Original Article

Global Research Topics and Trends of Myocardial Infarction with Nonobstructive Coronary Arteries: A Bibliometric Analysis

Tuko Srimulyo [1,2], Antonius Dwi Saputra [3], Arga Setyo Adji [4], Intan Komalasari [1,5], Atiyatum Billah [4], Diski Saisa [6], Yudi Her Oktaviano [1*]

[1] Department of Cardiology and Vascular Medicine, Dr Soetomo Academic Hospital, Surabaya, Indonesia.
[2] Cardiovascular Subspecialist Study Program, Faculty of Medicine, Universitas Airlangga, Surabaya, East Java, Indonesia
[3] Faculty of Medicine, University of Jember, Jember, Indonesia.
[4] Faculty of Medicine, Hang Tuah University, Surabaya, Indonesia.
[5] Department of Cardiology and Vascular Medicine, Ramelan Center Navy Hospital, Surabaya, Indonesia.
[6] Faculty of Medicine, University of Indonesia, Jakarta, Indonesia.

Citation: Srimulyo T, Dwi Saputra A, Adji AS, Komalasari I, Billah A, Saisa D, et al. Global Research Topics and Trends of Myocardial Infarction with Nonobstructive Coronary Arteries: A Bibliometric Analysis. Res Heart Yield Transl Med 2025; 20(4):294-309.

https://doi.org/10.18502/jthc.v20i4.20746

Highlights

- MINOCA research output has increased markedly, led by the United States, Italy, and China.
- Key research hotspots include pathophysiology, imaging diagnostics, prognosis, and sex differences.
- Current evidence highlights the need for standardized diagnostics and tailored management strategies.

Article info:

Received: 20 Aug. 2025
Revised: 27 Aug. 2025
Accepted: 21 Sep. 2025

*** Corresponding Author:**
Yudi Her Oktaviano
Professor, Department of Cardiology and Vascular Medicine, Faculty of Medicine, Universitas Airlangga - General Academic Hospital Dr Soetomo, Surabaya, East Java, Indonesia.
E-mail: yudi.her@fk.unair.ac.id

ABSTRACT

Background: Myocardial infarction with nonobstructive coronary arteries (MINOCA) is a heterogeneous clinical entity characterized by evidence of myocardial infarction (MI) in the absence of obstructive coronary artery disease (CAD) on angiography. This study aimed to explore and visualize the global research trends and hotspots of MINOCA using bibliometric approaches.

Methods: The search was performed on October 1, 2025, using the keyword “MINOCA” and its synonyms. Data were obtained from the Scopus, Web of Science, and PubMed databases and analyzed using RStudio (version 4.5.0), employing the Bibliometrix package (via Biblioshiny) alongside VOSviewer (version 1.6.20) for bibliometric visualization.

Results: A total of 1,562 publications related to MINOCA were identified, showing a marked increase in output over the past decade. The mean number of citations per article was 19.21, with the highest citation count occurring in 2018. International Journal of Cardiology published the most articles, while F. Crea was the most contributing author. The United States, Italy, and China emerged as leading contributors. High-impact articles primarily focused on the pathophysiology, diagnostic algorithms, and prognosis of MINOCA. Keyword analysis revealed evolving research hotspots, including pathophysiology, imaging diagnostics, prognosis, therapy, and sex differences, indicating a growing focus on precision diagnostics and patient-tailored management strategies in MINOCA research.

Conclusion: The research landscape of MINOCA has expanded substantially, with growing attention to its underlying mechanisms and diagnostic challenges. Future studies should prioritize the development of standardized diagnostic criteria and the implementation of tailored therapeutic approaches. This bibliometric analysis provides a valuable framework for clinicians and researchers to navigate the evolving field of MINOCA.

Keywords: MINOCA; Myocardial Infarction; Nonobstructive Coronary Artery Disease; Acute Coronary Syndrome; Bibliometric Analysis

Copyright © 2025 Tehran University of Medical Sciences. Published by Tehran University of Medical Sciences.
This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International license (https://creativecommons.org/licenses/by-nc/4.0/). Noncommercial uses of the work are permitted, provided the original work is properly cited

Introduction

Myocardial infarction with nonobstructive coronary arteries (MINOCA) is a heterogeneous clinical entity characterized by evidence of myocardial infarction (MI) in the absence of obstructive coronary artery disease (CAD) on angiography (ie, <50% stenosis in any major epicardial vessel).[1] Accounting for approximately 6% to 15% of all acute MIs, MINOCA predominantly affects younger patients and women, posing unique diagnostic and therapeutic challenges compared with classical MI presentations.[2,3]

The past decade has witnessed growing interest in understanding the underlying mechanisms, diagnostic pathways, and management strategies for MINOCA. Pathophysiological mechanisms such as plaque disruption, coronary spasm, microvascular dysfunction, and nonischemic causes (eg, myocarditis or Takotsubo cardiomyopathy) have been proposed to explain the spectrum of this condition.[4,5] Despite being historically underrecognized, accumulating evidence suggests that MINOCA is not a benign condition. Patients with MINOCA experience considerable morbidity and mortality, with long-term outcomes that, while somewhat better than myocardial infarction with obstructive coronary artery disease (MI-CAD), remain clinically significant.[6] This underscores the importance of early recognition, accurate diagnostic workup, and tailored therapeutic strategies. Nonetheless, current management remains challenging, as there are no universally accepted guidelines, and most therapeutic decisions are extrapolated from obstructive MI populations.[7,8]

In parallel with advances in diagnostic imaging modalities such as cardiac magnetic resonance (CMR) and optical coherence tomography (OCT), the scientific community has increasingly focused on unraveling the pathophysiological mechanisms of MINOCA and its prognostic implications.[4] These developments have led to a surge in publications addressing epidemiology, diagnostic strategies, and patient outcomes. Nevertheless, the research landscape on MINOCA remains fragmented, with diverse terminologies, varying methodological approaches, and limited consensus.

Bibliometric analysis is a powerful tool to quantitatively and qualitatively assess the development, hotspots, and trends within a scientific field. Through bibliometric methods, researchers can map influential publications, identify key contributing countries and institutions, analyse collaboration networks, and track emerging research frontiers.[9]

Despite the increasing number of publications on MINOCA, to our knowledge, no systematic bibliometric study has been conducted to evaluate its research trajectory. Therefore, this study aimed to explore and visualize the global research trends and hotspots of MINOCA using bibliometric approaches. This will not only aid researchers and clinicians in identifying knowledge gaps and collaborative opportunities but also guide future investigations in this evolving domain.

Methods

Data Source

Bibliographic data for this study were retrieved from Scopus, Web of Science, and PubMed databases on October 1, 2025. These three databases were selected to ensure comprehensive coverage and cross-validation of the bibliometric dataset of relevant publications related to MINOCA. Combining these three databases minimizes coverage bias and enhances the completeness and validity of the bibliometric dataset, as no single database provides exhaustive coverage of the scientific literature. Previous comparative studies have demonstrated that Scopus and Web of Science differ in their journal inclusion and disciplinary focus, emphasizing the value of integrating multiple data sources for comprehensive bibliometric analyses.[10,12]

Search Strategy

The search strategy used the following query string to capture relevant articles: “MINOCA” OR “myocardial infarction with nonobstructive coronary arteries.” This query was applied to the title, abstract, and keywords to ensure comprehensive coverage of the topic. After

duplicate removal, 1,562 documents were retained for analysis. The inclusion criteria were (1) document type (article, review, guideline, editorial, or letter); (2) the English language; and (3) final publication stage in peer-reviewed journals. Subsequently, the articles were organized by the number of citations, in descending order. The date range spanned from database inception through October 1, 2025. The literature search process is presented in (Figure 1).

Data Extraction and Analysis

The extracted metadata, including authorship, title, abstract, keywords, source journal, year of publication, citation count, and references, were exported in CSV format for further analysis. For each article, citation density was measured to reflect its influence adjusted for the time elapsed since publication. The calculation was performed using the following equation:

Citation density=Total citations accrued / Years since publication

This study used R software (version 4.5.0) with the Bibliometrix package (version 5.0.1) and its web interface, Biblioshiny, within RStudio (version 2025.05.1 + 513) to perform an in-depth bibliometric analysis. In addition, VOSviewer (version 1.6.20) was employed to conduct bibliographic visualization and coupling.

Results

The bibliometric dataset comprised 1,562 documents published from 1988 through October 2025 and retrieved from 470 distinct sources. Annual scientific production showed a steady increase, with an annual growth rate of 3.72%, indicating a consistent rise in research interest over time. A total of 8,554 authors contributed to the literature, with an average of 8.59 coauthors per document, reflecting a high level of scientific collaboration. Only 54 publications were single authored, suggesting that research in this domain is predominantly conducted through teamwork and collaborative efforts. The rate of international coauthorship reached 19.21%, emphasizing the global and interdisciplinary nature of the field. The dataset contained 2,450 unique author keywords, demonstrating thematic diversity across publications. The average document age was 3.99 years, indicating that the topic remains relatively recent and dynamically evolving. Moreover, each article received an average of 19.21 citations, underscoring the field's strong academic impact and relevance within the broader scientific community.

Publication Timeline

Research on MINOCA showed minimal activity from 1988 through 2010, with fewer than 30 articles per year. This was followed by a steady rise after 2015, corresponding to increased clinical recognition of MINOCA and advances in diagnostic imaging. A marked surge occurred after 2017, coinciding with the Fourth Universal Definition of Myocardial Infarction and the European Society of Cardiology (ESC) STEMI guidelines, which established MINOCA as a distinct entity.[13,14] Publication output peaked in 2023 (245 articles), followed by a slight decline in 2024 to 2025, reflecting the postpandemic normalization of research volume (Figure 2).

Citation Analysis

The dataset accumulated 29,733 citations, averaging 19.21 citations per document, with an h-index of 75. Although early publications contributed to the cumulative citation impact, most highly cited works appeared between 2015 and 2020. The notable surge in MINOCA citations in 2018 can be attributed mainly to the publication of major consensus and definition papers, most prominently the Fourth Universal Definition of Myocardial Infarction, which formally incorporated MINOCA into the diagnostic framework and rapidly became a foundational reference for subsequent clinical and epidemiological studies (Figure 3). Notably, publications in high-impact cardiology journals demonstrated more substantial citation influence compared with those in broader clinical medicine outlets.

(Table 1) presents the most cited articles on MINOCA, highlighting the 2017 ESC Guidelines for the Management of Acute Myocardial Infarction in Patients Presenting With ST-Segment Elevation (2018) as the most influential

publication, with 8,284 citations and a citation density of 1,183.4 citations per year, followed by major consensus and guideline documents such as the 2020 ESC Guidelines for the Management of Acute Coronary Syndromes in Patients Presenting Without Persistent ST-Segment Elevation (2021) and the Fourth Universal Definition of Myocardial Infarction (2017), which collectively shaped current understanding and management of MINOCA.[13,15]

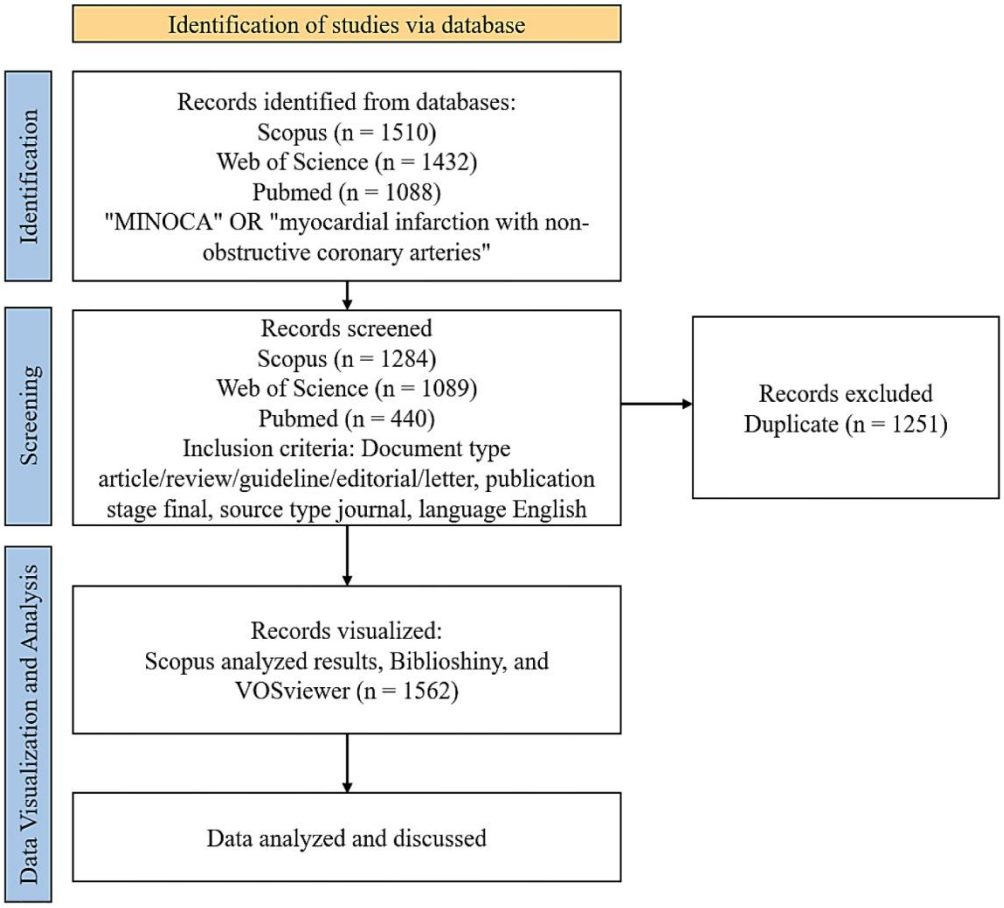


Figure 1. Flow chart of literature screening included in this study

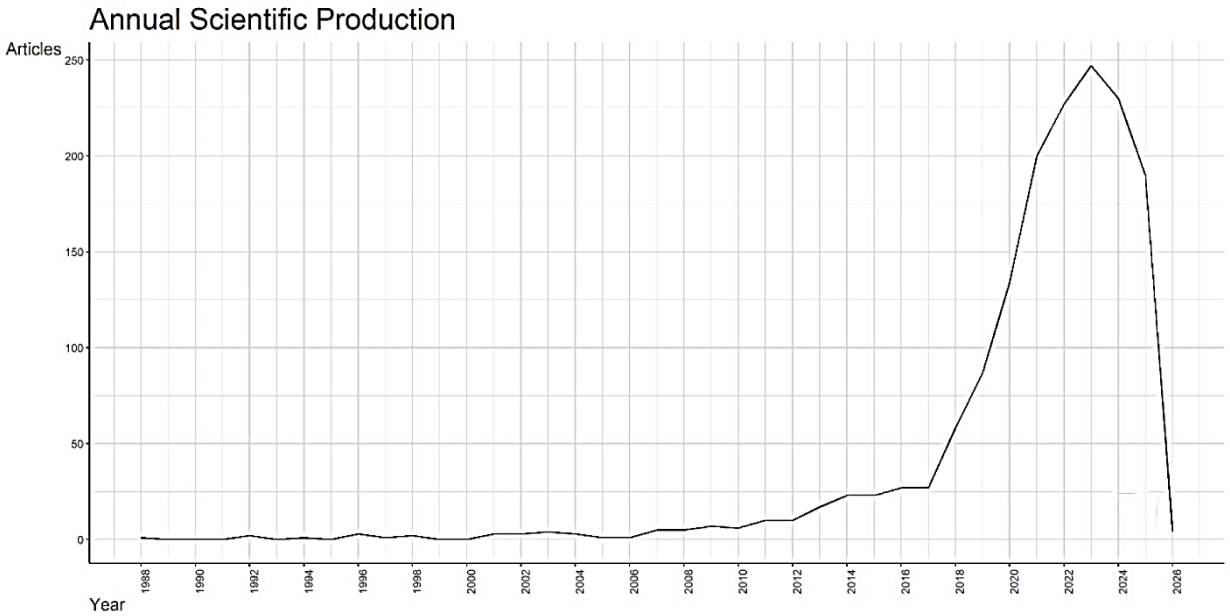


Figure 2. Annual scientific production of myocardial infarction with nonobstructive coronary arteries (MINOCA) research (1988–October 2025). The steady growth in publications on MINOCA, with a sharp increase after 2015 and a peak in 2023, with over 300 articles. This reflects the growing clinical recognition of MINOCA and its formal inclusion in international guidelines.

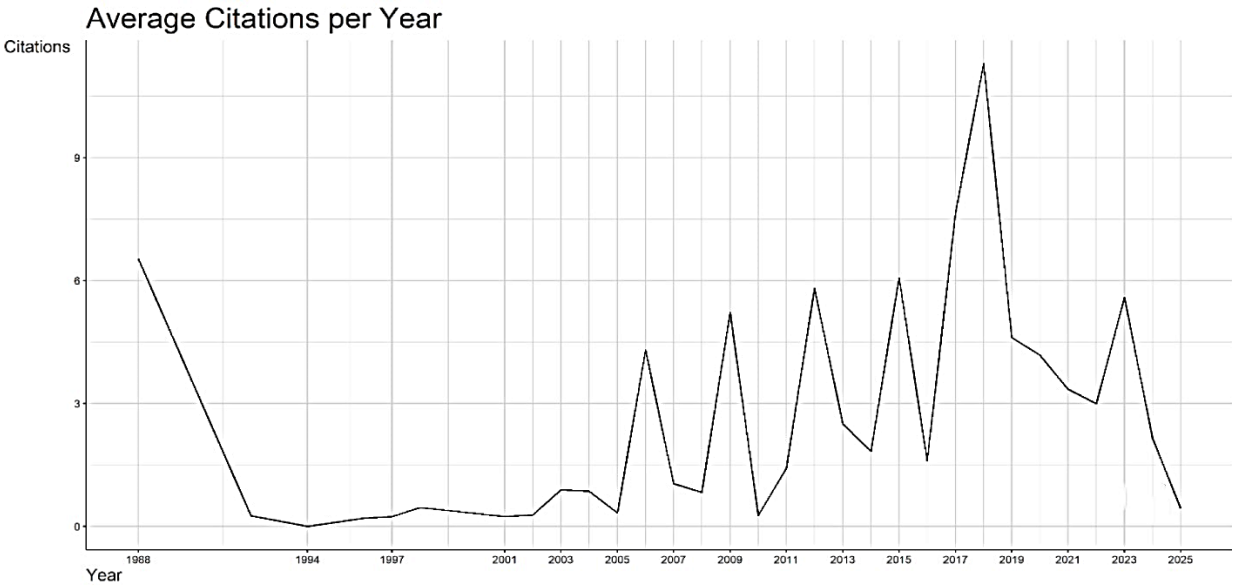


Figure 3. The average citation rate per year in the field of myocardial infarction with nonobstructive coronary arteries (MINOCA) showed fluctuating patterns, with a notable peak in 2018 (12.3 citations/article/year). The surge corresponds to the publication of consensus documents such as the Fourth Universal Definition of Myocardial Infarction and ESC Guidelines, indicating their pivotal influence on the field.

Table 1. The most cited articles on MINOCA

Rank	Article Title	Source Title	Citations	Publication Year	Citation Density
1	2017 ESC Guidelines for the Management of Acute Myocardial Infarction in Patients Presenting With ST-Segment Elevation[14]	European Heart Journal	8284	2018	1183,4
2	2020 ESC Guidelines for the Management of Acute Coronary Syndromes in Patients Presenting Without Persistent ST-Segment Elevation[15]	European Heart Journal	3946	2021	986,5
3	Fourth Universal Definition of Myocardial Infarction (2018)[13]	Journal of the American College of Cardiology	3059	2018	437
4	2023 ESC Guidelines for the Management of Acute Coronary Syndromes[16]	European Heart Journal	2679	2023	1339,5
5	Stable Angina Pectoris with No Obstructive Coronary Artery Disease Is Associated with Increased Risks of Major Adverse Cardiovascular Events[17]	European Heart Journal	797	2012	61,3
6	Systematic Review of Patients Presenting with Suspected Myocardial Infarction and Nonobstructive Coronary Arteries[3]	Circulation	753	2015	75,3
7	ESC Working Group Position Paper on Myocardial Infarction with Nonobstructive Coronary Arteries[1]	European Heart Journal	747	2017	93,4
8	Contemporary Diagnosis and Management of Patients with Myocardial Infarction in the Absence of Obstructive Coronary Artery Disease: A Scientific Statement from the American Heart Association[2]	Circulation	708	2019	118
9	An EAPCI Expert Consensus Document on Ischaemia with Nonobstructive Coronary Arteries in Collaboration with European Society of Cardiology Working Group on Coronary Pathophysiology & Microcirculation Endorsed by Coronary Vasomotor Disorders International Study Group[18]	European Heart Journal	616	2020	123,2
10	Ischemia and No Obstructive Coronary Artery Disease (INOCA): Developing Evidence-Based Therapies and Research Agenda for the Next Decade[7]	Circulation	600	2017	75

Source Analysis

The European Heart Journal (EHJ) emerged as the leading publication outlet for MINOCA-related research, accounting for the highest citation impact and several of the most influential guideline and consensus papers, including the ESC Working Group Position Paper1 and the EAPCI Consensus on INOCA.[18] The Journal of the American College of Cardiology (JACC) and Circulation ranked closely behind, reflecting their prominence in publishing multidisciplinary cardiovascular research and official society statements. The most productive journals were the International Journal of Cardiology (IJC) (77 articles), followed by the Journal of Clinical Medicine (48 articles) and Frontiers in Cardiovascular Medicine (45 articles), which together accounted for more than 15% of total publications (Figure 4).

Countries and Institutions Analysis

The United States (27.6%), Italy (14.1%), and China (11.9%) had the highest publication output on MINOCA, followed by several European countries, including the United Kingdom, Sweden, and Germany (Figure 6).[1] The temporal trend shows a sharp increase in publications after 2012, with China experiencing the most significant growth and surpassing other countries in recent years. China's marked increase in MINOCA publications can be attributed to substantial national research investment, the country's very high burden of ischemic heart disease, and expanding access to advanced cardiac imaging that facilitates mechanistic studies.[19,20]

At the institutional level, Karolinska Institutet in Sweden ranked first with 103 publications, reflecting its pivotal role in population-based registry research through SWEDEHEART and long-term outcome studies.[6,21] Uppsala University (60 publications) and Università Cattolica del Sacro Cuore (56 publications) in Italy followed; both have contributed extensively to mechanistic and prognostic studies integrating imaging and vascular pathophysiology (Figure 5).[1] Outside Europe, the University of Adelaide in Australia, under the leadership of J. F. Beltrame, has focused on the pathophysiological continuum between MINOCA and microvascular angina, advancing the understanding of coronary vasomotor disorders.[22]

The Chinese Academy of Medical Sciences and Tongji University School of Medicine lead MINOCA research in China, concentrating on 3 key areas: a comprehensive clinical overview of the definition and pathophysiology of MINOCA,[23] evaluation of the atherogenic index of plasma (AIP) as a prognostic biomarker,[24] and outcomes of secondary prevention therapy in patients with MINOCA from a cohort at Shanghai Tenth People's Hospital.[25] These contributions underscore the pivotal role of these institutions in advancing both the diagnostic framework and therapeutic strategies.

Collaboration Analysis

The country collaboration map (Figure 6B) indicates that the United States, Italy, and China serve as central hubs of international collaboration, building extensive networks with European and Asian partners. European countries, particularly the United Kingdom, Germany, and Sweden, also show strong interconnections, reflecting the global and interdisciplinary nature of the research. Despite this, collaboration intensity varies, with some countries contributing predominantly at the national rather than international level. Our dataset indicates that multicountry studies accounted for only 19.21% of total publications, showing that while international partnerships exist, most research remains nationally concentrated (Figure 8).

Author Analysis

The analysis of author productivity (Figure 7) revealed that F. Crea from Università Cattolica del Sacro Cuore, Rome, Italy, emerged as the most prolific contributor in MINOCA research, with 40 publications, reflecting his pivotal role in shaping the conceptual and clinical understanding of ischemic heart disease without obstructive coronary arteries.[26] Following closely, J. F. Beltrame and H. R. Reynolds produced 37 and 33 documents, respectively. In a landmark study, H. R. Reynolds, in collaboration with J. F. Beltrame, demonstrated key mechanisms, such

as plaque disruption, microvascular dysfunction, and vasospasm in patients without obstructive coronary disease.[22,27] H. R. Reynolds also led the 2019 AHA scientific statement on MINOCA, which established a framework for its diagnosis and management.[2] More recently, their contributions to the ESC document on ischemia with nonobstructive coronary arteries highlight their pivotal role in shaping contemporary understanding and clinical practice in this field.[1]

P. Tornvall ranked fourth with 31 publications, emphasizing his contributions to large-scale clinical studies and registries, particularly in Northern European research networks. Meanwhile, R. Montone and G. Niccoli, each with 27 papers, demonstrated strong collaborative ties with Crea and other Italian cardiovascular research groups, reflecting a robust European research cluster focused on coronary microvascular dysfunction and vasospasm.[28]

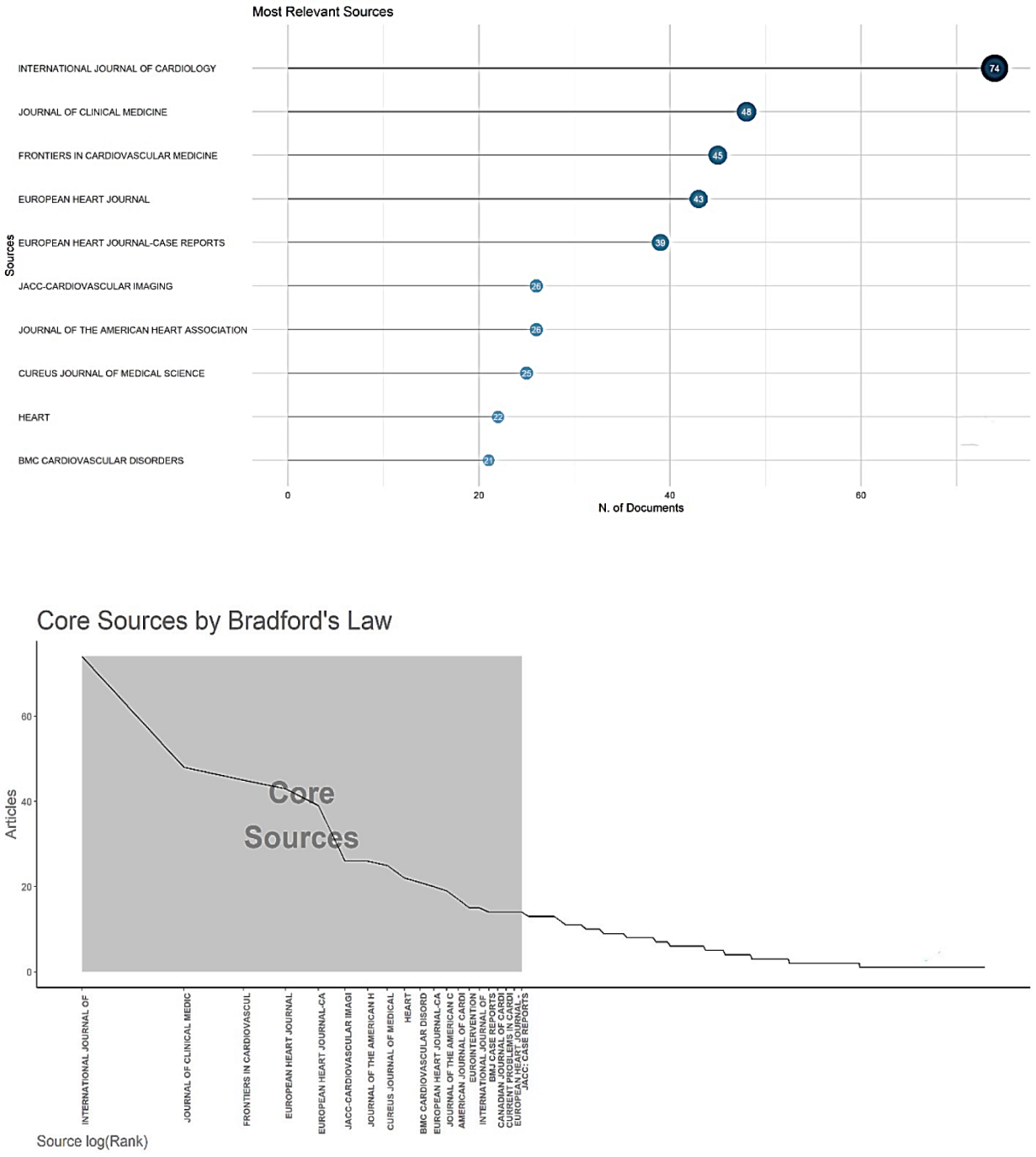


Figure 4. The most productive journals in the field of myocardial infarction with nonobstructive coronary arteries (MINOCA) included International Journal of Cardiology (IJC) (77 articles), followed by Journal of Clinical Medicine (48 articles), and Frontiers in Cardiovascular Medicine (45 articles), which together accounted for over 15% of total publications.

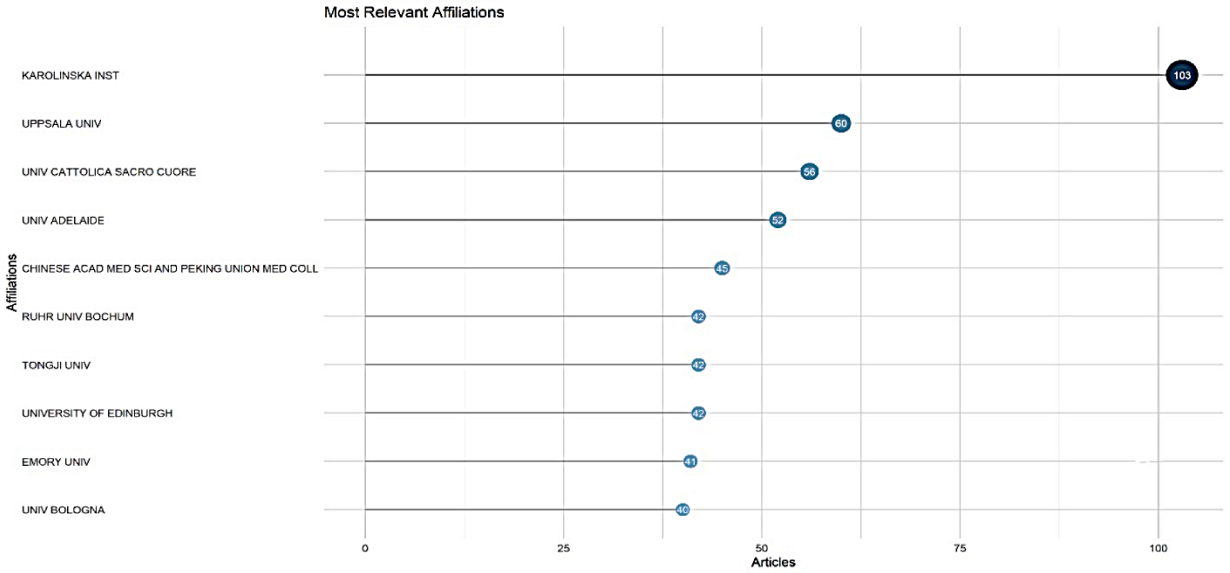


Figure 5. The most relevant affiliation in the field of myocardial infarction with nonobstructive coronary arteries (MINOCA) research. Karolinska Institutet (103 publications) and Uppsala University (60 publications) from Sweden dominate global output through SWEDEHEART-based studies, followed by Italy's Università Cattolica del Sacro Cuore (56 publications) and Australia's University of Adelaide (32 publications).

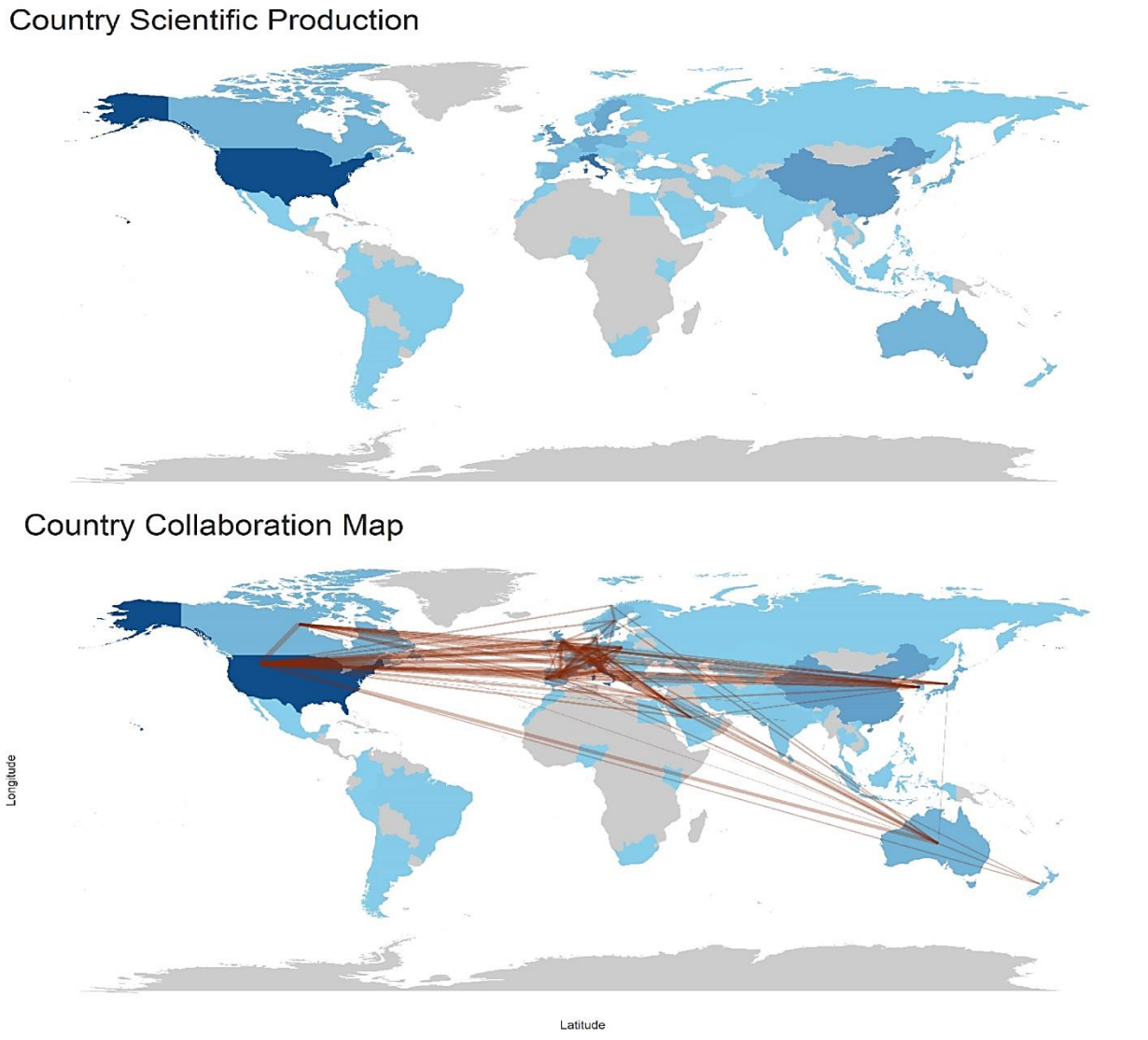


Figure 6. (a) The country scientific production map illustrates that the United States, Italy, and China are the most prolific contributors to myocardial infarction with nonobstructive coronary arteries (MINOCA) research, indicated by the darkest shading. **(b)** The collaboration map also reveals that strong collaboration clusters between the United States, Italy, and China. Despite increasing global cooperation, international studies comprise only 19.2% of total publications, suggesting potential for greater global integration.

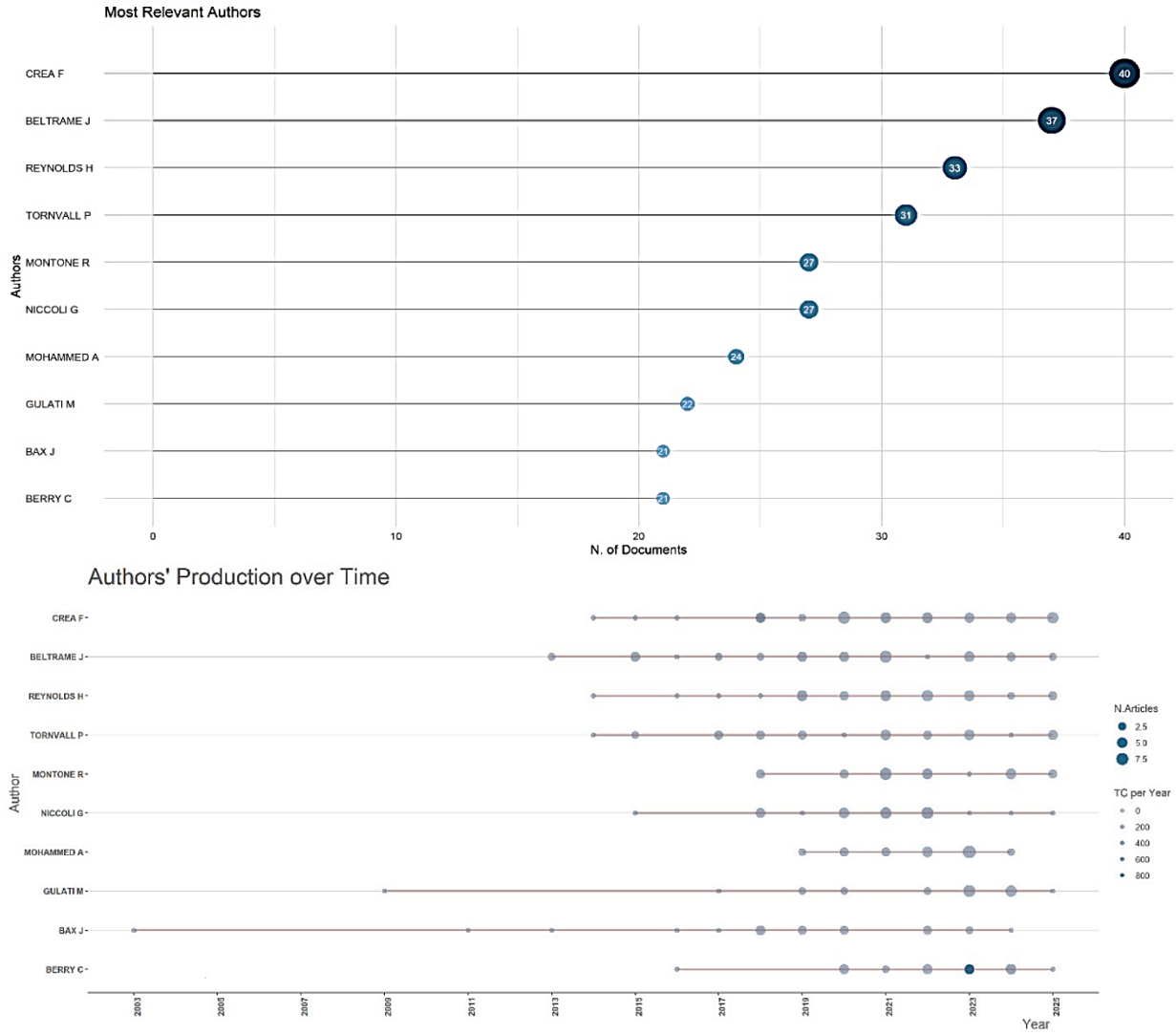


Figure 7. The most relevant authors in the field of myocardial infarction with nonobstructive coronary arteries (MINOCA) included F. Crea (40 publications), J. F. Beltrame (37 publications), and H. R. Reynolds (33 publications), reflecting their central roles in developing diagnostic criteria, registry studies, and pathophysiological models of MINOCA.

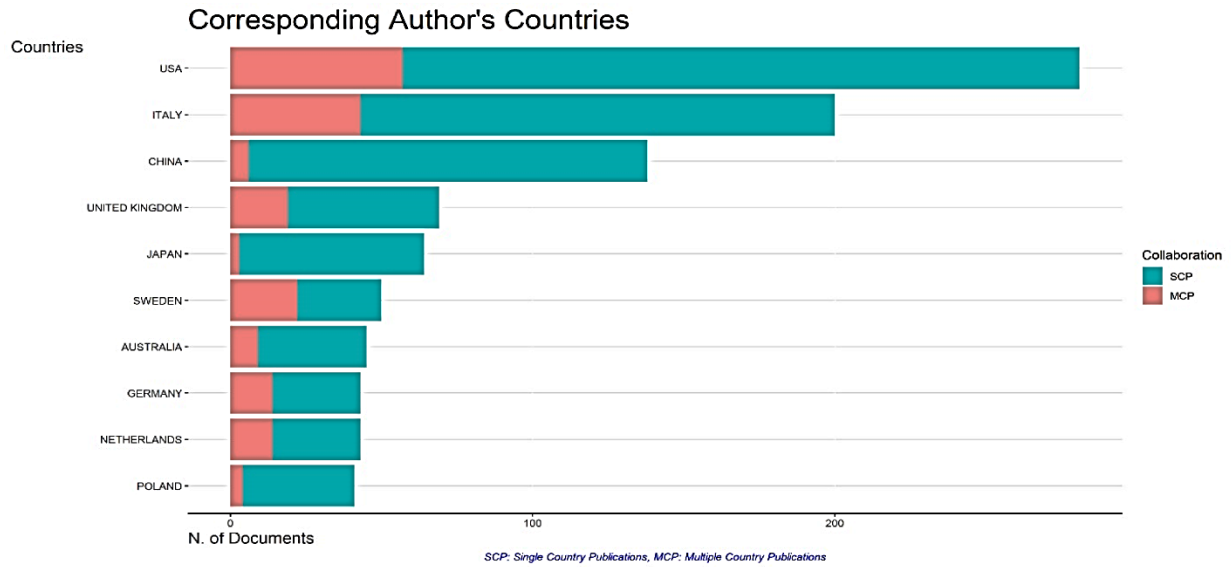


Figure 8. Distribution of corresponding authors' countries and international collaboration patterns in myocardial infarction with nonobstructive coronary arteries (MINOCA) research. The geographical distribution of corresponding authors and the proportion of single-country publications (SCP) versus multiple-country publications (MCP) in MINOCA–related research. The United States leads with the highest number of publications, reflecting its dominant role in cardiovascular clinical research and international collaboration. The high proportion of MCPs among top-producing countries underscores the increasingly international and collaborative nature of MINOCA research, facilitating broader data integration and improved understanding of diverse pathophysiological mechanisms.

Keyword Analysis

The keyword co-occurrence network map (Figure 9) visualizes the conceptual structure of MINOCA-related research, revealing distinct thematic clusters, as follows:

1.Red cluster: clinical focus and pathophysiology

This cluster forms the central core of the network, dominated by the keywords "MINOCA," "myocardial infarction," "coronary artery disease," "disease," "prognosis," "outcomes," and "management." This cluster represents the clinical and pathophysiological dimension of MINOCA research. It encompasses studies focusing on the definition, diagnosis, therapeutic strategies, and prognosis of MINOCA, as well as its association with coronary microvascular dysfunction and vasospasm. The strong linkages among these terms indicate that research is largely oriented toward understanding the mechanisms underlying nonobstructive myocardial infarction, clinical outcomes, and evidence-based management approaches. This cluster signifies the core knowledge domain around which other research themes are organized.

2.Green cluster: demographic and clinical characterization

Dominated by keywords such as "human," "female," "male," "aged," "adult," "coronary artery disease," "diagnostic imaging," and "percutaneous coronary intervention," this cluster reflects the clinical and demographic characterization of MINOCA patients. It also highlights studies addressing patient populations, comorbidities, and diagnostic tools used in clinical evaluation, including imaging techniques such as echocardiography and coronary computed tomography angiography. The frequent co-occurrence of sex-related terms (eg, "female" and "women") underscores the growing recognition of sex-specific differences in MINOCA presentation and outcomes, particularly the higher prevalence among women. Overall, this cluster represents patient-centered and diagnostic-oriented research that complements the pathophysiological investigations represented in the red cluster.

3.Blue cluster: diagnostic methods and case based evidence

This cluster includes "case report," "clinical article," "echocardiography," "magnetic resonance," "chest pain," and "troponin," capturing the diagnostic and descriptive dimensions of MINOCA research. This cluster primarily encompasses case-based studies and reports focusing on the clinical presentation, diagnostic testing, and imaging modalities used in the identification and differentiation of MINOCA from other cardiac conditions. The interconnections between imaging modalities (eg, "magnetic resonance" and "echocardiography") and clinical manifestations (eg, "chest pain") emphasize the importance of advanced imaging and functional assessment in diagnosing microvascular or vasospastic etiologies of MINOCA.

4.Yellow cluster: mechanistic and translational research

Comprising terms such as "coronary flow reserve," "microcirculation," "endothelial dysfunction," "ischemia," and "coronary microvascular dysfunction," this cluster represents mechanistic and translational research exploring the underlying microvascular and physiological processes that contribute to MINOCA and related syndromes. It connects closely with both the red and green clusters, bridging clinical findings and experimental mechanisms. The emphasis on "coronary microvascular dysfunction" and "coronary flow reserve" suggests that emerging research is increasingly oriented toward understanding the pathobiological mechanisms driving ischemia in the absence of obstructive coronary disease, which may inform future diagnostic and therapeutic innovations.

Overall, the network demonstrates that the interconnectivity among all four clusters indicates a highly integrated and multidisciplinary research landscape, linking clinical, demographic, diagnostic, and mechanistic insights. The central positioning of "MINOCA" within the network underscores its pivotal role as a unifying research focus.

The frequent co-occurrence of "coronary artery disease," "ischemia," "microvascular dysfunction," and "outcomes" illustrates the convergence between clinical cardiology, imaging sciences, and vascular biology.

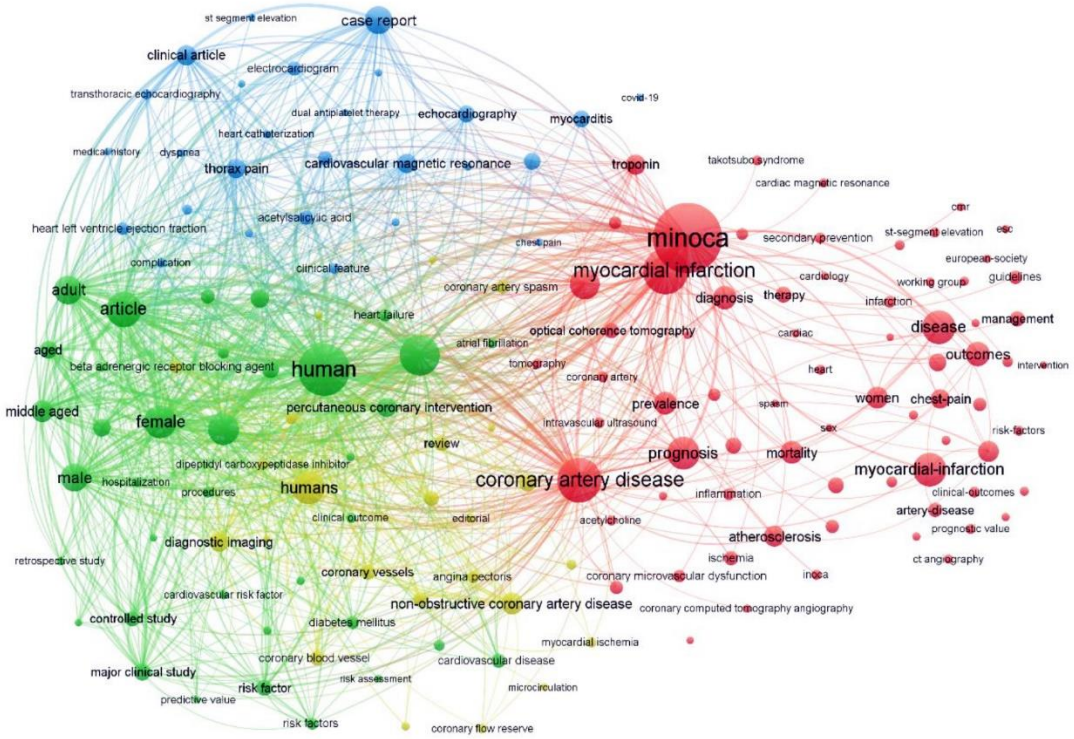


Figure 9. The Visualization network map of the most common keywords in the field of myocardial infarction with nonobstructive coronary arteries (MINOCA) using VOSviewer. A network visualization organized into four clusters: (1) clinical-pathophysiological core (red cluster); (2) demographic and clinical characterization (green cluster); (3) diagnostic/case-based (blue cluster); and (4) mechanistic-translational research (yellow cluster). The centrality of "MINOCA" demonstrates its role as the unifying concept in this multidisciplinary field.

Trend Topics Analysis

Analysis of all keyword trends over time (Figure 10) revealed an evolution in research priorities within the MINOCA literature. Early research (2008–2015) primarily centred on fundamental ischemic heart disease concepts such as stable angina pectoris, coronary artery atherosclerosis, and angiocardiography, reflecting an initial effort to differentiate MINOCA from obstructive coronary syndromes. Subsequent years (2016–2020) marked a shift toward prospective studies, stratification, and treatment outcomes, coinciding with the growing recognition of MINOCA as a distinct clinical entity in the 2017 ESC and 2019 American Heart Association (AHA) scientific statements.[1,2]

From 2020 onward, research trends show an increasing emphasis on women, risk factors, dual antiplatelet therapy, and coronary artery dissection, indicating heightened awareness of sex-specific mechanisms and tailored management strategies. Emerging topics such as CT angiography and CMR demonstrate the integration of advanced multimodality imaging into diagnostic frameworks for MINOCA and ischemia with nonobstructive coronary arteries (INOCA)[29]

The most recent (2022–2024) surge in keywords such as revascularization, dual antiplatelet therapy, and treatment outcome suggests a growing interest in interventional strategies and secondary prevention approaches for patients without obstructive coronary disease. This evolution underscores the field's transition from pathophysiological characterization toward evidence-based therapeutic optimization, marking a maturing phase in MINOCA research (Figure 11).

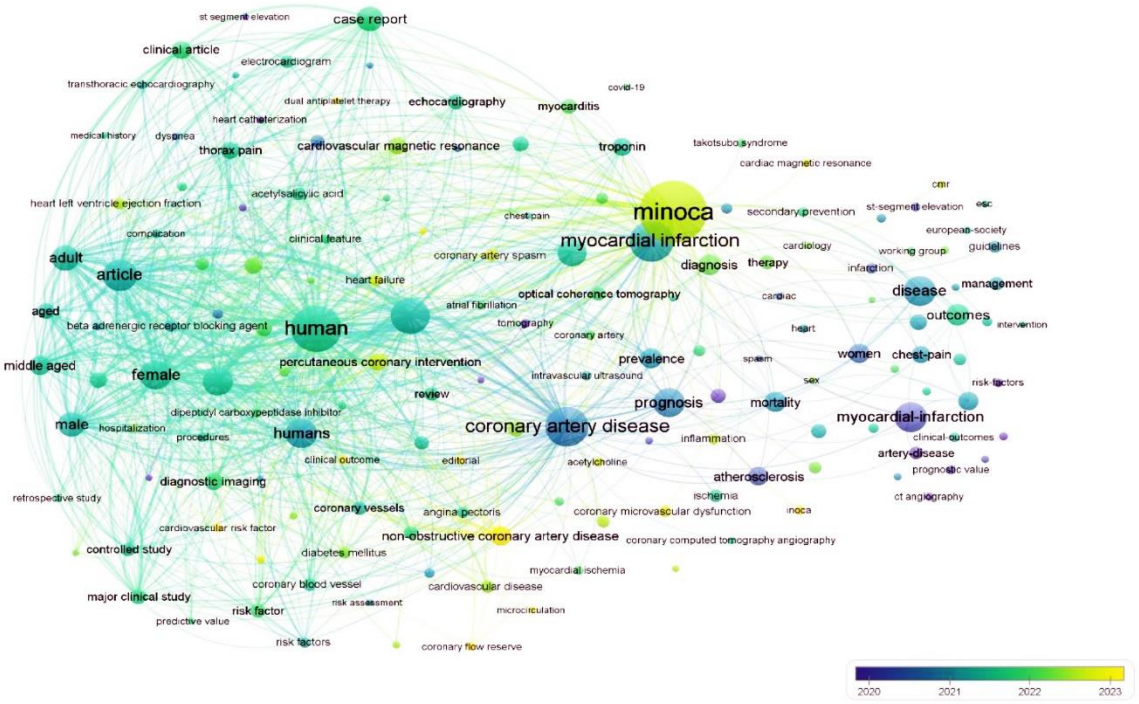


Figure 10. The overlay visualization map of the most common keywords in the field of myocardial infarction with nonobstructive coronary arteries (MINOCA) using VOSviewer. The color gradient from blue (earlier years, ~2020) to yellow (more recent, ~2023) demonstrates the chronological shift in research focus. Early studies concentrated on diagnosis, case reports, and clinical outcomes, whereas more recent publications emphasize pathophysiological mechanisms such as microcirculation, risk factors, and myocardial ischemia. The keyword “MINOCA” appears in bright yellow, confirming it as a contemporary and rapidly expanding research topic.

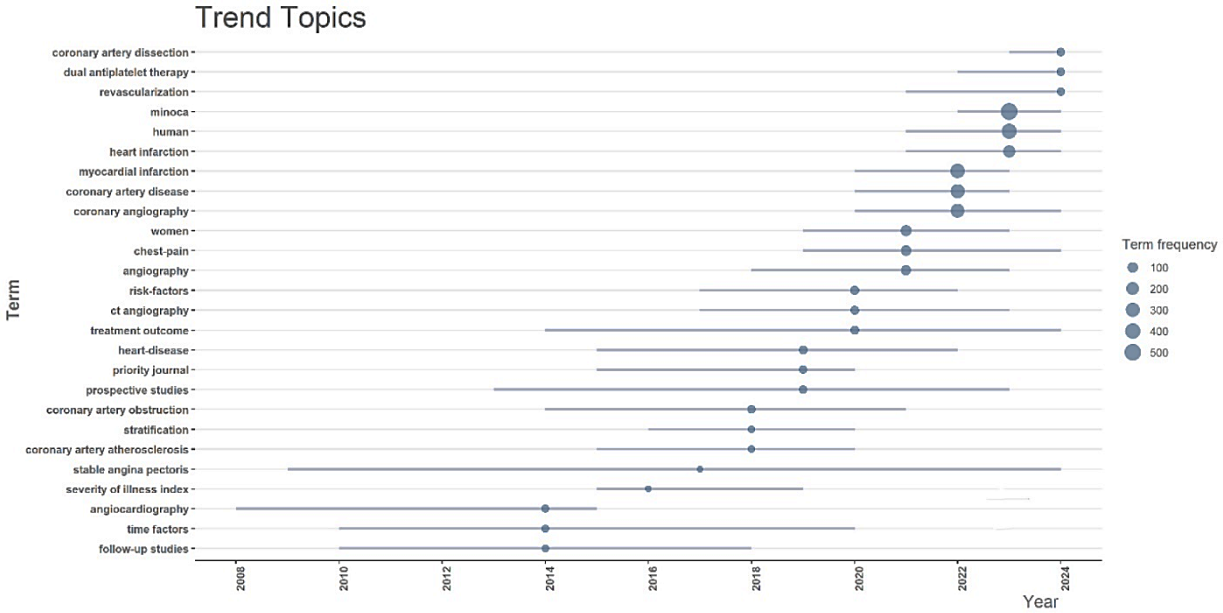


Figure 11. Trend topics analysis in the field of myocardial infarction with nonobstructive coronary arteries (MINOCA). Early work focused on ischemic heart disease and angina, whereas recent years emphasize advanced imaging (optical coherence tomography [OCT] and cardiac magnetic resonance [CMR]), sex-specific differences, and treatment outcomes—marking a transition toward precision and interventional research.

Discussion

This bibliometric analysis of 1,562 publications on MINOCA from 1987 through 2025 highlights a significant shift in scientific attention. Annual scientific production shows an apparent acceleration after 2015, with a peak of over 300 papers in 2023. This sharp growth reflects the transition of MINOCA from being considered a rare clinical entity to being recognized as a syndrome requiring systematic investigation. A similar upward trend in coronary microvascular

dysfunction bibliometrics has been observed in other niche conditions, where disease recognition by international societies often drives research growth.[30]

The citation analysis revealed 29,733 total citations with an average of 19.21 citations per document and an h-index of 75. High citation counts were linked to consensus statements and registry-based studies, especially those addressing diagnostic pathways and pathophysiology.[2,3] These findings indicate that the scientific community places strong emphasis on authoritative frameworks and large-scale observational data.

In terms of source distribution, European Heart Journal, Circulation, and Journal of the American College of Cardiology emerged as the most influential outlets, publishing major society-endorsed documents and expert consensus statements. Meanwhile, International Journal of Cardiology, Frontiers in Cardiovascular Medicine, and Journal of Clinical Medicine demonstrated high productivity, reflecting the democratization of knowledge through open-access platforms. This duality echoes findings in bibliometric research across cardiology, where open-access expands accessibility while traditional journals sustain prestige. [9]

The United States (27.6%), Italy (14.1%), and China (11.9%) dominated the global MINOCA research output, collectively producing over half of all publications. The strong performance of the United States is attributable to well-established multicenter research infrastructures and registry initiatives. In contrast, China's steep publication growth since 2015 aligns with major national investments in cardiovascular research and the country's high ischemic heart disease burden.[19,20] Sweden, despite a smaller output, contributed disproportionately through registry-based investigations such as SWEDEHEART, which has shaped the understanding of prognosis and treatment. [6] However, only 19.21% of papers were produced through multicountry authorship, suggesting that although global partnerships are emerging, research activity remains predominantly nationally concentrated.

Analysis of author productivity revealed F. Crea (Italy) as the most prolific contributor with 40 publications, followed by J. F. Beltrame (Australia) and H. R. Reynolds (USA) with 37 and 33 publications, respectively. Collectively, these researchers have driven the conceptual and clinical evolution of MINOCA through mechanistic studies, consensus documents, and registry-based research.

Keyword analysis revealed a thematic evolution. Earlier decades were dominated by general terms such as "ischemia" and "acute myocardial infarction." Since 2018, specific terms including "MINOCA," "nonobstructive coronary artery disease," "optical coherence tomography (OCT)," and "cardiac magnetic resonance (CMR)" have emerged as central research foci. This trend reflects the adoption of advanced imaging modalities to elucidate mechanisms, in line with evidence that OCT and CMR improve etiological classification and guide treatment.[4,31] Moreover, emerging terms such as "spontaneous coronary artery dissection (SCAD)," "microvascular dysfunction," and "Takotsubo cardiomyopathy" underscore recognition of MINOCA as a heterogeneous syndrome.[32]

The thematic shift toward mechanistic clarity parallels guideline recommendations, including the ESC's 2017 position paper, which called for systematic imaging in MINOCA patients.[1] Studies combining OCT and CMR have since shown that up to 85% of MINOCA cases can be mechanistically explained, substantially improving diagnostic yield.[4] Nevertheless, therapeutic strategies remain limited, and randomized controlled trials in this population are still scarce.[21] This gap emphasizes the need for mechanism-specific trials and international registries.

In summary, MINOCA research has matured from descriptive epidemiology to a precision-oriented field focused on pathophysiological mechanisms and advanced imaging. Future work should prioritize (1) standardized diagnostic protocols, (2) randomized trials targeting mechanistic subgroups, (3) stronger global collaboration, and (4) longitudinal studies assessing prognosis. These steps are essential to translate bibliometric growth into meaningful clinical impact.

This study has several limitations inherent to bibliometric analyses. First, the data were limited to publications indexed in selected databases, which may exclude relevant articles from nonindexed sources. Second, bibliometric

indicators such as citation counts may be influenced by journal impact and publication year, potentially underrepresenting newer studies. Finally, although keyword analysis provides insights into research themes, it may not fully capture nuanced conceptual developments within clinical cardiology.

Conclusion

The research landscape of MINOCA has expanded markedly, shifting from descriptive studies to mechanistic and imaging-based investigations. Advances in modalities such as CMR and OCT have improved diagnostic yield. Future research should focus on establishing standardized diagnostic criteria, conducting mechanism-specific clinical trials, and strengthening global collaboration through the establishment of international registries. This bibliometric analysis offers a comprehensive framework for clinicians and researchers to understand current progress, identify knowledge gaps, and guide future directions in the evolving field of MINOCA.

Declarations:

Ethical Approval

Ethical approval was not required for conducting this research.

Funding

The authors received no financial support for their research, authorship, or publication of this article.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgment

The authors would like to express their sincere appreciation to all institutions and researchers whose publications formed the basis of this bibliometric analysis. We also acknowledge the support provided by the affiliated institutions for facilitating access to scientific databases and analytical tools used in this study. The authors thank colleagues who provided valuable methodological input during the study design and data analysis. No external funding was received for this research.

References

1. Agewall S, Beltrame JF, Reynolds HR, Niessner A, Rosano G, Caforio ALP, et al. ESC working group position paper on myocardial infarction with non-obstructive coronary arteries. Eur Heart J. 2017;38(3):143-53.
2. Tamis-Holland JE, Jneid H, Reynolds HR, Agewall S, Brilakis ES, Brown TM, et al. Contemporary Diagnosis and Management of Patients with Myocardial Infarction in the Absence of Obstructive Coronary Artery Disease: A Scientific Statement from the American Heart Association. Circulation. 2019;139(18): e891-908.
3. Pasupathy S, Air T, Dreyer RP, Tavella R, Beltrame JF. Systematic review of patients presenting with suspected myocardial infarction and nonobstructive coronary arteries. Circulation. 2015;131(10):861-70.
4. Reynolds HR, Maehara A, Kwong RY, Sedlak T, Saw J, Smilowitz NR, et al. Coronary Optical Coherence Tomography and Cardiac Magnetic Resonance Imaging to Determine Underlying Causes of Myocardial Infarction with Nonobstructive Coronary Arteries in Women. Circulation. 2021;143(7):624-40.
5. Tognola C, Maloberti A, Varrenti M, Mazzone P, Giannattasio C, Guarracini F. Myocardial Infarction with Nonobstructive Coronary Arteries (MINOCA): Current Insights into Pathophysiology, Diagnosis, and Management. Diagnostics (Basel). 2025;15(7):942.
6. Nordenskjöld AM, Baron T, Eggers KM, Jernberg T, Lindahl B. Predictors of adverse outcome in patients with myocardial infarction with non-obstructive coronary artery (MINOCA) disease. Int J Cardiol. 2018; 261:18-23.
7. Bairey Merz CN, Pepine CJ, Walsh MN, Fleg JL, Camici PG, Chilian WM, et al. Ischemia and No Obstructive Coronary Artery Disease (INOCA). Circulation. 2017;135(11):1075-92.
8. Pustjens TFS, Appelman Y, Damman P, ten Berg JM, Jukema JW, de Winter RJ, et al. Guidelines for the management of myocardial infarction/injury with non-obstructive coronary arteries (MINOCA): a position paper from the Dutch ACS working group. Neth Heart J. 2020;28(3):116-30.
9. 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(March):285-96.

10. Mongeon P, Paul-Hus A. The journal coverage of Web of Science and Scopus: a comparative analysis. Scientometrics. 2016;106(1):213-28.

11. Martín-Martín A, Orduna-Malea E, Thelwall M, Delgado López-Cózar E. Google Scholar, Web of Science, and Scopus: A systematic comparison of citations in 252 subject categories. J Informetr. 2018;12(4):1160-77.

12. Montazeri A, Mohammadi S, M. Hesari P, Ghaemi M, Riazi H, Sheikhi-Mobarakeh Z. Preliminary guideline for reporting bibliometric reviews of the biomedical literature (BIBLIO): a minimum requirement. Syst Rev. 2023;12(1):239.

13. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth Universal Definition of Myocardial Infarction (2018). J Am Coll Cardiol. 2018;72(18):2231-64.

14. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Eur Heart J. 2018;39(2):119-77.

15. Collet J-P, Thiele H, Barbato E, Barthélémy O, Bauersachs J, Bhatt DL, et al. 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. Eur Heart J. 2021;42(14):1289-367.

16. Byrne RA, Rossello X, Coughlan JJ, Barbato E, Berry C, Chieffo A, et al. 2023 ESC Guidelines for the management of acute coronary syndromes. Eur Heart J. 2023;44(38):3720-826.

17. Jespersen L, Hvelplund A, Abildstrom SZ, Pedersen F, Galatius S, Madsen JK, et al. Stable angina pectoris with no obstructive coronary artery disease is associated with increased risks of major adverse cardiovascular events. Eur Heart J. 2012;33(6):734-44.

18. Kunadian V, Chieffo A, Camici PG, Berry C, Escaned J, Maas AHEM, et al. An EAPCI Expert Consensus Document on Ischaemia with Non-Obstructive Coronary Arteries in Collaboration with European Society of Cardiology Working Group on Coronary Pathophysiology & Microcirculation Endorsed by Coronary Vasomotor Disorders Internati. EuroIntervention. 2021;16(13):1049-69.

19. Zhou M, Wang H, Zeng X, Yin P, Zhu J, Chen W, et al. Mortality, morbidity, and risk factors in China and its provinces, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet. 2019;394(10204):1145-58.

20. Li H, Ge J. Cardiovascular diseases in China: Current status and future perspectives. IJC Heart Vasc. 2015; 6:25-31.

21. Lindahl B, Baron T, Erlinge D, Hadziosmanovic N, Nordenskjöld A, Gard A, et al. Medical Therapy for Secondary Prevention and Long-Term Outcome in Patients with Myocardial Infarction with Nonobstructive Coronary Artery Disease. Circulation. 2017;135(16):1481-9.

22. Beltrame JF, Crea F, Kaski JC, Ogawa H, Ong P, Sechtem U, et al. international standardization of diagnostic criteria for vasospastic angina. Eur Heart J. 2017;38(33):2565-8.

23. Abdu FA, Mohammed A-Q, Liu L, Xu Y, Che W. Myocardial Infarction with Nonobstructive Coronary Arteries (MINOCA): A Review of the Current Position. Cardiology. 2020;145(9):543-52.

24. Abdu FA, Alifu J, Mohammed A-Q, Liu L, Zhang W, Yin G, et al. The correlation of atherogenic index of plasma with non-obstructive CAD and unfavorable prognosis among patients diagnosed with MINOCA. Eur J Intern Med. 2024; 125:111-9.

25. Abdu FA, Liu L, Mohammed A-Q, Xu B, Yin G, Xu S, et al. Effect of Secondary Prevention Medication on the Prognosis in Patients with Myocardial Infarction with Nonobstructive Coronary Artery Disease. J Cardiovasc Pharmacol. 2020;76(6):678-83.

26. Scalone G, Niccoli G, Crea F. Editor's Choice-Pathophysiology, diagnosis and management of MINOCA: an update. Eur Heart J Acute Cardiovasc Care. 2019;8(1):54-62.

27. Reynolds HR, Srichai MB, Iqbal SN, Slater JN, Mancini GBJ, Feit F, et al. Mechanisms of Myocardial Infarction in Women Without Angiographically Obstructive Coronary Artery Disease. Circulation. 2011;124(13):1414-25.

28. Montone RA, Niccoli G, Fracassi F, Russo M, Gurgoglione F, Cammà G, et al. Patients with acute myocardial infarction and non-obstructive coronary arteries: safety and prognostic relevance of invasive coronary provocative tests. Eur Heart J. 2018;39(2):91-8.

29. Reynolds HR, Maehara A, Kwong RY, Sedlak T, Saw J, Smilowitz NR, et al. Coronary Optical Coherence Tomography and Cardiac Magnetic Resonance Imaging to Determine Underlying Causes of Myocardial Infarction with Nonobstructive Coronary Arteries in Women. Circulation. 2021;143(7):624-40.

30. Gao J, Meng T, Li M, Du R, Ding J, Li A, et al. Global trends and frontiers in research on coronary microvascular dysfunction: a bibliometric analysis from 2002 to 2022. Eur J Med Res. 2022;27(1):233.

31. Gudenkauf B, Hays AG, Tamis-Holland J, Trost J, Ambinder DI, Wu KC, et al. Role of Multimodality Imaging in the Assessment of Myocardial Infarction with Nonobstructive Coronary Arteries: Beyond Conventional Coronary Angiography. J Am Heart Assoc. 2022;11(1): e022787.

32. Niccoli G, Scalone G, Lerman A, Crea F. Coronary microvascular obstruction in acute myocardial infarction. Eur Heart J. 2016;37(13):1024-33.