

## Global Research Trends of Cryoablation for Atrial Fibrillation from 2002 to 2022: A Bibliometric Analysis

### ABSTRACT

**Background:** Atrial fibrillation is a common arrhythmia. Cryoablation is a treatment for atrial fibrillation, which has achieved remarkable results. But there are still many problems worthy of improvement and discussion. We aim to evaluate the scientific outputs of global cryoablation of atrial fibrillation research, providing new ideas and directions for further research.

**Methods:** The data were retrieved from the Web of Science Core Collection on July 28, 2022. Bibliometrics tools—CiteSpace V, Microsoft Excel 2019, and the Online Analysis Platform of Literature Metrology—were used for bibliometric analysis of the published outputs.

**Results:** A total of 1676 research articles were obtained from the Web of Science Core Collection published between 2002 and 2022, and the number of annual publications has gradually increased, with a slight decline in 2006-2008, 2011-2012, and 2021, reaching a peak in 2020. The institution with the highest number of research publications in this field was Asklepios Klin St. Georg, followed by Vrije Univ Brussel. The most productive researchers were Carlo De Asmundis, Gianbattista Chierchia, Pedro Brugada, Karlheinz Kuck, and Andreas Metzner. The most prolific journal has been the US publication *Journal of Cardiovascular Electrophysiology*, and *Europace* from England ranked second. The article "Cryoballoon or Radiofrequency Ablation for Paroxysmal Atrial Fibrillation" ranked first among all cited articles. Burst detection analysis of top keywords suggested that follow-up, task force, trial, phrenic nerve injury, and radiofrequency ablation were research hotspots.

**Conclusion:** This study provides a comprehensive overview of cryoablation in atrial fibrillation research using bibliometric and visual methods, which will help researchers better understand the development status and trends in this field.

**Keywords:** Atrial fibrillation, cryoablation, bibliometric analysis

### INTRODUCTION

Atrial fibrillation (AF) is one of the most common arrhythmias in clinical practice. Due to changes in the population structure, aging, and other facts, its prevalence is increasing year by year.<sup>1</sup> It is because of these trends in AF that more and more experts and scholars describe AF as a global epidemic.<sup>2</sup> Thromboembolism prevention and heart rate or rhythm control are the main therapeutic strategies for AF.<sup>3</sup> Drug therapy is currently the main method and cornerstone for the treatment of AF. However, drug therapy is incurable and prone to recurrence. There is increasing evidence that catheter ablation is superior to antiarrhythmic drug therapy,<sup>4,5</sup> and catheter ablation for rhythm control is also recommended in specific patient populations, especially for those drug-refractory, highly symptomatic patients.<sup>6</sup> Currently, the 2 most common ablation technologies for AF include radiofrequency ablation and cryoablation. Cryoablation is an alternative energy source that uses liquid nitrous oxide, delivered in a balloon under pressure to freeze the surrounding tissue.<sup>7</sup> Over 100 000 cryoballoon ablation procedures have been performed with first- to fourth-generation cryoballoons in the past years,<sup>8</sup> and more are being performed now. Cryoballoon ablation for AF has become an effective method to

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Received: May 16, 2023

Accepted: July 4, 2023

Available Online Date: September 26, 2023

**Cite this article as:** Yang H, Xiang J, Shen J, Zhang L, Tang B. Global research trends of cryoablation for atrial fibrillation from 2002 to 2022: A bibliometric analysis. *Anatol J Cardiol*. 2023;27(12):688-696.

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achieve pulmonary vein isolation. Simultaneously, our understanding of optimal procedural techniques for cryoablation in AF has advanced significantly over the past few decades.

Bibliometrics is a method for exploring the library and information sciences and analyzing the academic influence and characteristics of scientific output through the comprehensive analysis of bibliographic data based on quantitative measurements and statistics.<sup>9,10</sup> Bibliometrics has been widely used in information science, chemistry, and physics, with new potential in medicine.<sup>11</sup> It helps us to analyze and visualize the disorganized literature data through quantitative analysis and visualization to explore the relationship between countries, institutions, and authors.<sup>12</sup> In addition to, it can also quickly grasp the hot spots and development trends in our fields.<sup>13</sup> Over the years, bibliometrics has also been applied in cardiovascular diseases<sup>14–16</sup> and involved in AF,<sup>17</sup> but there is no report on the cryoablation of AF. Therefore, since cryoablation is cutting-edge technology for the treatment of AF, we should know more about its research hotspots and future development trends.

In our study, bibliometric tools and online tools were used to analyze articles on cryoablation of AF published from 2002 to 2022. Our findings provide influential countries, institutions, authors, publications, and frontier research hotspots in cryoablation of AF, and future research trends in this field are also predicted.

## METHODS

### Data Sources and Search Strategies

The Web of Science Core Collection (WoSCC) was selected as the target database for conducting bibliometric analysis research. The search formula was set to TS=("Atrial Fibrillations" OR "Persistent Atrial Fibrillation" OR "Paroxysmal Atrial Fibrillation" OR "Auricular Fibrillation") AND TS=("Cryoablation" OR "Cryoballoon" OR "Cryoballoon ablation"), and the dates of the search were from 2002 to 2022. Literature retrieval was conducted within 1 day (July 20, 2022) to avoid omissions arising from rapid database renewal. A total of 2448 records were obtained, including 1676 articles and 772 others (318 meeting abstracts, 188 reviews, or 181 editorial materials and 85 others), and only articles were included in the analysis. Ethical consent was not applicable, as all data were downloaded from public databases and do not contain private information. The authors declare that all supporting data are available within the article and in the Data Supplement.

## HIGHLIGHTS

- This is the first study on cryoablation of atrial fibrillation (AF) based on bibliometric analysis and information visualization.
- Our research shows the most productive countries, institutions, authors, and publications; it also analyzes the most cited authors and articles.
- The evolutionary history of this field is also explored.

## Statistical Analysis

CiteSpace V (Version 5.8 R3, Drexel University, Chaomei Chen), Microsoft Excel 2019 (Redmond, Wash, USA), the Online Analysis Platform of Literature Metrology (<http://bibliometric.com/>), and the Web of Science online analysis tool were used for bibliometric analysis of the data we retrieved. Data from WoSCC were converted into text format and imported into analysis tools.

CiteSpace V was used to conduct cluster analysis and bursts of keywords, timeline views, characteristics of the authors, journals, institutions, countries/regions, and keyword networks.

Microsoft Office Excel 2019 was employed to count various ranking situations and quantity distributions presented in this study.

The Online Analysis Platform of Literature Metrology was used to analyze the number of publications in each country in different years and their collaborations, citations by different authors, and the number of publications in journals.

## RESULTS

### Distribution of Articles by Publication Years

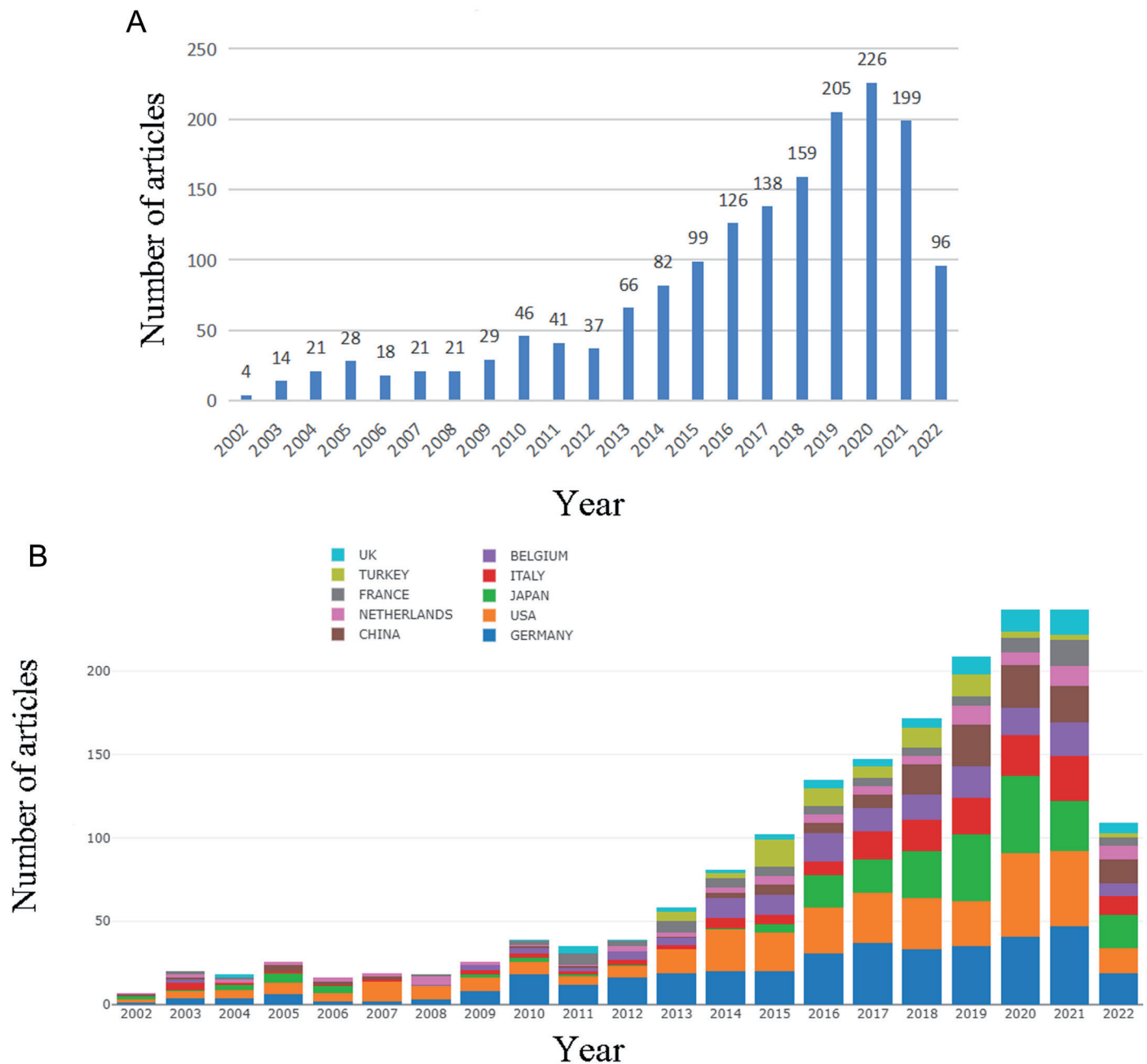
Between the years 2002 and 2022, a total of 1676 original articles met the search criteria. The number of published articles on cryoablation of AF was increasing year by year (Figure 1A) and reached its peak in 2020, with a slight decline in 2006–2008, 2011–2012, and 2021. In 2016, the number of published articles exceeded 100. Compared with 2002–2015, the number of published articles increased sharply from 2016 to 2022, and the number of published articles from 2016 to 2022 was 1148, accounting for 68.56% of the total number of articles.

### Country/Region Analysis

The 1676 publications focusing on cryoablation of AF research were contributed by at least 64 countries/regions (Dataset S1). Figure 1B provides a bar chart of the top 10 countries/regions based on the percentage of publications by year. The top 10 countries/regions with the most publications are listed in Table 1. Among the top 10 countries, Germany published the most original articles, followed by the United States and Japan. The sum of the top 3 accounted for more than half of the total number of articles. In particular, Türkiye and China are the only 2 developing countries in the top 10. The research network map among countries/regions showed a high density ( $n = 82$ ,  $E = 110$ , density = 0.0331) (Figure 2A), indicating the close cooperation between countries/regions. In terms of centrality, the United States ranked first (0.53). Figure 2B shows that collaboration between the USA and Canada, the USA and Germany, and Italy and Belgium occurred frequently.

### Distribution of Authors

In our study, a total of 1676 manuscripts were contributed by at least 6400 authors (Dataset S2), and the top 10 high-production authors who published the most articles are listed in Table 2. The top 3 authors were all from the same institution, Free University of Brussels in Brussels (Belgium).



**Figure 1. Distribution of articles by publication years (A) and the top 10 countries/regions of publications by years (B).**

Gian-Battista Chierchia ranked first (113), followed by Pedro Brugada (100), and Carlo de Asmundis came third (97). Of the top 10 high-production authors, 4 were from Belgium, 4 were from Germany, and 2 were from Italy. In terms of total citations, Karl-Heinz Kuck from Asklepios Klinik St. Georg (Germany) ranked first (2166), and Andreas Metzner ranked second by a very small margin (2052). At the same time, Andreas Metzner from Asklepios Klinik St. Georg (Germany) ranked first in the average citation (26.31), followed by Ouyang FF from the same institution (25.46). The research network map among authors showed a middle density ( $n=295$ ,  $E=516$ ,  $density=0.0119$ ) (Figure 3A). The top 5 authors with the highest centrality

value were Carlo de Asmundis (0.35), Boris Schmidt (0.35), Rui Providência (0.34), Francesca Salghetti (0.24), and Alexander Fuernkranz (0.19).

**Institution Analysis**

In terms of research institutions, the Asklepios Klin St. Georg is at the top of the list, with 352 articles (Table 3), followed by Vrije Univ Brussel with a small margin (349). However, the number of articles varies widely between the second and third (Tokyo Med & Dent Univ, 210). The top 3 accounted for nearly half of the total. The research network map of institutions had a low density ( $n=223$ ,  $E=189$ ,  $density=0.0076$ ) (Figure 3B), indicating the lack of necessary cooperation

**Table 1. Top 10 Countries/Regions Contributing to Publications in Cryoablation of AF**

Rank	Country	Centrality	Frequency
1	Germany	0.11	371
2	USA	0.53	349
3	Japan	0.00	224
4	Italy	0.09	153
5	Belgium	0.00	142
6	Peoples R. China	0.00	123
7	France	0.24	85
8	Türkiye	0.16	82
9	Netherlands	0.19	82
10	England	0.17	71

AF, atrial fibrillation.

between these research institutions. Thus, strengthening the cooperation of the various institutions is needed.

**Journal Analysis and Most Frequently Cited Articles**

The top 10 most productive journals that published articles on cryoablation of AF are listed in Table 4. The most prolific journal has been the US publication *Journal of Cardiovascular Electrophysiology* with 217 articles (12.95%), *Europace* from England ranked second with 166 (9.91%), followed by *Journal of Interventional Cardiac Electrophysiology* (162, 9.67%) from Netherlands. The top 10 cited articles on cryoablation of AF are listed in Table 5. Among these most frequently cited articles, “Cryoballoon or Radiofrequency Ablation for Paroxysmal Atrial Fibrillation” by Kuck et al<sup>19</sup> published in 2016 in *New England Journal of Medicine* (910 citations) ranked first; and “Cryoballoon Ablation of Pulmonary Veins for Paroxysmal Atrial Fibrillation: First Results of the North American Arctic Front (STOP AF) Pivotal Trial” by Packer et al<sup>18</sup> published in 2013 in *Journal of the American College*

of Cardiology (499 citations), ranked second, followed by “Circumferential pulmonary vein isolation with the cryoballoon technique” by Neumann, Thomas, published in 2008 in the same journal. All top 10 articles were cited more than 200 times.

**Keyword Co-occurrence Analysis of Research Hotspots**

CiteSpace V was used to analyze keywords, identified from the content of the titles and abstracts of the 1676 articles and draw a keyword co-occurrence graph, which included 214 nodes and 285 links (Figure 3C). Table 6 shows the top 10 most frequently occurring keywords in cryoablation of AF. The word “catheter ablation” ranked first (525 records), followed by “pulmonary vein isolation” (457 records) and “efficacy” (312 records). In terms of centrality in the top 10, “cryoablation” ranked first (0.32), followed by “radiofrequency ablation” (0.17) and “efficacy” (0.13). To better show when keywords first appeared, keyword time zone view was designed by CiteSpace V, which could show the evolution of high-frequency keywords clearly (Figure 4A).

In our study, the 214 keywords were aggregated using the log-likelihood ratio algorithm, resulting in 9 clusters (Figure 4B). The silhouette value of clusters 0 to 8 was from 0.876 to 0.989, which shows good homogeneity. All clusters are marked by index words extracted from keywords. The largest cluster (#0) was marked as “impact,” followed by the second largest cluster (#1) marked as “management,” and the third largest cluster (#2) was marked as “damage.” For a more intuitive understanding, these clusters were shown in a timeline view (Figure 4C).

Searching for research frontiers in cryoablation of AF, CiteSpace V was used to detect the keywords with the strongest citation bursts (Figure 4D). Between 2002 and 2022, the top 3 keywords with the highest burst strength were cryoablation (15.23), follow-up (12.65), and efficacy (12.24).



**Figure 2. The network map of countries/regions (A) and cooperation between countries/regions (B).**

**Table 2. Top 10 Authors with The Most Publications in Cryoablation of AF**

Rank	Author	Country	Article Counts	Total Citations	Average Citations
1	Chierchia, GB	Belgium	113	1590	14.07
2	Brugada, P	Belgium	100	1525	15.25
3	de Asmundis, C	Belgium	97	1334	13.75
4	Kuck, KH	Germany	95	2166	22.8
5	Metzner, A	Germany	78	2052	26.31
6	Stroker, E	Belgium	67	573	8.55
7	Iacopino, S	Italy	59	272	4.61
8	Mugnai, G	Italy	58	1092	18.83
9	Schmidt, B	Germany	55	1212	22.04
10	Ouyang, FF	Germany	54	1375	25.46

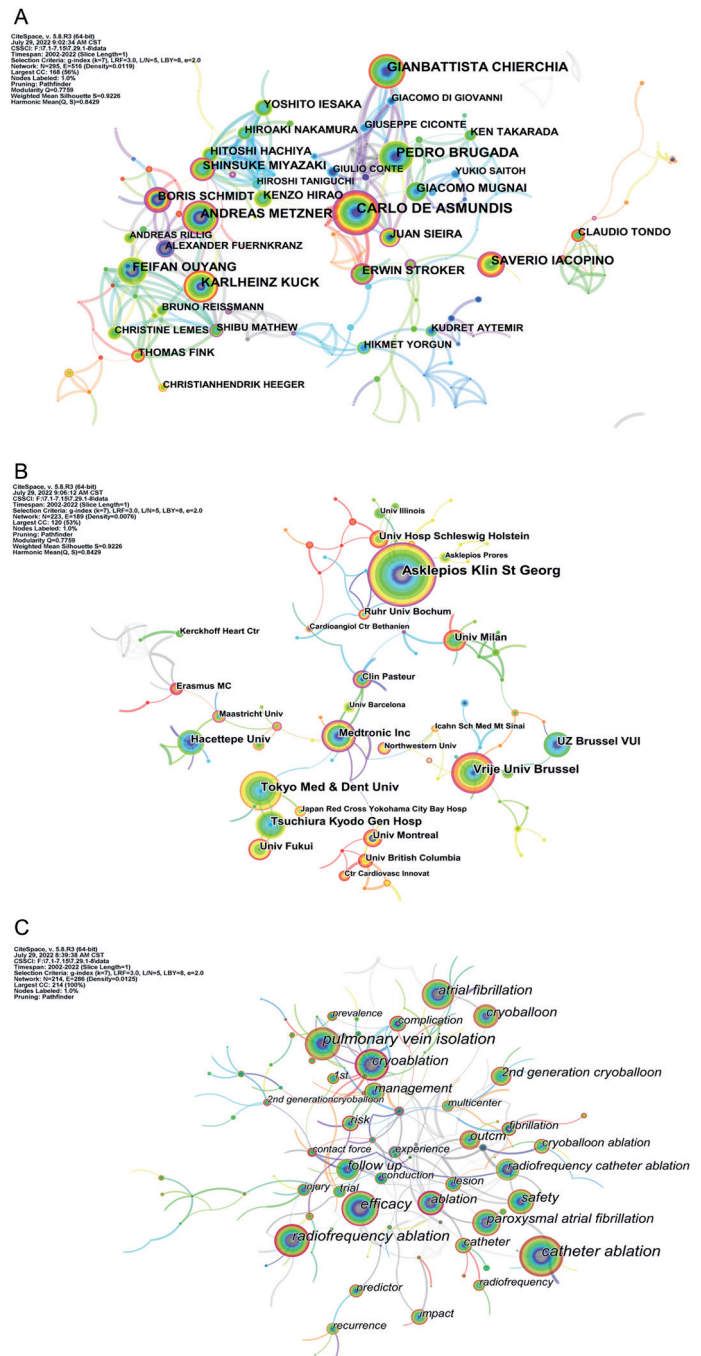
AF, atrial fibrillation.

**DISCUSSION**

Catheter ablation was introduced in the late 1990s as a treatment option for AF.<sup>18</sup> It is widely applied all over the world, and with the continuous maturity of the technology, its various performances are constantly optimized. Radiofrequency ablation is currently the most widely used technique. Cryoablation for AF began in 2005, but it was not widely used until the publication of the STOP AF study,<sup>19</sup> which demonstrated that cryoablation is a safe and effective alternative to antiarrhythmic drugs for the treatment of patients with paroxysmal AF. With the development of technology and the accumulation of clinical experience, cryoablation is constantly being updated, from the previous first generation to the latest generation. Hence, in order to better understand the development process and characteristics of cryoablation of AF, a comprehensive analysis of articles on this topic from 2002 to 2022 using bibliometric methods was conducted.

In general, the number of publications on cryoablation of AF has increased from 2002 to 2022. Specifically, the quantity of publications from 2002 to 2012 showed a wave-like distribution, with a sharp increase in 2013, a slight decline in 2021, and the largest number of articles in 2020. Since the STOP AF study<sup>19</sup> was published in 2013, it has further demonstrated the safety and efficacy of cryoablation for the treatment of AF. Compared with 2002 to 2015, the number of published articles increased sharply from 2016 to 2022, and the quantity of published articles from 2016 to 2022 was 1148, accounting for 68.56% of the total number of articles. This trend partially reflects the fact that cryoablation is becoming a very important means of treating AF.

In all countries, Germany leads the position in the number of original articles, with the United States in second place by a smaller margin. But the United States had the highest value of centrality, indicating high research quality and great influence. In terms of national geographic distribution, 1 is from North America, 2 are from Asia, 6 are from Europe, and 1 is across Asia and Europe. This shows that Europe is the absolute leader in cryoablation of AF. In terms of economy, 8 are



**Figure 3. The network map of authors (A) and institutions (B); the map of keyword co-occurrence (C).**

developed countries and 2 are developing countries. On the one hand, China's economy is developing greatly; on the other hand, China is the most populous country in the world, and there is a huge population of AF patients. These 2 reasons promoted the development of cryoablation in China. From our analysis results, it can be seen that the cooperation between the United States and Canada, the United States and Germany, and Italy and Belgium is close, and the remaining countries have only a small amount of cooperation. Therefore, it is necessary to strengthen international cooperation.

**Table 3. Top 10 Institutions With the Most Publications in Cryoablation of AF**

Rank	Institution	Centrality	Frequency
1	Asklepios Klin St Georg	0.22	352
2	Vrije Univ. Brussel	0.13	349
3	Tokyo Med. & Dent Univ.	0.05	210
4	Tsuchiura Kyodo Gen Hosp.	0.01	144
5	UZ Brussel VUB	0.00	140
6	Medtronic Inc.	0.38	112
7	Hacettepe Univ.	0.05	82
8	Univ. Fukui	0.00	81
9	Univ. Milan	0.08	72
10	Univ. Hosp. Schleswig Holstein	0.06	69

AF, atrial fibrillation.

Of the top 10 most prolific authors, 4 are from the same institution in Belgium, 4 are from 2 different institutions in Germany (3 of them from the same institution), and 2 are from different institutions in Italy. This explains why there is a mismatch between the most prolific countries and the most prolific authors, as there are multiple authors for the same article. Karl-Heinz Kuck from Germany ranked first in total citations and third in average citations, and Andreas Metzner ranked second in total citations and first in average citations, showing outstanding performance. The above results show that a higher number of publications do not mean higher total and average citations. This suggests that the quality of the article plays an important role in being cited. Carlo de Asmundis has the highest central value among the top 10 authors. This reminds us to pay more attention to the quality of the articles, not just the quantity.

**Table 4. Top 10 Journals that Published Articles in Cryoablation of AF**

Rank	Journal	Count	Percent	IF2022
1	<i>Journal of Cardiovascular Electrophysiology</i>	217	12.95	2.942
2	<i>Europace</i>	166	9.91	5.486
3	<i>Journal of Interventional Cardiac Electrophysiology</i>	162	9.67	1.759
4	<i>Pace Pacing and clinical electrophysiology</i>	101	6.03	1.912
5	<i>Heart Rhythm</i>	97	5.79	6.779
6	<i>Circulation Arrhythmia and Electrophysiology</i>	46	2.75	7.718
7	<i>International Journal of Cardiology</i>	43	2.57	4.039
8	<i>Journal of Arrhythmia</i>	37	2.21	NA
9	<i>Circulation Journal</i>	32	1.91	3.350
10	<i>Annals of Thoracic Surgery</i>	22	1.31	5.102

AF, atrial fibrillation.

Asklepios Klin St. Georg ranked first in the number of publications among all institutions, followed by Vrije Univ Brussel. Medtronic was the only medical technology company to make to the top 10. Meanwhile, Medtronic has the highest centrality, indicating that the company has mastered certain core technologies in this field. The journal *Journal of Cardiovascular Electrophysiology* (IF<sub>2022</sub>=2.942) was by far the most preeminent journal with 217 articles, followed by *Europace* (IF<sub>2022</sub>=5.486), *Journal of Interventional Cardiac Electrophysiology* (IF<sub>2022</sub>=1.759), *Pace Pacing and Clinical Electrophysiology* (IF<sub>2022</sub>=1.912), and *Heart Rhythm* (IF<sub>2022</sub>=6.779). Among all journals, *Circulation Arrhythmia and Electrophysiology* (IF<sub>2022</sub>=7.718) has the highest impact factor, while the *Journal of Arrhythmia* has no impact factor. From the perspective of impact factor alone, the top 10 journals did not exceed 10, and most of them were concentrated between 1 and 8. But many of them are very well-known magazines like *Heart Rhythm* and *Europace*. The most frequently co-cited reference was published in 2016 in the *New England Journal of Medicine* (910 citations) by Kuck et al.<sup>19</sup> This randomized trial demonstrated that cryoablation was non-inferior to radiofrequency ablation with respect to efficacy for the treatment of patients with drug-refractory paroxysmal AF, and there was no significant difference between the 2 methods with regard to overall safety.<sup>18</sup> Also, a clinical trial, "Cryoballoon Ablation of Pulmonary Veins for Paroxysmal Atrial Fibrillation First Results of the North American Arctic Front (STOP AF) Pivotal Trial" was published in 2013 in *Journal of the American College of Cardiology* by Packer et al.<sup>18</sup> ranked second. The STOP AF trial demonstrated that cryoablation was a safe and effective alternative to antiarrhythmic medication for the treatment of patients with symptomatic paroxysmal AF.<sup>20</sup> Among the top 10 most frequently cited references, 7 were human clinical trials and only 1 was animal research.

Keywords reflect the core theme and main content of the paper and can reasonably describe research hotspots.<sup>21</sup> The top 5 high-frequency keywords include catheter ablation, pulmonary vein isolation, efficacy, radiofrequency ablation, and AF. Whether it is radiofrequency ablation or catheter ablation, pulmonary vein isolation is the cornerstone of the treatment of AF.<sup>22</sup> Since cryoablation has been clinically used for the treatment of AF, many studies have continuously compared its efficacy and safety with radiofrequency ablation.<sup>18,23,24</sup> It is easy to understand why pulmonary vein isolation, efficacy, and radiofrequency ablation appear in the top 5 high-frequency keywords.

In order to explore the evolutionary path of this field, the keyword time zone view was used to show the year that each keyword first appeared in the analyzed dataset. From 2002 to 2012, cryoablation for the treatment of AF was in the preliminary clinical exploration stage. Until 2013, STOP AF<sup>20</sup> demonstrated its safety and efficacy, and cryoablation began to be widely used in clinical practice. Therefore, from 2013 to 2021, cryoablation and radiofrequency ablation were

**Table 5. Top 10 Articles with the Most Citation Frequency in Cryoablation of AF**

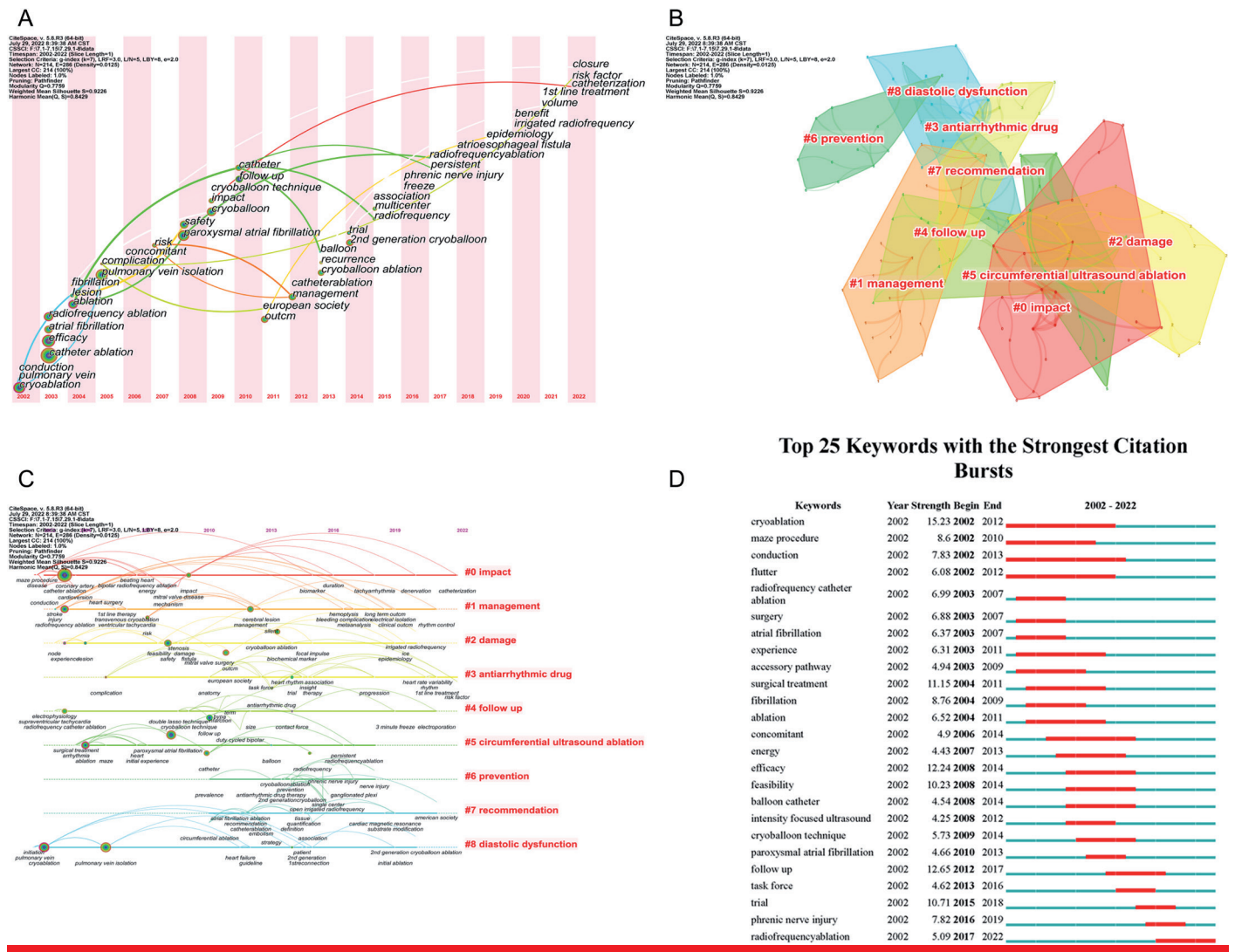
Rank	Title	First author	Journal	Publication Year	Total Citations	DOI
1	Cryoballoon or Radiofrequency Ablation for Paroxysmal Atrial Fibrillation	Kuck, Karl-Heinz	<i>New England Journal of Medicine</i>	2016	910	10.1056/NEJMoa1602014
2	Cryoballoon Ablation of Pulmonary Veins for Paroxysmal Atrial Fibrillation First Results of the North American Arctic Front (STOP AF) Pivotal Trial	Packer, Douglas L	<i>Journal of the American College of Cardiology</i>	2013	499	10.1016/j.jacc.2012.11.064
3	Circumferential pulmonary vein isolation with the cryoballoon technique	Neumann, Thomas	<i>Journal of the American College of Cardiology</i>	2008	348	10.1016/j.jacc.2008.04.021
4	Lower incidence of thrombus formation with cryoenergy versus radiofrequency catheter ablation	Khairy, P	<i>Circulation</i>	2003	337	10.1161/01.CIR.0000058706.82623.A1
5	The 'single big cryoballoon' technique for acute pulmonary vein isolation in patients with paroxysmal atrial fibrillation: a prospective observational single centre study	Chun, Kyoung-Ryul Julian	<i>European Heart Journal</i>	2009	252	10.1093/eurheartj/ehn570
6	Efficacy and safety of cryoballoon ablation for atrial fibrillation: A systematic review of published studies	Andrade, Jason G	<i>Heart Rhythm</i>	2011	233	10.1016/j.hrthm.2011.03.050
7	Incidence of Asymptomatic Intracranial Embolic Events After Pulmonary Vein Isolation Comparison of Different Atrial Fibrillation Ablation Technologies in a Multicenter Study	Siklody, Claudia Herrera	<i>Journal of the American College of Cardiology</i>	2011	224	10.1016/j.jacc.2011.04.010
8	Pulmonary vein isolation using an occluding cryoballoon for circumferential ablation: feasibility, complications, and short-term outcome	Van Belle, Yves	<i>European Heart Journal</i>	2007	220	10.1093/eurheartj/ehm227
9	Neural mechanisms of paroxysmal atrial fibrillation and paroxysmal atrial tachycardia in ambulatory canines	Tan, Alex Y	<i>Circulation</i>	2008	213	10.1161/CIRCULATIONAHA.108.776203
10	Surgical treatment of atrial fibrillation; a systematic review	Khargi, K	<i>European Journal of Cardio-Thoracic Surgery</i>	2005	202	10.1016/j.ejcts.2004.11.003

AF, atrial fibrillation.

continuously compared in terms of safety, efficacy, recurrence rate, and complications. The second generation of cryoballoon ablation was first developed and clinically used in 2013-2014 and proved to be safe and effective.<sup>25-27</sup> By 2021, many guidelines consider catheter ablation as a conditional recommendation for first-line treatment of AF.<sup>28,29</sup> The first appearance of "first line treatment" in the keyword time zone view is 2021, roughly in line with trends in the field.

A cluster map of keywords can indicate different research concerns in the field.<sup>31</sup> Keyword co-occurrence cluster analysis results show that cryoablation of AF is still a research hotspot in the aspects: of influencing factors, postoperative

management, follow-up, and comparison with antiarrhythmic drugs. The timeline view of the keyword cluster graph shows that its keywords are constantly changing dynamically over time. Analysis of keywords using burst detection suggests that cryoablation, follow-up, efficacy, surgical treatment, trial, and feasibility have attracted great attention from researchers during the past few decades. Radiofrequency ablation is the current research frontier in this field and is currently within the burst period. The reason may be that radiofrequency ablation and cryoablation are different energy sources for catheter ablation. The former uses "fire" and the latter uses "ice," which has been compared.



**Figure 4. Keyword time zone view (A); clustered network map of keywords co-occurrence (B); timeline view of keyword clusters (C); and top 25 keywords with the strongest citation bursts (D).**

**Table 6. Top 10 Keywords Co-occurrence with the Most Frequency in Cryoablation of AF**

Rank	Frequency	Centrality	Year	Keyword
1	525	0.04	2003	catheter ablation
2	457	0.05	2005	pulmonary vein isolation
3	312	0.13	2003	efficacy
4	305	0.17	2003	radiofrequency ablation
5	219	0.05	2003	atrial fibrillation
6	216	0.32	2002	cryoablation
7	204	0.09	2008	safety
8	195	0.02	2010	follow up
9	191	0.05	2009	cryoballoon
10	170	0.02	2008	paroxysmal atrial fibrillation

AF, atrial fibrillation.

**CONCLUSIONS**

This is the first study on cryoablation of AF based on bibliometric analysis and information visualization. Our research shows the most productive countries, institutions, authors, and publications; it also analyzes the most cited authors and articles. In addition, the evolutionary history of this field is explored, and the choice between cryoablation and radiofrequency ablation will be the focus of future research.

**Ethics Committee Approval:** This study does not involve animal and human studies, and the data used are all public databases, so it does not involve medical ethics.

**Peer-review:** Externally peer-reviewed.

**Author Contributions:** Concept – H.Y., B.P.T.; Design – H.Y., J.X., B.P.T.; Supervision – B.P.T., L.Z.; Resources – B.P.T., L.Z.; Materials – H.Y., J.X.; Data Collection and/or Processing – H.Y., J.X., J.S.; Analysis and/



or Interpretation – H.Y., J.X., L.Z.; Literature Search – H.Y., J.X., J.S.; Writing – H.Y., J.X.; Critical Review – B.P.T., L.Z.

**Declaration of Interests:** The authors have no conflict of interest to declare.

**Funding:** This work was supported by grants obtained from the National Natural Science Foundation of China [nos 81873488].

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