

Global Landscape and Temporal Evolution of Left Atrial Appendage Occlusion and Closure Research in Atrial Fibrillation (2006–2026): A 20-Year Bibliometric Analysis

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Abstract

This study aimed to map publication trends, leading contributors, international collaboration patterns, and evolving research themes in left atrial appendage occlusion (LAAO), also referred to as left atrial appendage closure (LAAC), for patients with atrial fibrillation between 2006 and the 2026 literature search period. A bibliometric analysis was conducted using publications indexed in PubMed. An initial 3,684 records were identified and subsequently screened using predefined filters for publication date, language, document type, and preprint status, resulting in a final dataset of 833 publications from 230 publication sources. Bibliometrix, through its Biblioshiny interface, and VOSviewer were employed to analyze bibliometric indicators, research productivity, collaboration networks, and thematic developments. The final dataset comprised 833 publications involving 4,212 unique authors, with a reported annual publication growth rate of 21.42%. Research output and collaboration networks were predominantly concentrated in North America, Europe, and selected Asian countries. Thematic mapping indicated a shift from early investigations of procedural feasibility and safety toward imaging-guided interventions, device optimization, and postprocedural antithrombotic management. Publication data for 2026 represented the records available at the time of the literature search rather than a complete calendar-year assessment. The findings demonstrated substantial growth and increasing thematic diversity in LAAO/LAAC research over the study period. However, because the analysis was restricted to PubMed-indexed publications meeting specific eligibility criteria, the results reflected the characteristics of the selected bibliographic dataset rather than the entire global research landscape. Furthermore, bibliometric indicators and thematic networks did not establish the clinical effectiveness, comparative safety, or methodological quality of individual interventions or studies.

INTRODUCTION

Atrial fibrillation (AF) is the most common sustained cardiac arrhythmia worldwide and contributes substantially to cardiovascular morbidity, hospitalization, and mortality (Kornej et al., 2020). One of its most serious complications is thromboembolic stroke, with AF associated with an approximately fivefold increase in stroke risk compared with individuals without AF (Kornej et al., 2020). From a pathophysiological perspective, more than 90% of left atrial thrombi identified in patients with nonvalvular AF originate in the left atrial appendage (LAA),

primarily because of its complex trabeculated anatomy, impaired mechanical contraction, blood stasis, and associated prothrombotic conditions (Blackshear & Odell, 1996).

For decades, oral anticoagulation (OAC), initially involving vitamin K antagonists (VKAs) such as warfarin and subsequently direct oral anticoagulants (DOACs), has remained the cornerstone of stroke prevention in patients with AF who are at elevated thromboembolic risk (Connolly et al., 2009; Ruff et al., 2014). Compared with warfarin, DOACs have demonstrated at least comparable efficacy in preventing stroke and systemic embolism, with a generally more favorable safety profile, particularly regarding intracranial hemorrhage (Ruff et al., 2014). Nevertheless, long-term anticoagulation remains challenging for certain patient populations. Treatment discontinuation or underutilization may occur because of major bleeding events, concerns regarding bleeding risk, severe renal impairment, medication-related barriers, or absolute contraindications to anticoagulant therapy (Ruff et al., 2014). These limitations have highlighted the need for alternative stroke prevention strategies in appropriately selected patients (Gladstone et al., 2022).

To address the limitations of long-term systemic anticoagulation, percutaneous left atrial appendage occlusion (LAAO), also referred to as left atrial appendage closure (LAAC), has emerged as a nonpharmacological strategy for reducing thromboembolic risk in selected patients with AF (Holmes et al., 2009). Evidence from clinical trials and recommendations from international professional societies has supported its use in specific clinical circumstances, particularly when long-term oral anticoagulation is contraindicated or presents substantial bleeding concerns (Hindricks et al., 2021; Holmes et al., 2009; Joglar et al., 2024). Over the past two decades, LAAO/LAAC research has expanded alongside advances in occlusion device technology, procedural techniques, and multimodality cardiovascular imaging, including three-dimensional transesophageal echocardiography and cardiac computed tomography. Increasing attention to device-related complications, postprocedural antithrombotic therapy, patient selection, and long-term clinical outcomes has further contributed to the diversification of scientific research in this field.

Despite the expansion of clinical and procedural research on LAAO/LAAC, the bibliometric structure, collaborative networks, and evolution of research themes have received comparatively limited integrated examination. Understanding these developments is important for identifying influential contributors, patterns of scientific collaboration, and emerging areas of investigation. Accordingly, this study aimed to map publication trends, source productivity, authorship and collaboration networks, and thematic developments within a defined corpus of PubMed-indexed publications from 2006 through the 2026 literature extraction date. By combining descriptive bibliometric indicators with keyword co-occurrence and thematic network analyses, the study sought to characterize the evolution of LAAO/LAAC research and identify prominent areas of scientific interest. However, the findings were interpreted within the limitations of PubMed coverage, the applied eligibility filters, and incomplete indexing for 2026, rather than as a comprehensive representation of all global publications or a direct assessment of clinical effectiveness.

METHOD

Study design. This study used quantitative bibliometric methods to describe the publication landscape concerning left atrial appendage occlusion and closure in atrial

fibrillation in the PubMed-indexed corpus from 2006–2026. The unit of analysis was the indexed document, not a patient or intervention outcome. Publication counts and co-occurrence maps cannot determine clinical effectiveness or establish causal explanations for changes in research activity.

Data source and search strategy. Records were obtained from PubMed (NCBI) using the MeSH/free-text strategy and database filters described below. The original query was: ((“left atrial appendage occlusion”[Title/Abstract] OR “left atrial appendage closure”[Title/Abstract] OR “left atrial appendage sealing”[Title/Abstract] OR “left atrial appendage exclusion”[Title/Abstract] OR “left atrial appendage ligation”[Title/Abstract] OR “left atrial appendage obliteration”[Title/Abstract] OR “LAAO”[Title/Abstract] OR “LAAC”[Title/Abstract]) AND (“Atrial Fibrillation”[MeSH Terms] OR “Atrial Fibrillation”[Title/Abstract])) AND (excludepreprints[Filter] AND (booksdocs[Filter] OR clinicaltrial[Filter] OR meta-analysis[Filter] OR randomizedcontrolledtrial[Filter] OR review[Filter] OR systematicreview[Filter]) AND 2861clude[Filter] AND (2006:2026[pdat])). The precise search execution date is not reported in the manuscript; thus, 2026 publication totals should be read as provisional.

Eligibility criteria and document selection. The reported PubMed search returned 3,684 records before application of the predefined publication-date, language, document-type, and preprint filters. The filtered corpus comprised 833 records. Eligible records were English-language documents indexed from 2006 through the search-period portion of 2026, within the specified PubMed publication types. Document selection was database-filter based; the authors did not report full-text clinical eligibility assessment or screening adjudication. These choices limit interpretation of the resulting publication distribution.

Bibliometric indicators and data analysis The bibliometric indicators analyzed in this study included: (1) Main dataset characteristics and document distribution ; (2) Annual scientific production and publication output growth trends ; (3) Most relevant sources (journals) and publication venues ; (4) Author productivity and top contributing academic affiliations ; (5) Country-level scientific output, including Single Country Publications (SCP) and Multiple Country Publications (MCP) ; (6) International collaboration patterns and geographical co-authorship networks ; and (7) Author keyword frequencies, temporal trend topics, and conceptual thematic structures (Basic, Emerging, and Motor themes). All bibliometric extractions, quantitative computations, and visual network mappings were executed using the Bibliometrix R package and its web-based interface, Biblioshiny, within the Rstudio environment. In addition, network visualizations—specifically bibliometric mapping were constructed and analyzed using VOSviewer software (version 1.6.20, Center for Science and Technology Studies, Leiden University, Leiden, The Netherlands)

RESULTS AND DISCUSSION

General Bibliometric Characteristics

A total of 833 PubMed-indexed documents published between 2006 and 2026 across 230 academic sources were included in the bibliometric analysis (Fig. 1). The dataset encompasses 4,212 unique authors, with 25 authors contributing to 29 single-authored documents. The co-authorship density was calculated at an average of 7.55 co-authors per document, with an international co-authorship rate of 26.41%. The field demonstrated an annual publication

growth rate of 21.42%, with a mean document age of 5.47 years. Content indexing yielded 1,182 author keywords (DE) and 1,182 Keywords Plus (ID), illustrating a rich diversity of clinical and technical descriptors surrounding left atrial appendage occlusion (LAAO) and closure (LAAC).



Figure 1. General bibliometric characteristics of publications related to left atrial appendage occlusion and closure in atrial fibrillation from 2006 to 2026. The figure summarises the main dataset indicators, including publication output, sources, authorship, collaboration patterns, references, and citation metrics

Source: Authors' PubMed bibliometric analysis using Biblioshiny/VOSviewer (2026).

Publication Development Trend

Within the selected dataset, the reported publication series rises from 2 articles in 2006 to 97 records indexed for 2026 at the time of extraction, with a reported annual growth indicator of 21.42%. This pattern is descriptive of the defined PubMed search and its document-type filters. As the extraction date is unspecified and 2026 may be incomplete, the 2026 value should not be described as a finalized full-year publication peak. The apparent growth may also reflect changes in indexing, coverage, document-type eligibility, and scholarly attention, not clinical adoption alone.

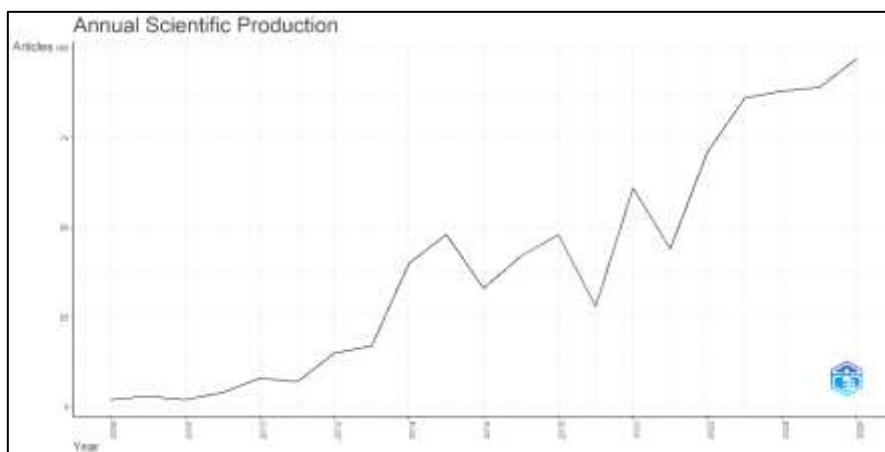


Figure 2. Annual publication trends of studies related to left atrial appendage occlusion and closure in atrial fibrillation from 2006 to 2026. Publication output increased markedly after 2012 and reached its peak in 2026.

Source: Authors' PubMed bibliometric analysis using Biblioshiny/VOSviewer (2026).

Most Relevant Sources And Leading Authors/Affiliations

The publications were distributed across 230 specialized journals, predominantly within interventional cardiology, electrophysiology, and general cardiovascular medicine. Table 1 details the top 10 most relevant publishing venues. Interventional Cardiology Clinics contributed the highest document volume ($n = 31$), followed closely by Cardiac

Electrophysiology Clinics (n = 27), Heart Rhythm (n = 27), Journal of Clinical Medicine (n = 23), and Journal of the American College of Cardiology (n = 22).

Table 1. Top 10 Most Relevant Sources in LAAO/LAAC Research

Source / Journal Title	Articles (n)
Interventional Cardiology Clinics	31
Cardiac Electrophysiology Clinics	27
Heart Rhythm	27
Journal Of Clinical Medicine	23
Journal Of The American College Of Cardiology	22
Journal Of Atrial Fibrillation	19
Journal Of Cardiovascular Electrophysiology	19
Reviews In Cardiovascular Medicine	17
Europace	16
Journal Of Interventional Cardiac Electrophysiology	16

Source: Authors' bibliometric analysis of the PubMed dataset (2026).

In terms of author productivity, Dhanunjaya Lakkireddy emerged as the most prolific investigator with 37 publications (fractionalized frequency of 4.28), followed by Jens Erik Nielsen-Kudsk (n = 31; fractionalized: 3.86), Vivek Yerrapu Reddy (n = 31; fractionalized: 4.49), Jacqueline Saw (n = 27; fractionalized: 4.29), and David R. Holmes (n = 24; fractionalized: 6.69).

Institutional output was led by premier academic medical centers and international research consortia. The Mayo Clinic ranked first with 107 published articles, followed by McMaster University (n = 88), National and Kapodistrian University of Athens (n = 62), Thessaloniki Consortium/University (n = 58), University of Foggia (n = 55), Harvard Medical School (n = 52), and Imperial College London (n = 51).

Country-Level Scientific Production And International Collaboration

An analysis of global scientific output revealed that LAAO research is spearheaded by major medical research hubs across North America, Asia, and Europe. Considering overall institutional and co-author occurrences, the United States produced the highest cumulative frequency (n = 1,200), followed by China (n = 536), Italy (n = 502), Germany (n = 300), Canada (n = 230), Spain (n = 184), and Greece (n = 167).

When categorized by the corresponding author's country of affiliation (Table 2), the United States maintained the lead with 201 primary articles (24.1% of global output), comprising 154 Single Country Publications (SCP) and 47 Multiple Country Publications (MCP), yielding an MCP ratio of 23.4%. China ranked second with 61 articles (7.3% of global output; MCP ratio: 9.8%). Notably, European nations demonstrated exceptionally high proportions of international collaboration, including Denmark (MCP ratio: 53.8%), Germany (MCP ratio: 45.5%), Switzerland (MCP ratio: 43.5%), Italy (MCP ratio: 42.1%), and Canada (MCP ratio: 40.0%).

Table 2. Top 10 Contributing Countries by Corresponding Author Affiliation

Country	Articles (n)	Share (%)	SCP	MCP	MCP ratio (%)
USA	201	24.1	15 4	47	23.4
CHINA	61	7.3	55	6	9.8
ITALY	38	4.6	22	16	42.1
CANADA	35	4.2	21	14	40
GERMANY	33	4	18	15	45.5
SWITZERLAN	23	2.8	13	10	43.5
GREECE	18	2.2	12	6	33.3
SPAIN	16	1.9	10	6	37.5
AUSTRALIA	15	1.8	12	3	20
DENMARK	13	1.6	6	7	53.8

Source: Authors' bibliometric analysis of the PubMed dataset (2026).

SCP: Single Country Publication; MCP: Multiple Country Publication.

Bilateral co-authorship analysis highlighted the transatlantic research axis as the predominant vector of international synergy (Fig 3). The strongest bilateral collaboration links were observed between the USA and Germany (n = 26 joint publications), USA and Italy (n = 23), USA and Canada (n = 22), Italy and Belgium (n = 20), Italy and Germany (n = 20), USA and Denmark (n = 19), and Germany and Denmark (n = 18).

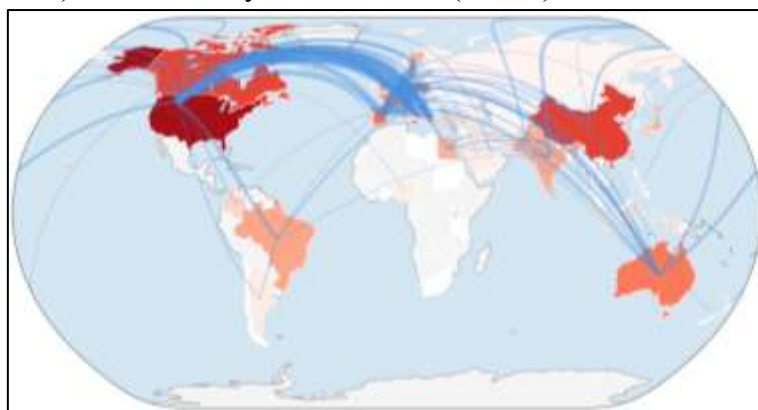


Figure 3. Countries' Collaboration World Map related to left atrial appendage occlusion and closure in atrial fibrillation from 2006 to 2026

Source: Authors' PubMed bibliometric analysis using Biblioshiny/VOSviewer (2026).

Keyword Frequencies, Trend Topics, And Thematic Structure

Medical Subject Headings (MeSH) and author keyword frequencies reflected the core clinical indications, imaging modalities, and technological devices defining LAOA practice. The most frequent index terms included atrial appendage/surgery (n = 239), anticoagulants/therapeutic use (n = 125), stroke/etiology/prevention & control (n = 119), septal

2865clude device (n = 89), atrial appendage/diagnostic imaging/surgery (n = 83), atrial
fibrillation/complications/surgery (n = 74), aged 80 and over (n = 65), and echocardiography,
transesophageal (n = 64) (Fig 4 and 5).

Temporal trend analysis revealed a progressive evolution in thematic emphasis over time:

Early Phase (2015–2018): Focused primarily on stroke etiology, early septal 2865clude device implantation, and initial risk assessments.

Intermediate Phase (2019–2022): Concentrated on comparative therapeutic use of oral anticoagulants, surgical appendage closure, and peri-procedural transesophageal echocardiography (TEE).

Emerging / Recent Phase (2023–2026): Shifted heavily toward specialized diagnostic imaging protocols, advanced stroke prevention strategies in high-risk elderly populations (age 80 years), and long-term time factor evaluations.



Figure 4. Word Cloud in Keyword Frequency related to left atrial appendage occlusion and closure in atrial fibrillation from 2006 to 2026

Source: Authors' PubMed bibliometric analysis using Biblioshiny/VOSviewer (2026).

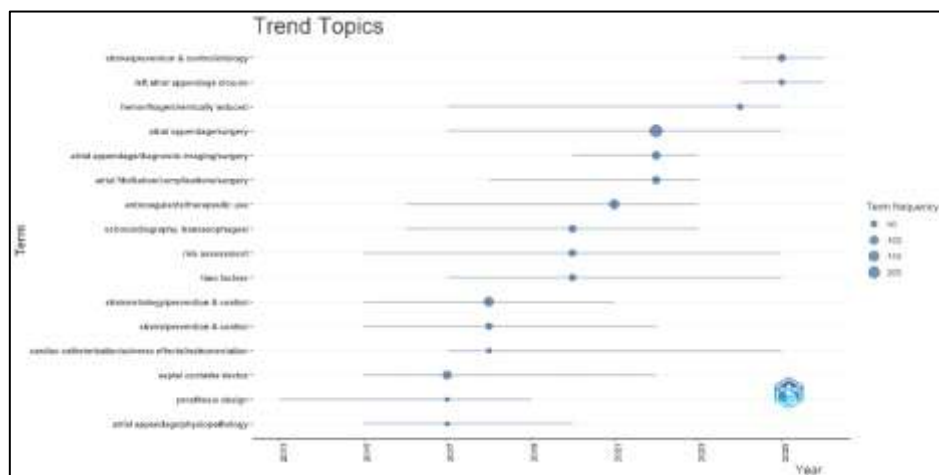


Figure 5. Trend Topics related to left atrial appendage occlusion and closure in atrial fibrillation from 2006 to 2026

Source: Authors' PubMed bibliometric analysis using Biblioshiny/VOSviewer (2026).

Thematic map matrix mapping (Figure 6) categorized the scientific domain into four distinct operational quadrants:

Basic Themes: Representing foundational core concepts in the field, including atrial appendage/surgery, anticoagulants/therapeutic use, and stroke/etiology/prevention and control.

Emerging or Declining Themes: Highlighting rapidly evolving procedural and diagnostic advances, notably atrial appendage/diagnostic imaging/surgery, echocardiography, transesophageal, and cardiac catheterization/methods.

Motor Themes: Driving forward-looking clinical management and safety evaluations, comprising risk assessment, time factors, and hemorrhage/chemically induced complications.

Niche Themes: Atrial fibrillation/surgery, prospective studies, catheter ablation/methods

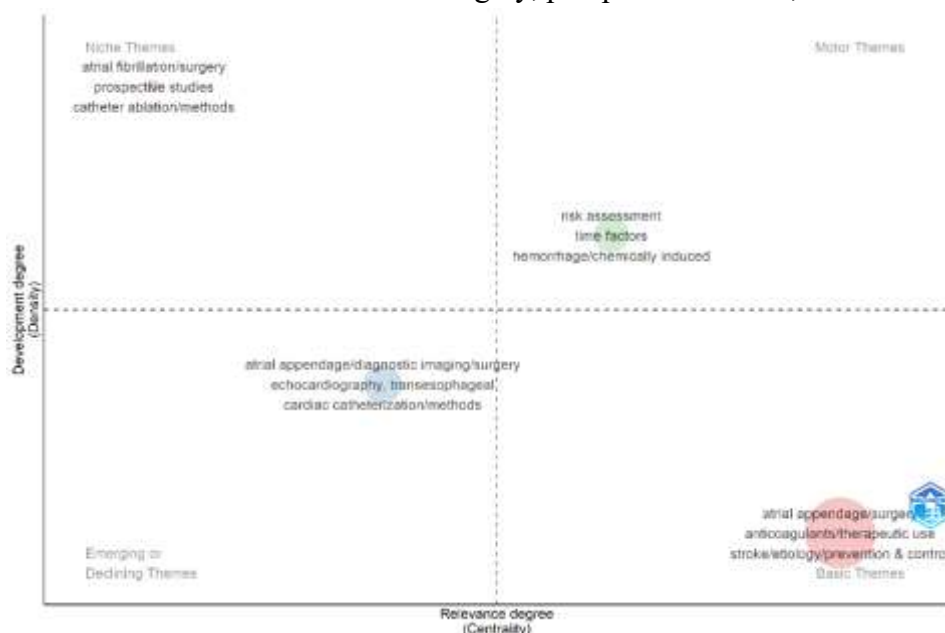


Figure 6. Thematic Map related to left atrial appendage occlusion and closure in atrial fibrillation from 2006 to 2026

Source: Authors' PubMed bibliometric analysis using Biblioshiny/VOSviewer (2026).

To further elucidate the intellectual domain and conceptual connections, a keyword co-occurrence network was constructed (Fig. 7). The visualization reveals major interconnected clusters representing foundational clinical indications.

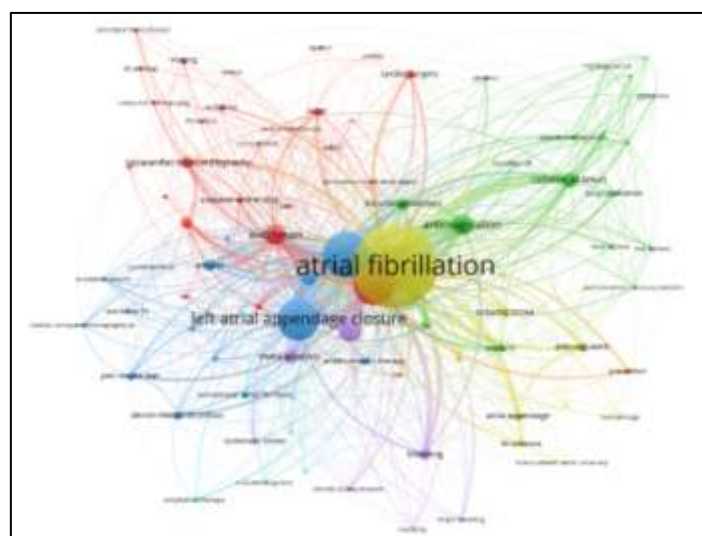


Figure 7. Keyword co-occurrence network related to left atrial appendage occlusion and closure in atrial fibrillation from 2006 to 2026 generated using VOSviewer software. Node size represents keyword frequency, while line thickness indicates the strength of co-occurrence between keywords. Different colours indicate thematic keyword clusters.

Source: Authors' PubMed bibliometric analysis using Biblioshiny/VOSviewer (2026).

Search Scope And Dataset Characteristics

This bibliometric analysis evaluated PubMed-indexed literature addressing left atrial appendage occlusion (LAAO) and closure (LAAC) in non-valvular atrial fibrillation (AF) over a 20-year span (2006–2026). The filtering strategy yielded a core corpus of 833 scientific documents across 230 peer-reviewed journals. The active involvement of 4,212 unique authors, a high co-authorship density (7.55 co-authors per document), and an international co-authorship rate of 26.41% reflect the multi-center collaborative nature characteristic of modern interventional cardiology research. The substantial annual publication growth rate of 21.42% and a mean document age of 5.47 years confirm that LAAO has rapidly transformed from an experimental procedure into an essential non-pharmacological strategy for stroke prevention (Donthu et al., 2021).

Publication development trend and technological evolution

The annual publication output from 2006 to 2026 exhibits a multi-phase growth trajectory closely aligned with landmark clinical trials, regulatory approvals, and technological iterations in mechanical appendage exclusion:

Foundational & Early Clinical Phase (2006–2012): Scientific production remained low (2–15 articles/year), reflecting initial feasibility assessments, early device designs, and preliminary safety studies in patients ineligible for oral anticoagulation.

Acceleration & Landmark RCT Era (2013–2020): Publication volume expanded markedly, reaching 48 articles in 2015 and 61 in 2020. This surge was anchored by the publication and long-term follow-up of randomized controlled trials (RCTs). The PROTECT AF trial (Holmes et al., 2009) and PREVAIL trial (Holmes et al., 2014) demonstrated that Watchman LAA closure was non-inferior to chronic warfarin for ischemic stroke prevention, while with reported differences in selected hemorrhagic and mortality outcomes (Reddy et al., 2017). The U.S. FDA approval of the Watchman device in March 2015 served as a primary catalyst, driving widespread clinical adoption, national registry tracking, and real-world safety evaluations such as the EWOLUTION registry (Boersma et al., 2017).

Surge & NOAC Comparison Era (2021–2026): Research momentum accelerated dramatically, rising from 71 publications in 2022 to 86 in 2023, 88 in 2024, 89 in 2025, and peaking at 97 publications in 2026. This exponential expansion reflects several breakthrough developments:

Comparison Against Direct Oral Anticoagulants (DOACs): The landmark PRAGUE-17 trial (Osmancik et al., 2020, 2022) established that LAAO was non-inferior to DOACs in high-risk AF patients for major cardiovascular and bleeding events, validating LAAO in the modern pharmacotherapy era.

Surgical and Multimodal Interventions: The randomized LAAOS III trial (Whitlock et al., 2021) demonstrated that concomitant surgical LAA occlusion during cardiac surgery significantly reduced stroke risk on top of standard anticoagulation.

Next-Generation Occluders: Introduction of advanced closure systems—such as the Watchman FLX (evaluated in PINNACLE FLX) (Kar et al., 2021) and the Amplatzer Amulet (evaluated in the Amulet IDE trial (Lakkireddy et al., 2021) and SWISS-APERO trial (Galea et al., 2022))—offered superior sealing, lower device-related thrombosis (DRT) (Dukkipati et al., 2018), and lower peri-device leak (PDL) rates.

Conceptual Thematic Structure And Trend Topics

The evolution of author keywords and MeSH indexing reflects key clinical priorities in the field:

Basic Themes: Terms such as atrial appendage/surgery, anticoagulants/therapeutic use, and stroke prevention highlight the foundational objective of substituting long-term systemic anticoagulation with a localized mechanical barrier (Blackshear & Odell, 1996; Connolly et al., 2009; Ruff et al., 2014).

Emerging Themes & Procedural Imaging: High-density keywords including echocardiography, transesophageal, diagnostic imaging, and cardiac catheterization/methods emphasize the vital role of intra-procedural 3D TEE and pre-procedural cardiac CT in optimizing device sizing, minimizing residual peri-device leaks, and preventing peri-procedural complications.

Motor Themes & Complication Management: Recent topics (2023–2026) focus heavily on risk assessment, time factors, and the mitigation of post-procedural complications, such as device-related thrombosis (Dukkipati et al., 2018) and post-implantation antithrombotic optimization (Della Rocca et al., 2021). Furthermore, expanding indications in vulnerable subgroups, such as octogenarians (aged >80 years), reflect a movement toward personalized interventional electrophysiology.

Academic Leadership And Global Collaboration Dynamics

The geographical concentration of publications highlights North America and Europe as the primary drivers of LAAO innovation. The United States produced the largest overall volume (201 primary articles; 24.1%), supported by large-scale procedural registries such as the NCDR LAAO Registry (Freeman et al., 2020). China ranked second (61 articles; 7.3%), reflecting rapid adoption across Asia. Notably, European nations exhibited the highest Multiple Country Publication (MCP) collaboration ratios—including Denmark (53.8%), Germany (45.5%), and Switzerland (43.5%). Dense bilateral collaboration axes (e.g., USA–Germany with 26 joint publications; USA–Italy with 23) underscore international consortia that continue to drive device surveillance and societal guideline consensus (Glikson et al., 2020; Hindricks et al., 2021; Joglar et al., 2024).

Clinical Implications And Future Research Directions

The bibliometric findings carry direct clinical relevance for cardiovascular practice. Societal guidelines, including the 2020 ESC AF Guidelines (Hindricks et al., 2021) and the 2023 ACC/AHA/ACCP/HRS AF Guidelines (Joglar et al., 2024), assign a Class Iib recommendation for percutaneous LAAO in non-valvular AF patients with long-term contraindications to oral anticoagulants (Reddy et al., 2013). As device safety profiles improve, ongoing randomized trials are evaluating LAAO as a first-line alternative to DOACs or in combination with catheter ablation. Key priorities for future research include establishing standardized post-implantation antithrombotic regimens (Della Rocca et al., 2021), refining CT-based pre-procedural planning, and managing long-term residual peri-device leaks.

Limitations

Several limitations inherent to bibliometric methodology should be acknowledged. First, data retrieval was restricted to the PubMed database, which may omit relevant studies indexed exclusively in Scopus, Web of Science, or non-English journals. Second, citation counts were not analyzed on an individual article level due to database extraction parameters. Third, while bibliometric metrics reflect publication volume and academic interest, they do not directly evaluate the methodological quality or risk of bias of individual clinical trials (Donthu et al., 2021).

CONCLUSION

This bibliometric analysis of 833 PubMed-indexed publications demonstrated substantial growth in research on left atrial appendage occlusion (LAAO) and left atrial appendage closure (LAAC), accompanied by increasing thematic emphasis on imaging-guided interventions, procedural advancements, device optimization, and postprocedural management. The findings also revealed a concentration of scientific output among leading countries, research institutions, and clinical journals, alongside established patterns of international research collaboration. The study's principal contribution was a structured bibliometric overview of publication trends, collaborative networks, and evolving research themes within the selected PubMed corpus from 2006 through the 2026 literature search period. However, publication counts for 2026 remained provisional, and the findings were limited to records meeting the predefined database filters and eligibility criteria rather than representing the entire global research landscape. Although these bibliometric indicators provided insights into scientific productivity and emerging research priorities, they did not establish the comparative clinical effectiveness, procedural safety, or superiority of LAAO/LAAC interventions. Future research should integrate broader bibliographic databases, longitudinal bibliometric assessments, and systematic evaluations of clinical evidence to provide a more comprehensive understanding of research developments and their implications for patient care.

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CONFLICT OF INTEREST

The author states that there is no conflict of interest in the preparation of this article.

AUTHOR CONTRIBUTIONS

All authors contributed to conceptualization, search and synthesis of literature, interpretation of results, manuscript preparation, and critical review of manuscripts. All authors have read and approved the final version of the manuscript.

GENERATIVE AI STATEMENT

The authors declare that Generative Artificial Intelligence (Generative AI) was used solely to assist with language refinement, grammatical correction, and improvement of manuscript readability. All scientific concepts, interpretations, literature synthesis, analyses, and conclusions were developed by the authors. All AI-assisted content was carefully reviewed, verified, and revised by the authors, who take full responsibility for the accuracy, integrity, and final content of the manuscript.

REFERENCE

- Blackshear, J. L., & Odell, J. A. (1996). Appendage obliteration to reduce stroke in cardiac surgical patients with atrial fibrillation. *The Annals of Thoracic Surgery*, 61(2), 755–759.
- Boersma, L. V., Ince, H., Kische, S., et al. (2017). Efficacy and safety of left atrial appendage closure with WATCHMAN in patients with or without contraindication to oral anticoagulation: 1-year follow-up outcome data of the EWOLUTION trial. *Heart Rhythm*. <https://doi.org/10.1016/j.hrthm.2017.05.038>
- Connolly, S. J., Ezekowitz, M. D., Yusuf, S., et al. (2009). Dabigatran versus warfarin in patients with atrial fibrillation. *New England Journal of Medicine*, 361(12), 1139–1151.
- Della Rocca, D. G., Magnocavallo, M., Di Biase, L., et al. (2021). Half-dose direct oral anticoagulation versus standard antithrombotic therapy after left atrial appendage occlusion. *JACC: Cardiovascular Interventions*, 14, 2353–2364. <https://doi.org/10.1016/j.jcin.2021.07.031>
- Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, 133, 285–296.
- Dukkipati, S. R., Kar, S., Holmes, D. R., et al. (2018). Device-related thrombus after left atrial appendage closure: Incidence, predictors, and outcomes. *Circulation*. <https://doi.org/10.1161/CIRCULATIONAHA.118.035090>
- Freeman, J. V., Higgins, A. Y., Wang, Y., et al. (2020). Trends in practice patterns and outcomes of percutaneous left atrial appendage occlusion with the WATCHMAN device in the United States. *Journal of the American College of Cardiology*, 75(13), 1503–1518.
- Galea, R., De Marco, F., Meneveau, N., et al. (2022). Amulet or Watchman device for percutaneous left atrial appendage closure: Primary results of the SWISS-APERO randomized clinical trial. *Circulation*, 145(10), 724–738. <https://doi.org/10.1161/CIRCULATIONAHA.121.057859>
- Gladstone, D. J., Lindsay, M. P., Douketis, J., Smith, E. E., Dowlatshahi, D., Wein, T., Bourgoin, A., Cox, J., Falconer, J. B., & Graham, B. R. (2022). Canadian stroke best practice recommendations: secondary prevention of stroke update 2020. *Canadian Journal of Neurological Sciences*, 49(3), 315–337.
- Glikson, M., Wolff, R., Hindricks, G., et al. (2020). EHRA/EAPCI expert consensus statement on catheter-based left atrial appendage occlusion – An update. *Europace*, 22(2), 184.
- Hindricks, G., Potpara, T., Dagres, N., et al. (2021). 2020 ESC guidelines for the diagnosis and management of atrial fibrillation. *European Heart Journal*, 42(5), 373–498.
- Holmes, D. R., Reddy, V. Y., Turi, Z. G., et al. (2009). Percutaneous closure of the left atrial appendage versus warfarin therapy for prevention of stroke in patients with atrial fibrillation: A randomised non-inferiority trial. *The Lancet*, 374(9689), 534–542.
- Holmes, D. R., Jr., Kar, S., Price, M. J., et al. (2014). Prospective randomized evaluation of the Watchman left atrial appendage closure device in patients with atrial fibrillation versus long-term warfarin therapy: The PREVAIL trial. *Journal of the American College of Cardiology*, 64(1), 1–12.
- Joglar, J. A., Chung, M. K., Armbruster, A. L., et al. (2024). 2023 ACC/AHA/ACCP/HRS guideline for the diagnosis and management of atrial fibrillation. *Circulation*, 149(1), e1–e156.

- Kar, S., Doshi, S. K., Sadhu, A., et al. (2021). Primary outcome evaluation of a next-generation left atrial appendage closure device: Results from the PINNACLE FLX trial. *Circulation*, 143(18). <https://doi.org/10.1161/CIRCULATIONAHA.120.050117>
- Kornej, J., Börschel, C. S., Benjamin, E. J., & Schnabel, R. B. (2020). Epidemiology of atrial fibrillation in the 21st century. *Circulation Research*, 127(1), 4–20.
- Lakkireddy, D., Thaler, D., Ellis, C. R., et al. (2021). Amplatzer Amulet left atrial appendage occluder versus Watchman device for stroke prophylaxis (Amulet IDE): A randomized, controlled trial. *Circulation*, 144(19), 1543–1552.
- Osmancik, P., Herman, D., Neuzil, P., et al. (2020). Left atrial appendage closure versus direct oral anticoagulants in high-risk patients with atrial fibrillation. *Journal of the American College of Cardiology*, 75(25), 3122–3135.
- Osmancik, P., Herman, D., Neuzil, P., et al. (2022). 4-year outcomes after left atrial appendage closure versus nonwarfarin oral anticoagulation for atrial fibrillation. *Journal of the American College of Cardiology*, 79(1), 1–14.
- Reddy, V. Y., Doshi, S. K., Kar, S., et al. (2017). 5-year outcomes after left atrial appendage closure: From the PREVAIL and PROTECT AF trials. *Journal of the American College of Cardiology*, 70(24), 2964–2975.
- Reddy, V. Y., Möbius-Winkler, S., Miller, M. A., et al. (2013). Left atrial appendage closure with the Watchman device in patients with a contraindication for oral anticoagulation: The ASAP study (ASA Plavix Feasibility Study With Watchman Left Atrial Appendage Closure Technology). *Journal of the American College of Cardiology*, 61(25), 2551–2556.
- Ruff, C. T., Giugliano, R. P., Braunwald, E., et al. (2014). Comparison of the efficacy and safety of new oral anticoagulants with warfarin in patients with atrial fibrillation: A meta-analysis of randomised trials. *The Lancet*, 383(9921), 955–962.
- Whitlock, R. P., Belley-Cote, E. P., Paparella, D., et al. (2021). Left atrial appendage occlusion during cardiac surgery to prevent stroke. *New England Journal of Medicine*, 384(22), 2081–2091.