group of internationally recognized authors who have shaped the literature on RFA significantly, particularly in domains such as spinal interventions, genicular nerve ablation, and multidisciplinary pain management strategies.

Table 2 lists the most productive authors based on the counts of both total publications and fractionalized article counts. The fractionalized count adjusts for co-authorship by assigning proportional credit to each author, offering a more refined measure of individual contribution.

Analysis of Journals

A review of source dynamics revealed a sharp rise in publication output after 2010, largely driven by 3 core journals: Pain Physician, Pain Medicine, and Regional Anesthesia and Pain Medicine (Fig. 5A). Among those, Pain Physician and Pain Medicine showed the most consistent growth trajectories over time. According to Bradford's Law (Fig. 5B), only those 3 journals met the criteria to be considered core sources, implying a highly focused and specialized publishing landscape. This concentration suggests that much of the discourse around the use of RFA to treat musculoskeletal pain is channeled through a narrow set of field-specific outlets.

To offer a broader view of publication dynamics, Table 3 presents the 15 sources that are both highly cited and actively publishing in this area. While journals such as *Spine* and *Pain Physician* ranked highest in total citation counts, Pain Physician and Pain Medicine again stood out in terms of article volume. This contrast between citation impact and publication output illustrates how both long-standing influence and current research momentum shape the field's bibliographic core.

Table 2. *The top 15 authors by number of publications in the field of RFA for musculoskeletal pain (2000-2024).*

Authors	Articles	Articles Fractionalized
COHEN SP	40	8.09
MANCHIKANTI L	35	4.75
MCCORMICK ZL	23	3.05
VAN ZUNDERT J	22	2.75
ABD-ELSAYED A	19	3.66
HIRSCH JA	19	2.51
KAPURAL L	18	4.30
KAYE AD	17	1.71
SINGH V	16	1.86
CONGER A	14	1.78
MEKHAIL N	14	2.31
VAN KLEEF M	13	1.89
DATTA S	12	1.34
FALCO FJE	12	1.62
PAMPATI V	11	1.72

Analysis of Institutions and Countries

Geographical and institutional analysis revealed that the United States was the most prolific contributor to the literature on the use RFA for the treatment of musculoskeletal pain. As illustrated in Fig. 6A, international collaborations were frequently centered around the USA, which formed strong bilateral connections with countries such as the Netherlands, Canada, South Korea, and China. This finding reflects the dominant role of North American and European institutions in leading global research efforts in this domain.

Institutional analysis further indicated that the Johns Hopkins School of Medicine, the University of Wisconsin, and the University of Utah were the most productive affiliations in terms of publication volume (Fig. 6B). These institutions, along with others, such as the University of Toronto and Maastricht University, appear to play a major role in shaping the academic landscape of interventional pain research.

The 3-field plot (Fig. 6C) highlights the relationships among top authors, their affiliations, and contributing countries. Prominent figures such as Manchikanti, Hirsch, and Cohen are shown to be affiliated with highly active institutions in the USA, which further emphasizes the country's central role in this field. Notably, strong author-institution-country linkages were also observed in the Netherlands, Canada,

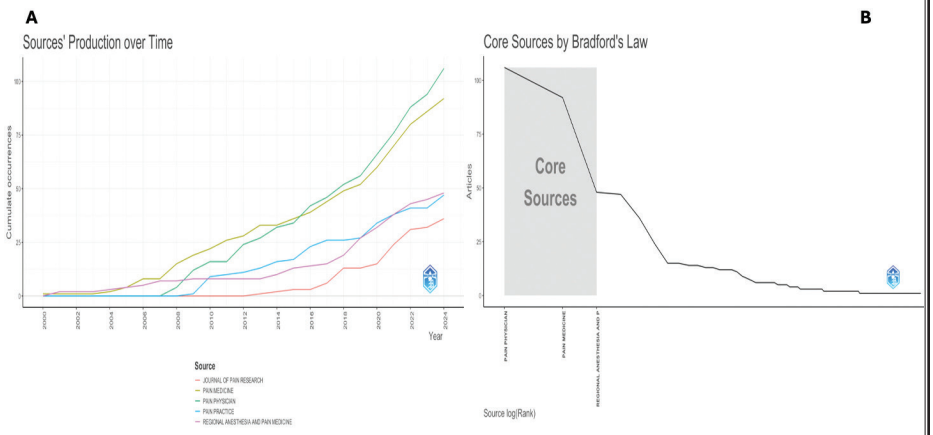

Fig 5. *The analysis of journals. (A) Cumulative publication output of the most relevant sources from 2000 to 2024. (B) Core sources identified according to Bradford's Law.*

Table 3. *Top 15 most cited and most relevant sources in the field of musculoskeletal RFA (2000-2024).*

Rank	Most Cited Sources	Citations	Most Relevant Sources	Articles
1	SPINE	3969	PAIN PHYSICIAN	106
2	PAIN PHYSICIAN	3547	PAIN MEDICINE	92
3	PAIN MED	2069	REGIONAL ANESTHESIA AND PAIN MEDICINE	48
4	REGION ANESTH PAIN M	1514	PAIN PRACTICE	47
5	PAIN	1116	JOURNAL OF PAIN RESEARCH	36
6	PAIN PRACT	910	SPINE	24
7	SPINE J	767	CURRENT PAIN AND HEADACHE REPORTS	15
8	CLIN J PAIN	753	EUROPEAN SPINE JOURNAL	15
9	EUR SPINE J	599	CLINICAL JOURNAL OF PAIN	14
10	ANESTHESIOLOGY	511	CUREUS JOURNAL OF MEDICAL SCIENCE	14
11	JAMA-J AM MED ASSOC	377	MEDICINE	13
12	NEW ENGL J MED	356	SPINE JOURNAL	13
13	ANESTH ANALG	353	KOREAN JOURNAL OF PAIN	12
14	ARCH PHYS MED REHAB	333	PAIN MANAGEMENT	12
15	J PAIN RES	304	PHYS MED REHABIL CLIN N AM	12

and Belgium, suggesting regional research hubs with substantial collaborative capacity.

Co-citation Analysis of References

Fig. 7A shows the co-citation network of the most influential references in musculoskeletal RFA, revealing 3 main clusters. The red cluster includes foundational spinal studies (Nath 2008, Cohen 2007, Manchikanti 2004). The green cluster represents broader spinal pain research and guidelines (Cohen 2008, Juch 2017). The blue cluster reflects emerging interest in peripheral ablation and consensus practices (Cohen 2020, Cosman 2014, Choi 2011).

Fig. 7B presents a timeline view of thematic clusters based on keyword co-occurrence. Notable themes include "genicular nerve radiofrequency ablation" (#0), "facet joint intervention" (#1), "therapeutic efficacy" (#4), and "assessment development" (#5). This distribution highlights a progression from diagnostic-focused research toward therapeutic and procedural advancements.

Fig. 7C displays the 25 references with the strongest citation bursts between 2000 and 2024. These publications, distinguished by high burst strength and sustained influence, represent seminal works that have shaped the trajectory of RFA research. While earlier bursts were dominated by spinal RFA studies, recent bursts include guideline publications and emerging peripheral applications.

Together, these findings illustrate the evolving intellectual structure of research on the use of RFA for the treatment of musculoskeletal pain, transitioning from spinal interventions to broader, multidisciplinary applications.

Discussion

The number of publications on the use of RFA

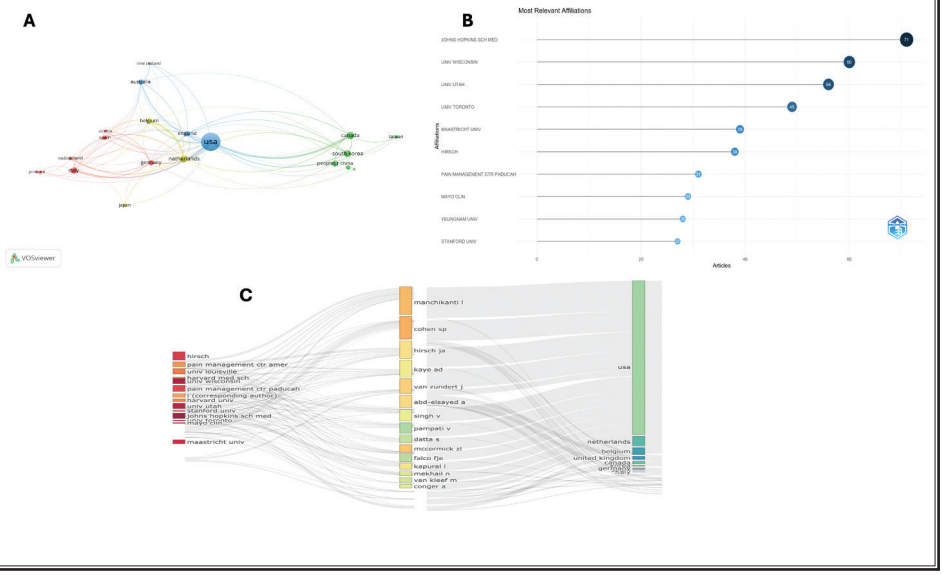

Fig. 6. *The analysis of countries and institutions. (A) Country collaboration network, visualized with VOSviewer. The size of each node represents the number of publications, and the connecting lines indicate co-authorship links between countries. (B) Most relevant affiliations based on the number of publications in the field of RFA for musculoskeletal pain. (C) Three-field plot showing the relationships among top authors, their affiliations, and countries of contribution.*

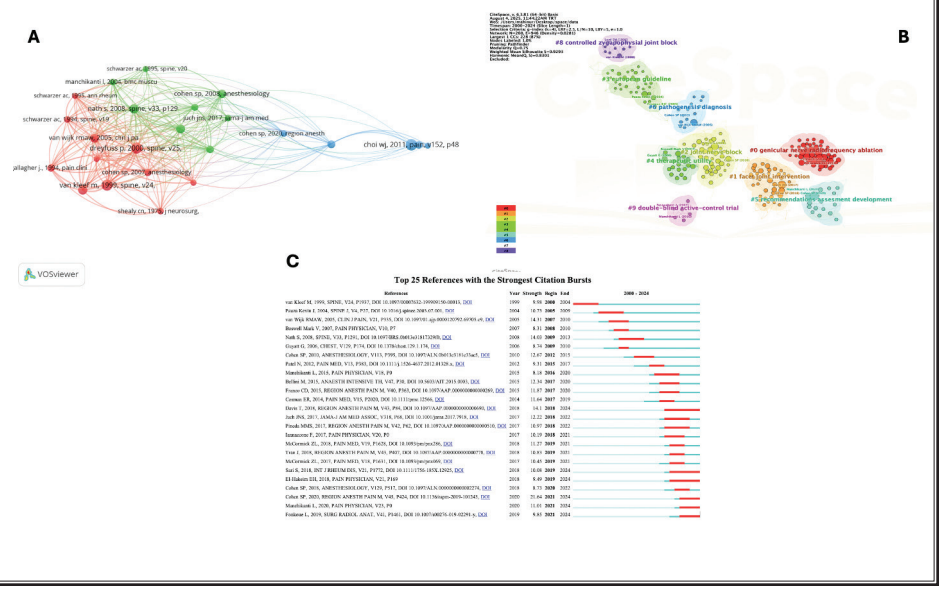

Fig. 7. *Reference co-citation and thematic trends in RFA research. (A) Co-citation network revealing clusters on spinal interventions (red), guidelines (green), and peripheral nerve ablation (blue). (B) Timeline view showing thematic evolution, including genicular RFA and facet joint interventions. (C) Top 25 references with strongest citation bursts, reflecting key shifts in research focus.*

to treat musculoskeletal pain has shown a general upward trend since 2000. This aligns with findings by Manchikanti et al (21), who reported a 199% increase in interventional pain management publications between 2000 and 2011. However, notable fluctuations were observed between 2011 and 2016, likely reflecting ongoing debates about RFA's efficacy, particularly for facet joint interventions and nonspecific low back pain. For example, the guideline by Manchikanti et al (21), commonly referred to as the ASIPP guideline, described the evidence for lumbar RFA as "limited," while the NICE guideline (22) recommended its use for only carefully selected patients. Such cautious positions may have contributed to reduced research funding and publication output. In addition, methodological limitations in early randomized controlled trials and uncertainties regarding long-term outcomes may have further constrained scholarly activity (23,24). Nevertheless, this period laid the foundation for improvements in patient selection and procedural standardization.

In contrast, a marked and sustained increase in publication volume has been observed since 2017, with a peak reached in 2023. This trend likely reflects both efforts to fill prior evidence gaps and the integration of more precise, image-guided interventional techniques into clinical practice. Paralleling this trend, the American Society of Interventional Pain Physicians (ASIPP) updated its guideline on facet joint interventions (14) in 2020, reporting "moderate (Level II)" evidence for lumbar RFA in appropriately selected patients. The comprehensive consensus guideline by Cohen et al (13) in the same year also offered favorable recommendations supporting lumbar facet RFA, potentially contributing to the renewed clinical interest in spinal interventions. Similarly, the 2021 LEARN guidelines (12) from the American Society of Pain and Neuroscience (ASPN) provided best practice recommendations based on current evidence for RFN applications across spinal and peripheral targets, further reinforcing the evolving clinical role of RFA.

The increasing use of targeted RFA procedures guided by fluoroscopy or ultrasound has expanded indications to include peripheral joints such as the knee, sacroiliac joint, and shoulder (25-30). Additionally, several consensus statements and meta-analyses published after 2020 have supported the efficacy of genicular nerve ablation in managing knee osteoarthritis (15, 31). Those supportive publications might have helped reinvigorate clinical interest and expand the volume of literature in the field. Moreover, limited access to conservative care and rising demand for minimally invasive interventions in the post–COVID-19 era may have further intensified interest in techniques such as RFA, contributing to the publication peak observed in 2023. The relative decline in 2024, despite the year having concluded, may be attributed to delayed indexing of some journal issues in major databases.

Subgroup analyses indicated that the literature has focused predominantly on spine-related RFA applications, with this trend becoming particularly prominent after 2015. Publications addressing peripheral joints remained relatively limited until 2020 but then showed a notable surge in volume. Meanwhile, studies categorized under "general musculoskeletal pain approaches"—those lacking a specific anatomical target, involving multiple regions, addressing physiological mechanisms or technical aspects of RFA, or consisting of broad narrative/systematic reviews—stayed fairly stable over time. This distribution suggests a growing anatomical specialization in RFA applications, alongside a progressive diversification in clinical use (Fig. 2B).

Key word co-occurrence and citation burst analyses (Fig. 3, Table 1) reveal how research on the use of RFA for musculoskeletal pain has evolved thematically over the past 2 decades. Based on clustering and temporal patterns, these developments can be categorized into 3 main domains: early spinal interventions, a transition toward diagnostic precision and standardization, and increasing interest in peripheral and multidisciplinary applications.

Initial Focus on Spinal Interventions

In the early 2000s, keywords such as "low back pain" (2000–2007), "zygapophysial joint" (2004–2010), and "intradiscal electrothermal therapy" (2005–2011) exhibited strong citation bursts. These terms reflect an initial research focus on spinal structures, particularly facet joints, intervertebral discs, and the zygapophysial complex. During this period, lumbar medial branch neurotomy and intradiscal procedures were performed frequently, despite limited long-term evidence in favor of their use (23,24). The 2013 guidelines of the American Society of Interventional Pain Physicians (ASIPP) reported that the evidence supporting spinal RFA was generally moderate (Level II) or low (Level III–IV) and that clinical outcomes were often variable depending on patient selection (21).

Shift Toward Diagnostic Precision and Clinical Standardization

In the period following 2008, keywords such as

"evidence-based medicine" (2008–2012) and "medial branch blocks" (2009–2013) reflect a growing emphasis on standardized diagnostic criteria in interventional pain practice. During this period, the importance of accurate patient selection for RFA procedures was highlighted, and controlled diagnostic blocks were incorporated into clinical protocols, as were medial branch blocks.

The 2013 ASIPP guidelines emphasized that interventional procedures should be performed only when supported by valid diagnostic evidence (21), while Cohen et al (13) reaffirmed the central role of diagnostic blocks in the management of lumbar facet joint pain. The increase in randomized controlled trials during this time highlights a shift toward more selective, evidence-based, and protocol-driven approaches to RFA.

Transition to Peripheral and Multidisciplinary Approaches

Since 2017, citation bursts in terms such as "knee pain" (2017-2021), "osteoarthritis" (2018-2024), "chronic knee pain" (2019-2022), and "genicular nerve" (2022-2024) demonstrate a shift in research attention toward peripheral joint interventions. This trend is supported by clinical trials showing that genicular nerve RFA is effective for chronic knee pain, particularly in patients who are not surgical candidates or who prefer to avoid opioid-based therapies. Recent clinical trials and meta-analyses confirm the effectiveness of this intervention in its ability to bestow pain reduction and functional improvement (15,29,31-34).

Moreover, the burst in the key word "pain management" after 2021 suggests that RFA is increasingly regarded not only as a site-specific procedure but also as part of broader, multidisciplinary pain treatment strategies.

The identified thematic patterns clearly illustrate a transformation in interventional pain practice. Initially limited to anatomically targeted procedures, RFA has progressively evolved into a more selective, diagnosis-driven, and integrative modality. Future bibliometric and clinical studies may further explore how these patterns align with clinical guideline adoption, technological advancements, and changing health care demands.

Among the most influential contributors to RFA research for musculoskeletal pain, Steven P. Cohen and Laxmaiah Manchikanti stand out for their consistent productivity and high citation impact. Their work has shaped clinical practice, particularly in spinal and genicular nerve interventions. Both authors also occupy central positions in international co-authorship networks, highlighting their roles in global collaboration. As shown in Table 3, significant researchers are organized in tightly connected, predominantly U.S.-based clusters, reflecting sustained and meaningful authorship contributions. These findings underscore the importance of institutional and individual leadership in shaping the field.

Journals such as Pain Physician, Pain Medicine, and Regional Anesthesia and Pain Medicine were identified as core sources, highlighting a concentrated pattern of knowledge dissemination within a limited set of highly specialized publications. According to Bradford's Law, this clustering may reflect both the technically demanding and narrowly focused nature of RFA research and the central role of these journals in interventional pain literature.

However, expanding the dissemination of RFA-related studies beyond core interventional journals to broader disciplinary platforms, such as those in physical medicine, orthopedics, and rehabilitation, may reinforce the integration of RFA into the musculoskeletal literature and promote wider multidisciplinary adoption.

This analysis highlights the institutional concentration of RFA research, with the United States emerging as the leading contributor in both publication output and international collaboration. Major institutions such as Johns Hopkins, the University of Wisconsin, and the University of Utah—alongside prominent authors like Manchikanti, Hirsch, and Cohen—appear to form core academic clusters. These findings suggest that clinically influential RFA research is driven largely by a limited number of well-established research centers.

Analyses of co-citation and key words revealed a thematic shift in RFA research from spinal interventions and diagnostic blocks to evidence-based peripheral applications, particularly genicular nerve ablation. This transition reflects both advancements in procedural techniques and a broader integration of RFA into multidisciplinary pain management.

Limitations

The analysis was limited to English-language articles indexed in the WoSCC; publications in other databases, as well as conference abstracts and book chapters, were excluded. Therefore, some relevant studies might not have been captured.

Conclusion

This bibliometric analysis highlights the evolving role of RFA in musculoskeletal pain management, reflecting

a thematic expansion in which spinal applications remain predominant while peripheral and evidence-based interventions are gaining increasing prominence. The field continues to be shaped largely by U.S.-based institutions and researchers, with knowledge dissemination concentrated in a limited number of specialized journals. The integration of RFA into multidisciplinary treatment approaches is supported by growing clinical needs and ongoing technological advancements. Future research should evaluate the procedure's long-term efficacy, the clinical adoption of the technique, and evidence-based decision-making algorithms as they pertain to RFA across both spinal and peripheral applications.

Acknowledgments

We also thank all patients for their contribution to the study.

Author Contributions: Şahide Eda Artuç was responsible for the conception and design of the study, the data curation, the bibliometric analysis, the drafting of the manuscript, and the critical revision. Gizem Kılınç Kamacı was responsible for the data collection, the verification of results, the visualization, the editing of the manuscript, and the final approval of the version to be published.

References

1. Cao B, Lin X, Wu Y. Classification and definition of chronic pain. *Chin J Pain Med* 2021; 27:2-8.
2. El-Tallawy SN, Nalamasu R, Salem GI, LeQuang JAK, Pergolizzi JV, Christo PJ. Management of musculoskeletal pain: An update with emphasis on chronic musculoskeletal pain. *Pain Ther* 2021; 10:181-209.
3. GBD 2016 Disease and Injury Incidence and Prevalence Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: A systematic analysis for the Global Burden of Disease Study 2016. *Lancet* 2017; 390:1211-1259.
4. World Healh Organization. Musculoskeletal health. World Health Organization. Updated 07/14/2022. Accessed 07/17/2022. www.who.int/news-room/fact-sheets/detail/musculoskeletal-conditions
5. Smith E, Hoy DG, Cross M, et al. The global burden of other musculoskeletal disorders: Estimates from the Global Burden of Disease 2010 study. *Ann Rheum Dis* 2014; 73:1462-1469.
6. Cimmino MA, Ferrone C, Cutolo M. Epidemiology of chronic musculoskeletal pain. *Best Pract Res Clin Rheumatol* 2011; 25:173-183.
7. Geurts JW, Willems PC, Lockwood C, van Kleef M, Kleijnen J, Dirksen C. Patient expectations for management of chronic non-cancer pain: A systematic review. *Health Expectations* 2017; 20:1201-1217.
8. Soetjahjo B, Adriansyah D, Yudistira MB, Rahman AN, Herman H, Diwan. The analgesic effectiveness of genicular nerve-targeted cooled and pulsed radiofrequency ablation for osteoarthritis knee pain: A systematic review and meta-analysis. *Pain Physician* 2024; 27:357-373.
9. Hagedorn JM, Golovac S, Deer TR, Azeem N. History and development of radiofrequency ablation for chronic pain. In: Deer TR, Azeem N (eds). *Essentials of Radiofrequency Ablation of the Spine and Joints*. Springer, 2021, pp 3-6.
10. Aronow S. The use of radio-frequency power in making lesions in the brain. *J Neurosurg* 1960; 17:431-438.
11. Rodríguez-Merchán EC, Delgado-Martínez AD, De Andrés-Ares J. Upper limb and lower limb radiofrequency treatments in orthopaedics. *EFORT Open Rev* 2023; 8:424-435.
12. Lee DW, Pritzlaff S, Jung MJ, et al. Latest evidence-based application for radiofrequency neurotomy (LEARN): Best practice guidelines from the American Society of Pain and Neuroscience (ASPN). *J Pain Res* 2021; 14:2807-2831.
13. Cohen SP, Bhaskar A, Bhatia A, et al. Consensus practice guidelines on interventions for lumbar facet joint pain from a multispecialty, international working group. *Reg Anesth Pain Med* 2020; 45:424-467.
14. Manchikanti L, Kaye AD, Soin A, et al. Comprehensive evidence-based guidelines for facet joint interventions in the management of chronic spinal pain: American Society of Interventional Pain Physicians (ASIPP) guidelines. *Pain Physician* 2020; 23:S1.
15. Chen AF, Mullen K, Casambre F, Visvabharathy V, Brown GA. Thermal nerve radiofrequency ablation for the nonsurgical treatment of knee osteoarthritis: A systematic literature review. *J Am Acad Orthop Surg* 2021; 29:387-396.
16. Donthu N, Kumar S, Mukherjee D, Pandey N, Lim WM. How to conduct a bibliometric analysis: An overview and guidelines. *J Bus Res* 2021; 133:285-296.
17. Chaobo Feng M, Zhou Z, Miao Y, Yang S, Fan G, Liao X. Research focus involving and trends in artificial intelligence for spinal pain: A bibliometric analysis. *Pain Physician* 2025; 28:167-181.
18. Chen C. CiteSpace II: Detecting and visualizing emerging trends and transient patterns in scientific literature. *J Assoc Inf Sci Technol* 2006; 57:359-377.
19. van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics* 2010; 84:523-538.
20. Aria M, Cuccurullo C. bibliometrix: An R-tool for comprehensive science mapping analysis. *J Informetr* 2017; 11:959-975.
21. Manchikanti L, Abdi S, Atluri S, et al. An update of comprehensive evidence-based guidelines for interventional techniques in chronic spinal pain. Part II: Guidance and recommendations. *Pain Physician* 2013; 16:S49-S283.
22. de Campos TF. Low back pain and sciatica in over 16s: Assessment and management NICE Guideline [NG59]. *Journal of Physiother* 2017; 63:120.
23. van Wijk RM, Geurts JW, Wynne HJ, et al. Radiofrequency denervation of lumbar facet joints in the treatment of

chronic low back pain: A randomized, double-blind, sham lesion-controlled trial. *Clin J Pain* 2005; 21:335-344.

24. Leclaire R, Fortin L, Lambert R, Bergeron YM, Rossignol M. Radiofrequency facet joint denervation in the treatment of low back pain: A placebo-controlled clinical trial to assess efficacy. *Spine (Phila Pa 1976)* 2001; 26:1411-1416.
25. Jain E, O'Connor IT, Tram JK, et al. Radiofrequency ablation for shoulder pain: An updated systematic review. *Ann Palliat Med* 2024; 13:96375-96975.
26. Yang AJ, Wagner G, Burnham T, McCormick ZL, Schneider BJ. Radiofrequency ablation for chronic posterior sacroiliac joint complex pain: A comprehensive review. *Pain Med* 2021; 22:S9-S13.
27. Li G, Zhang Y, Tian L, Pan J. Radiofrequency ablation reduces pain for knee osteoarthritis: A meta-analysis of randomized controlled trials. *Int J Surg* 2021; 91:105951.
28. Orhurhu V, Akinola O, Grandhi R, Urits I, Abd-Elsayed A. Radiofrequency ablation for management of shoulder pain. *Curr Pain Headache Rep* 2019; 23:56.
29. Eckmann MS, Boies BT, Carroll DJ, Muir LD. Peripheral joint radiofrequency ablation. *Phys Med Rehabil Clin N Am* 2022; 33:519-531.
30. Yang AJ, McCormick ZL, Zheng PZ, Schneider BJ. Radiofrequency ablation for posterior sacroiliac joint complex pain: A narrative review. *PM R* 2019; 11:S105-S113.
31. Hunter CW, Deer TR, Jones MR, et al. Consensus guidelines on interventional therapies for knee pain (STEP Guidelines) from the American Society of Pain and Neuroscience. *J Pain Res* 2022; 2683-2745.
32. Chen B, Yang Y, Wang H, Guo X, Wu Z, Lan Z. Is radiofrequency ablation effective in treating patients with chronic knee osteoarthritis? A meta-analysis of randomized controlled trials. *Ann Medicine Surg (Lond)* 2024; 86:412-420.
33. Chang MC, Choi HH, Kwak SG, Chang MC. Effectiveness of radiofrequency ablation of the genicular nerves of the knee for the management of intractable pain from knee osteoarthritis. *Pain Physician* 2024; 27:E419-E429.
34. Kwon HJ, Kim CS, Kim DH, Shin JW, Choi D, Choi SS. Effectiveness of the cooled radiofrequency ablation of genicular nerves in patients with chronic knee pain due to osteoarthritis: A double-blind, randomized, controlled study. *Medicina* 2024; 60:857.