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Temporal Evolution and Determinants of Scientific Impact in Myocardial T1 and T2 Mapping in Cardiac MRI

Hakan Ayyıldız[1], Berke Ersoy[2], Ahmet Arslan[1], Yigit Can Kartal[1], Sercin Ozkok[1], Sukru Mehmet Erturk[3]

[1]Basaksehir Cam and Sakura City Hospital, Department of Radiology, Istanbul, Türkiye
[2]Istanbul University Oncology Institute, Department of Radiology, Istanbul, Türkiye
[3]Istanbul University, Istanbul Faculty of Medicine, Department of Radiology, Istanbul, Türkiye

Abstract

Introduction: Myocardial T1 and T2 mapping using cardiac MRI has expanded rapidly over the past decade. This bibliometric study aimed to evaluate global research trends and identify independent determinants of citation impact in this field.

Materials and Methods: Publications related to myocardial T1 and T2 mapping indexed in the Web of Science Core Collection (Science Citation Index Expanded, 2011–2024) were analyzed. Bibliometric indicators, keyword co-occurrence, and collaboration networks were assessed using Python and VOSviewer. Multivariable linear regression and negative binomial regression were performed to identify factors associated with citation impact.

Results: A total of 1,298 publications were included. Annual output showed a significant increasing trend, peaking in 2021. Keyword analysis identified four thematic clusters. Publication age and review article type were independently associated with citation impact in a multivariable model explaining approximately 46% of variance in log-transformed citation counts. Review articles accumulated approximately twice as many citations as original articles.

Conclusion: Research output accelerated after 2015, with a notable surge during the COVID-19 pandemic driven by studies on myocarditis and cardiac involvement. The high citation impact of review articles may reflect the field's prioritization of standardization and protocol harmonization over isolated original studies. The United States, Germany, and United Kingdom led globally in publication volume, with growing contributions from China. Publication age and document type are independent determinants of citation impact in myocardial T1 and T2 mapping research, highlighting the central role of evidence synthesis in cardiovascular magnetic resonance imaging.

Key words: Magnetic Resonance imaging; cardiac imaging techniques; bibliometrics; myocardium; fibrosis; extracellular space.

Introduction

Cardiac magnetic resonance imaging (CMR) has become a cornerstone modality for the noninvasive assessment of myocardial structure and function, offering unparalleled tissue characterization capabilities (1). Among advanced CMR techniques, myocardial T1 and T2 mapping have emerged as quantitative tools that enable objective assessment of diffuse myocardial abnormalities beyond the limitations of conventional qualitative imaging (2). By providing pixel-wise measurements of myocardial relaxation properties, these techniques allow for the detection and quantification of fibrosis, edema, and inflammation across a wide range of cardiovascular diseases (2). Since the early 2010s, research on myocardial T1 mapping has expanded rapidly. Early investigations focused primarily on sequence development, technical validation, and reproducibility, laying the groundwork for clinical translation. Subsequently, the incorporation of extracellular volume (ECV) quantification expanded the clinical utility of T1 mapping by enabling noninvasive assessment of diffuse myocardial fibrosis (3). In parallel, myocardial T2 mapping gained increasing attention for its role in detecting myocardial edema and inflammation, particularly in the context of acute myocardial injury and inflammatory cardiomyopathies (4). Over the past decade, the clinical applications of myocardial mapping have broadened substantially. These techniques are now routinely investigated in a wide spectrum of conditions, including cardiomyopathies, heart failure, ischemic heart disease, and systemic disorders with cardiac involvement. More recently, the global COVID-19 pandemic further accelerated research activity,

*Corresponding Author: Hakan Ayyıldız Department of Radiology, Basaksehir Cam and Sakura City Hospital, Istanbul, Türkiye **Email:** hakanayyildiz77@gmail.com **Orcid:** Hakan Ayyıldız 0000-0003-0244-7765, Berke Ersoy 0000-0003-0161-1914, Ahmet Arslan 0009-0005-0383-3491, Yigit Can Kartal 0000-0001-7881-1274 , Sercin Ozkok 0000-0002-2176-5278, Sukru Mehmet Erturk 0000-0003-4086-675X

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highlighting the role of T1 and T2 mapping in the evaluation of myocarditis and myocardial inflammation (5-7). In parallel, the publication of international guidelines and consensus statements has contributed to the standardization and wider adoption of myocardial mapping in clinical practice (8).Given this rapid expansion, the body of literature on myocardial T1 and T2 mapping has become large, diverse, and increasingly multidisciplinary. While numerous original validation studies and reviews have addressed specific clinical applications (9, 10) and recent bibliometric analyses have examined related topics such as cardiac fibrosis (11) or artificial intelligence in imaging (12), a comprehensive overview of the global research landscape, thematic structure, temporal evolution, and geographic distribution specifically dedicated to myocardial mapping is lacking. Bibliometric analysis, as demonstrated in recent studies ,offers a systematic and quantitative approach to address this gap by mapping publication trends, research themes, collaborative networks, and influential contributions within a given field (13-15). Therefore, the aim of this study was to perform a bibliometric and visualized analysis of global research on myocardial T1 and T2 mapping using CMR. By analyzing publication output, keyword co-occurrence, temporal trends, country-level contributions, and leading journals this study seeks to provide a structured overview of the development and current state of myocardial mapping research, as well as to identify emerging research directions and areas of growing clinical relevance. In addition to descriptive bibliometric mapping, this study further aims to evaluate factors associated with scientific impact within myocardial T1 and T2 mapping research. Citation-based statistical analyses were therefore performed to identify independent determinants of citation impact, while accounting for publication age and document type. By integrating inferential statistical modeling with bibliometric visualization, this study seeks to move beyond trend description and provide quantitative insight into factors shaping research influence in cardiovascular magnetic resonance imaging.

Materials and Methods

Study design: This study was designed as a bibliometric and visualized analysis to evaluate the global research landscape, thematic structure, temporal evolution, and geographic distribution of publications related to myocardial T1 and T2 mapping using cardiac magnetic resonance imaging (MRI).

Data source and search strategy: A comprehensive literature search was conducted in the Web of Science Core Collection database (Clarivate Analytics, Philadelphia, US), restricted to the Science Citation Index Expanded (SCI-EXPANDED). Publications were retrieved using a search query designed to identify studies of myocardial parametric (T1 and/or T2) mapping. The search strategy combined terms for parametric mapping techniques, cardiac magnetic resonance imaging, and myocardial focus using the following Boolean logic: TS = (("T1 mapping" OR "T2 mapping" OR "parametric mapping") AND ("cardiac MRI" OR "cardiovascular magnetic resonance" OR "CMR") AND (myocard*)). The search was limited to publications indexed between 2011 and 2024. Document type refinements were applied to include only original articles and reviews, excluding records still in Early Access status (i.e., not yet assigned to a final volume and issue), proceedings papers, retracted publications, and book chapters. Thirteen retrieved records whose early-access (online-first) dates fell within the search window had subsequently been assigned a final publication year of 2025; these records were retained and assigned to their early-access year for all time-based analyses, as citation accrual begins at online availability. No language restriction was applied; non-English publications (n = 8, 0.6%) were retained because the Web of Science provides English-language titles, abstracts, and author keywords for all indexed records and citation metrics are independent of publication language, thereby avoiding linguistic bias in geographic and collaboration analyses. All retrieved records were exported in plain text format, including full records and cited references. Due to export limitations, the dataset was downloaded in multiple batches and subsequently merged for analysis.

Data preprocessing: Exported Web of Science records were consolidated and processed using Python, v3.11 (Python Software Foundation, Wilmington, DE, USA) to extract descriptive bibliometric indicators. Records with missing or incomplete publication year information were excluded from time-based analyses. For the early-access records described in Data source and search strategy, the early-access year was used in all time-based analyses to ensure complete annual coverage. Country-level information was derived from author affiliations. For publications involving multiple countries, each country was counted once per publication, reflecting international collaboration patterns.

Statistical analysis: Citation-based statistical analyses were performed to identify factors associated with scientific impact in myocardial T1 and T2 mapping research. Citation counts (Times Cited, TC) were extracted from the Web of Science records and log-transformed [log(TC + 1)] to account for right-skewed distribution of citation data. Publication age was calculated as the difference between the most recent publication year included in the dataset (2024) and the effective publication year of each article (see Data source and search strategy). Document type was categorized as original article or review article. Multivariable linear regression analysis was conducted with log-transformed citation count as the dependent variable. Covariates included publication age, document type, number of authors, international collaboration status, funding status, and open-access availability. Regression coefficients with 95% confidence intervals were reported. Model assumptions were assessed, and a two-sided p value < 0.05 was considered statistically significant. Temporal trends in annual publication output were assessed using the non-parametric Mann–Kendall trend test to evaluate the presence of a monotonic trend over time. Sen's slope estimator was used to quantify the annual rate of change in publication output. As a sensitivity analysis, negative binomial regression was performed using citation counts as the dependent variable to account for overdispersion in count data, with the dispersion parameter estimated by maximum likelihood. All statistical analyses were performed using Python (pandas and statsmodels libraries).

Bibliometric analysis and visualization: To identify major research themes and conceptual structures, keyword co-occurrence analysis was performed using VOSviewer v1.6.20 (Centre for Science and Technology Studies, Leiden University, Leiden, The Netherlands) (16). Author keywords were analyzed using the full counting method. A minimum occurrence threshold of 20 was applied to reduce noise and improve interpretability by retaining frequently used and clinically meaningful terms, as commonly adopted in bibliometric network analyses (17). While this threshold ensures the analysis focuses on established, clinically relevant themes and reduces noise from transient keywords, it inherently filters out emerging or niche topics — such as 7T ultra-high-field mapping or novel pulse sequence developments — that have not yet accumulated sufficient occurrence counts to appear in the network. A thesaurus file was applied to merge synonymous terms (e.g., "T1 mapping," "native T1," "CMR," "cardiac MRI") and improve interpretability of the keyword network. An overlay visualization was generated to examine the temporal evolution of research topics. Keywords were color-coded according to their average publication year, allowing visualization of shifts from early technical validation studies toward more recent clinical, inflammatory, and guideline-oriented research. International research collaboration patterns were evaluated using co-authorship analysis by country in VOSviewer. Countries with a minimum number of publications were included, and network visualization was used to illustrate collaboration strength and geographic research distribution. Descriptive indicators, including annual publication output, top contributing journals, and top contributing countries, were calculated using Python-based data extraction. Annual publication trends were visualized using bar charts generated with the matplotlib library.

Ethical considerations: As this study was based exclusively on publicly available bibliographic data, ethical approval and informed consent were not required.

Results

Study selection and general characteristics: The search retrieved 1,298 records, all of which met the eligibility criteria and were included in the final bibliometric analysis. Of these, 1,140 (87.8%) were original articles and 158 (12.2%) were review articles. The publications were indexed between 2011 and 2024, reflecting the contemporary development and clinical adoption of myocardial parametric mapping techniques.

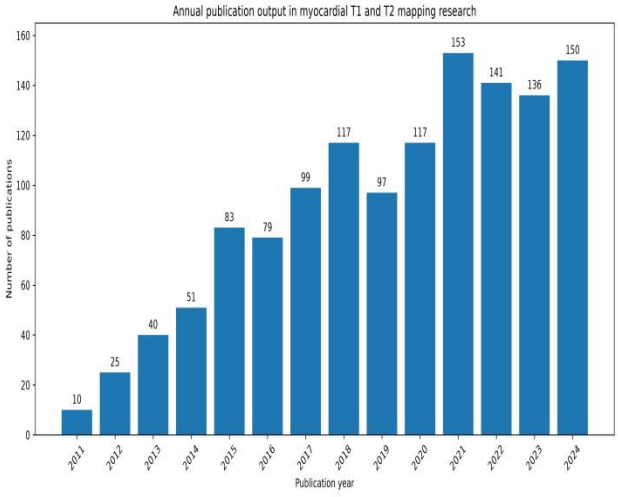


Figure 1: Annual number of publications on myocardial T1 and T2 mapping using cardiac magnetic resonance imaging from 2011 to 2024.

Annual publication trends: Annual publication output demonstrated a progressive increase over time (Figure 1). Mann–Kendall trend analysis demonstrated a statistically significant increasing trend in annual publication output over the study period ($Z = 4.11$, Kendall's $\tau = 0.84$, $p < 0.001$) Sen's slope estimation indicated an average increase of approximately 11.0 publications per year. Early research activity was limited between 2011 and 2014, with fewer than 60 publications per year, corresponding to the initial methodological development and validation phase of myocardial mapping techniques. From 2015 onward, a marked increase in publication volume was observed, coinciding with expanding clinical applications and the introduction of extracellular volume quantification. Research output continued to rise steadily after 2018, reaching a peak in 2021 ($n = 153$). High publication activity was sustained from 2019 to 2024, indicating ongoing scientific interest and maturation of myocardial T1 and T2 mapping research.

Keyword co-occurrence analysis: A central cluster was dominated by terms related to quantitative myocardial tissue characterization, including T1 mapping, myocardial fibrosis, and extracellular volume, highlighting the core role of parametric mapping in assessing diffuse myocardial disease. A second cluster focused on technical and methodological aspects, encompassing terms such as Modified Look-Locker inversion recovery (MOLLI), inversion recovery, reproducibility, and validation, representing early research efforts aimed at sequence optimization and standardization. A third cluster reflected clinical applications and prognostic assessment, characterized by keywords including cardiomyopathy, heart failure, late gadolinium enhancement, mortality, and prognosis. Additionally, a separate cluster emphasized myocardial inflammation and disease-specific applications, particularly myocarditis and inflammatory cardiomyopathies. Keyword co-occurrence analysis identified several distinct thematic clusters within myocardial T1 and T2 mapping research as shown in Figure 2.

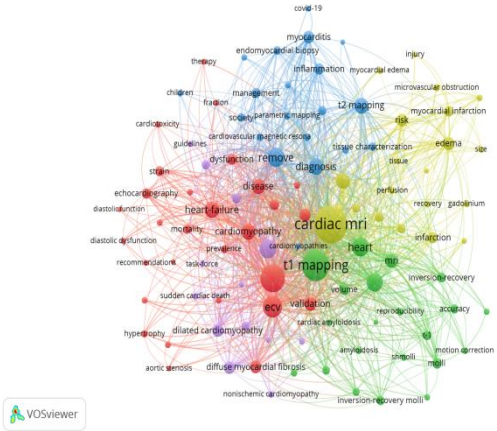


Figure 2: Keyword co-occurrence network of myocardial T1 and T2 mapping research. Node size represents keyword frequency, and links indicate co-occurrence relationships, revealing major thematic clusters.

Temporal evolution of research topics: Overlay visualization revealed a clear temporal evolution of research themes in myocardial T1 and T2 mapping (Figure 3).

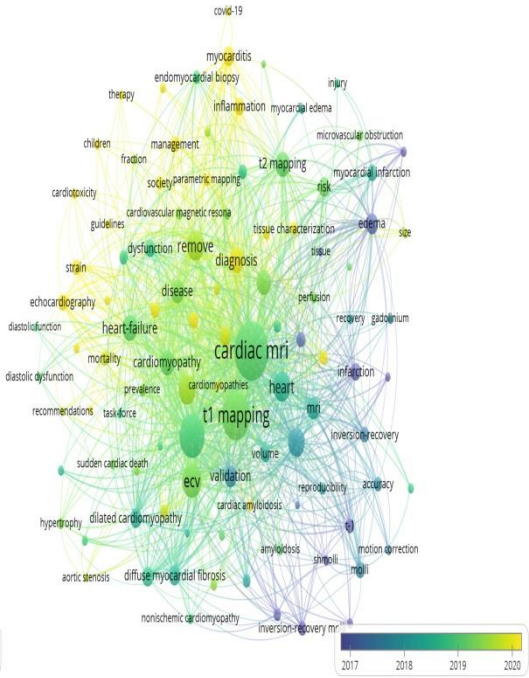


Figure 3: Overlay visualization of author keywords showing the temporal evolution of myocardial T1 and T2 mapping research, with colors indicating average publication year.

Earlier publications were predominantly associated with technical validation and sequence development, whereas more recent studies increasingly focused on clinical applications, inflammatory myocardial disease, and outcome assessment. Keywords related to myocarditis, including COVID-19–associated myocardial involvement, as well as guidelines and consensus statements, appeared more prominently in later years, underscoring the shift toward guideline-driven and clinically integrated research.

Geographic distribution and international collaboration: Country-level co-authorship

analysis demonstrated a broad international distribution of myocardial T1 and T2 mapping research (Figure 4).

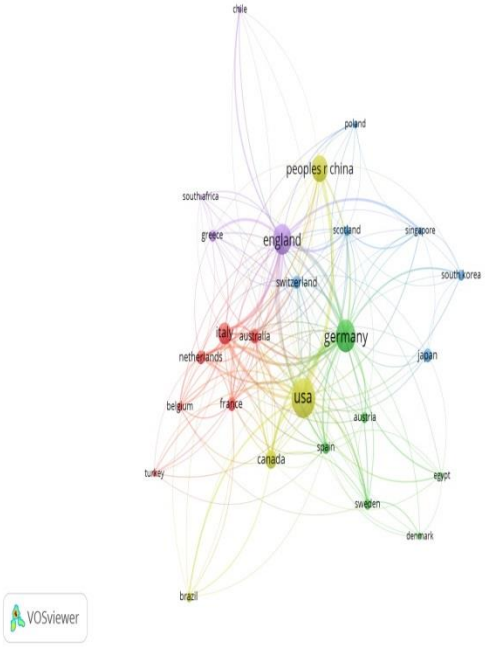


Figure 4: Country-level co-authorship network illustrating international research collaboration in myocardial T1 and T2 mapping studies. Node size reflects publication volume, and link thickness indicates collaboration strength.

Research output was predominantly contributed by North America, Western Europe, and East Asia, with the highest publication volumes originating from the United States, Germany, the United Kingdom, and China, followed by Italy and Canada (Table 1).

Table 1: Top contributing countries in myocardial T1 and T2 mapping research (2011–2024).

Rank	Country	Publications	% of total
1	United States	276	21.3
2	Germany	197	15.2
3	United Kingdom	144	11.1
4	China	131	10.1
5	Italy	78	6.0
6	Canada	60	4.6
7	Japan	45	3.5
8	Australia	34	2.6
9	France	31	2.4
10	Netherlands	31	2.4

*Percentages were calculated based on the total number of included (n = 1298).

Dense collaboration networks were observed among European countries and between Europe and North America, reflecting established international research partnerships and the influence of multinational guidelines and collaborative cardiovascular imaging initiatives.

Leading journals and publication venues: Analysis of publication venues revealed that myocardial T1 and T2 mapping research was primarily published in cardiovascular imaging and radiology journals. The highest number of publications appeared in specialized cardiac imaging journals, followed by high-impact general radiology and cardiology journals (Table 2). This distribution highlights the interdisciplinary nature of myocardial mapping research, bridging technical imaging innovation and clinical cardiovascular medicine.

Citation impact analysis: Citation-based statistical analysis included all 1,298 publications. Multivariable linear regression demonstrated that publication age was independently associated with higher citation impact ($\beta = 0.257$, 95% CI 0.241–0.273; $p < 0.001$). In addition, review articles exhibited significantly greater citation impact compared with original articles ($\beta = 0.724$, 95% CI 0.553–0.895; $p < 0.001$). The regression model explained approximately 46% of the variance in log-transformed citation counts (adjusted $R^2 = 0.462$), indicating a strong association between publication characteristics and scientific impact. When regression coefficients were exponentiated for interpretability, review articles were associated with approximately twice as many citations compared with original articles, independent of publication age. Sensitivity analysis using negative binomial regression demonstrated results consistent with the primary linear regression analysis. Publication age (IRR = 1.32, 95% CI 1.30–1.35; $p < 0.001$) and review article type (IRR = 2.48, 95% CI 2.08–2.95; $p < 0.001$) remained independently associated with higher citation counts. Because publication age was explicitly included as a covariate in the regression models, the observed associations reflect differences in citation impact independent of time since publication. In multivariable negative binomial regression model, number of authors (IRR = 1.07 per additional author, 95% CI 1.06–1.09; $p < 0.001$) was also independently associated with higher citation counts. In addition, funded studies demonstrated significantly higher citation impact compared with non-funded publications (IRR = 1.21, 95% CI 1.06–1.38; $p = 0.006$). In the negative binomial model, international collaboration showed a modest but statistically

Table 2: Top journals publishing research on myocardial T1 and T2 mapping using cardiac MRI (2011-2024).

Rank	Journal	Number of publications	JCR Quartile*
1	Journal of Cardiovascular Magnetic Resonance	184	Q1
2	International Journal of Cardiovascular Imaging	85	Q3
3	JACC: Cardiovascular Imaging	66	Q1
4	Frontiers in Cardiovascular Medicine	55	Q2
5	European Heart Journal – Cardiovascular Imaging	49	Q1
6	Journal of Magnetic Resonance Imaging	46	Q1
7	International Journal of Cardiology	43	Q2
8	European Radiology	43	Q1
9	Magnetic Resonance in Medicine	42	Q2
10	Circulation: Cardiovascular Imaging	38	Q1

* Journal quartile rankings were obtained from the most recent Journal Citation Reports (JCR) release available at the time of the study

Table 3: Multivariable linear and negative binomial regression analysis identifying factors associated with citation impact

Variable	Linear β (95% CI)	p	Negative binomial IRR (95% CI)	p
Publication age (per year)	0.257 (0.241 – 0.273)	<0.001	1.32 (1.30 – 1.35)	<0.001
Number of authors (per author)	0.059 (0.047 – 0.071)	<0.001	1.07 (1.06 – 1.09)	<0.001
Review article (vs article)	0.724 (0.553 – 0.895)	<0.001	2.48 (2.08 – 2.95)	<0.001
International collaboration (Yes vs No)	0.101 (−0.010 – 0.212)	0.074	1.22 (1.08 – 1.37)	0.001
Open access (Yes vs No)	0.088 (−0.028 – 0.205)	0.137	1.05 (0.93 – 1.19)	0.432
Funded study (Yes vs No)	0.229 (0.104 – 0.354)	<0.001	1.21 (1.06 – 1.38)	0.006

Linear regression: dependent variable log-transformed citation count, log(TC + 1); adjusted R^2 = 0.462. Negative binomial regression: dependent variable citation count. β: regression coefficient; IRR: incidence rate ratio; CI: confidence interval.

significant independent association with higher citation counts (IRR = 1.22, 95% CI 1.08–1.37; p = 0.001), whereas open-access availability was not an independent predictor after adjustment for authorship size, publication age, funding status, and article type (IRR = 1.05, 95% CI 0.93–1.19; p = 0.432). Complete results from the multivariable linear regression and negative binomial sensitivity analysis are presented in Table 3.

Discussion

The bibliometric analysis reveals a clear trajectory of rapid growth in research on myocardial T1 and T2 mapping over the past decade. Early foundational work introduced quantitative T1 mapping techniques (e.g., MOLLI sequences) (18). However, publication output remained modest until the mid 2010s. Since then, annual publications have accelerated markedly, reflecting both technical maturation and broader clinical adoption of mapping. Notably, by 2017 the field had matured enough to warrant formal clinical recommendations for CMR parametric mapping, underscoring that T1/T2 mapping had transitioned from experimental to routinely applicable technology (8, 19). Likewise, growing clinical evidence that mapping could non-invasively quantify diffuse fibrosis and edema (4, 20). This momentum culminated around 2020–2021 with an unprecedented surge in publications, coinciding with the COVID-19 pandemic. During this period, investigators worldwide pivoted to

apply T1/T2 mapping in studying COVID-related myocarditis and cardiac involvement, contributing to a conspicuous spike in output. This surge mirrors broader imaging research trends observed during the COVID-19 era (6, 21, 22). In our field, the pandemic acted as a catalyst that amplified an already upward trajectory of scholarly activity. Beyond descriptive bibliometric mapping, the present study quantitatively examined factors associated with scientific impact in myocardial T1 and T2 mapping research. After adjustment for publication age, review articles demonstrated substantially higher citation impact than original studies, a finding that was consistent across linear and negative binomial regression models. This observation underscores the influential role of evidence synthesis in consolidating methodological advances and guiding clinical adoption in cardiovascular magnetic resonance imaging. The consistency of findings across linear and negative binomial models supports the robustness of the identified determinants of citation impact in myocardial mapping research. The independent association between review articles and higher citation impact likely reflects the specific needs of the cardiac MRI community. Unlike mature modalities like CT, T1 and T2 mapping are technically complex techniques that suffer from variability across vendors and scanners. Consequently, the high citation rate of reviews and consensus statements suggests that the community prioritizes standardization and protocol harmonization over isolated original studies. For the clinician, this indicates that the field is still in a phase of 'consolidation' where establishing reference values and standardizing acquisition protocols is the primary driver of academic discourse. Notably, open-access availability, which is widely reported to enhance citation performance in bibliometric research, did not remain an independent predictor after adjustment for authorship size, funding status, publication age, and document type; this likely reflects the structure of the myocardial mapping literature, in which highly cited consensus and consortium publications are already disproportionately openly accessible, so any apparent citation advantage of open access may partly reflect differences in team size and funding. In contrast, in the negative binomial model, international collaboration retained a modest independent association with citation impact, consistent with the multinational character of the field's most influential standardization efforts. The analysis also highlights the global and collaborative nature of myocardial mapping research. The United States and several European countries (particularly the UK and Germany) have consistently led in publication volume, with China in recent years rapidly expanding its contribution. These leading countries frequently collaborate, resulting in an interconnected international co-authorship network. Large multi-center studies and consensus efforts – for example, the 2017 SCMR/EACVI parametric mapping guidelines assembled experts across North America, Europe, and Asia – exemplify this global teamwork (8). Such collaboration has enabled pooling of data and expertise, accelerating validation of mapping techniques across diverse populations and scanner platforms. The diverse origin of top-cited papers and the multinational composition of author teams indicate a research community that is widely distributed yet tightly knit. In terms of publication venues, the field straddles both radiology and cardiology domains. Specialized cardiovascular imaging journals – notably Journal of Cardiovascular Magnetic Resonance and cardiology imaging outlets like JACC: Cardiovascular Imaging – feature many of the seminal mapping studies, reflecting the strong cardiology interest in these MRI biomarkers (23). The prominence of journals such as the International Journal of Cardiovascular Imaging (Rank 2) illustrates that this topic is central to the specialized imaging community rather than general radiology alone. At the same time, general radiology journals (e.g., Radiology, Academic Radiology) and MRI-focused journals (Magnetic Resonance in Medicine, JMRI) have published key technical advancements. This dual presence underscores that myocardial T1/T2 mapping is a multidisciplinary endeavor: radiologists have driven technical development and sequence optimization, while cardiologists have embraced the techniques to answer clinical questions. Neither domain holds an absolute majority of publications; instead, the landscape is one of convergence between imaging science and cardiovascular medicine. Keyword analysis provides further insight into the evolving focus of the field. Classic pathological targets of mapping such as “fibrosis” and “edema” remain highly prevalent keywords, reaffirming that the core clinical motivation is to detect myocardial fibrosis (e.g., diffuse interstitial fibrosis in cardiomyopathies) and edema (as in acute inflammation or injury). The sustained prominence of these terms indicates that T1 and T2 mapping are firmly established as essential tools for tissue characterization of these conditions. In parallel, emerging computational

approaches are gaining traction in the wider literature, although terms related to artificial intelligence (AI) and radiomics did not reach the occurrence threshold of the keyword network, consistent with their still-emergent status in this field. Investigators are increasingly applying machine learning. Investigators are now applying machine learning to extract high-dimensional texture features from T1/T2 maps and to improve diagnostic classification – for example, radiomics analyses of T1 maps have shown promise in differentiating hypertrophic cardiomyopathy from other causes of hypertrophy (24, 25). Such studies illustrate how AI techniques are being integrated to enhance the interpretative power of mapping data (e.g., by uncovering subtle patterns beyond mean T1 values). Another notable trend is the rise of outcome-focused studies. Whereas early mapping research centered on technical validation and case-control disease differentiation, there is now a growing body of work linking mapping metrics to patient prognoses and clinical outcomes. For instance, native T1 of noninfarcted myocardium has been shown to predict adverse outcomes in patients with coronary artery disease (26). Recent studies continue this trajectory by evaluating mapping as a risk stratification tool in various populations. However, a critical gap remains. While there is a surge in AI/Radiomics and observational data, there appears to be a lack of multi-center randomized trials using T1 mapping as a primary endpoint. Finally, the keywords “myocarditis” and “acute myocardial infarction” have been notable, in part due to surges of interest in using T1 and T2 mapping to assess inflammatory injury (as seen during the COVID-19 myocarditis investigations and in post-infarction myocardial salvage assessments) (27). The continuing appearance of new keywords alongside established ones paints a picture of a field that is both consolidating its fundamental clinical applications and branching out into innovative methodologies. From a cardiovascular imaging perspective, these findings highlight how myocardial mapping has transitioned from sequence validation toward guideline-supported clinical implementation and emerging AI-assisted applications. This study has several strengths, including a large dataset covering more than a decade of myocardial T1 and T2 mapping research, comprehensive bibliometric visualization, and the integration of citation-based statistical modeling with sensitivity analyses.

Study limitations: Nevertheless, several limitations should be acknowledged. The analysis was restricted to articles and reviews indexed in the Science Citation Index Expanded (SCI-EXPANDED) of the Web of Science Core Collection to ensure the quality and consistency of citation data; journals covered only by other citation indices (e.g., the Emerging Sources Citation Index) were therefore not represented. In addition, although the search strategy was designed to capture myocardial parametric mapping research comprehensively, studies referring exclusively to derived measures such as native T1 values or extracellular volume without using the term "mapping" may not have been retrieved. The restriction to the Web of Science may also have excluded technical engineering studies often indexed in Scopus or IEEE Xplore, potentially underrepresenting purely methodological innovations in pulse sequence design that have not yet translated to clinical journals. In addition, citation counts reflect academic impact rather than clinical adoption and may be influenced by factors unrelated to scientific quality. Also the minimum keyword occurrence threshold of 20 applied in VOSviewer, while reducing noise, may have excluded emerging topics such as ultra-high-field (7T) mapping or novel pulse sequences from the co-occurrence network. Future research is likely to increasingly emphasize large-scale, multicenter outcome studies and standardized analytic frameworks to further define the prognostic and clinical utility of myocardial T1 and T2 mapping.

Conclusion

The bibliometric patterns observed in this study indicate that myocardial T1 and T2 mapping represents a young but rapidly maturing research field. The research community has expanded markedly in parallel with technical and clinical breakthroughs, resulting in a literature base that is both globally distributed and multidisciplinary in scope. The predominance of cardiovascular imaging journals in disseminating myocardial mapping research, alongside substantial contributions from radiology-focused journals, reflects a productive cross-pollination between technical MRI development and clinical cardiology applications. Furthermore, emerging directions in the wider literature, such as AI-driven analysis and radiomics, together with the growing body of outcome-oriented studies, indicate that the field is progressing beyond technical validation toward more integrated and clinically impactful applications. Overall, the bibliometric evolution and thematic shifts identified in this analysis highlight a dynamic interplay between innovation and clinical demand, suggesting that future

myocardial T1 and T2 mapping research will increasingly emphasize computational integration, large-scale outcome studies, and translational relevance, while continuing to focus on the fundamental pathophysiologic markers of fibrosis and edema that underpin the clinical value of these techniques.

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Data availability statement: The bibliographic data used in this study were obtained from the Web of Science Core Collection database. Processed data supporting the findings of this study are available from the corresponding author upon reasonable request.
Ethics statement: This study is a bibliometric analysis based entirely on publicly available published data retrieved from the Web of Science Core Collection. No human participants, patient data, or biological specimens were involved. Therefore, ethics committee approval and informed consent were not required.
Author contributions (CRediT): HA: Conceptualization; Methodology; Data curation; Formal analysis; Visualization; Writing – original draft; Writing – review & editing; Supervision. BE: Data curation; Formal analysis; Writing – review & editing. AA: Data curation; Investigation; Writing – review & editing. YCK: Data curation; Visualization; Writing – review & editing. SO: Methodology; Validation; Writing – review & editing. SME: Supervision; Conceptualization; Writing – review & editing.
Use of AI tools: AI tools were used solely to correct grammar in the manuscript. The authors reviewed all corrections and take full responsibility for the content of the manuscript.

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