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Global trends in research of acute type a aortic dissection: A bibliometric analysis from 2002 to 2022

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ABSTRACT

Background: Acute type A aortic dissection (ATAAD) is life-threatening and needs urgent and highly invasive surgery. So far, there is no comprehensive review of the status quo of ATAAD studies. Therefore, this study aimed to quantify and identify the global trends of ATAAD research over the past two decades through bibliometric analysis and to provide reference for clinical practice, research funding allocation, and decision-making.

Methods: The original research articles and reviews related to ATAAD research were downloaded from the Web of Science Core Collection on March 19, 2023. CiteSpace (6.2.1) and VOSviewer (1.6.18) were used for bibliometric analysis of the number of publications by each country, institution, and authors and the establishment of knowledge maps. The raw data collected were examined using the Online Analysis Platform of Bibliometric to assess the collaboration of countries in the field.

Results: The number of documents on ATAAD research increased continuously. A total of 1,943 publications published from 2002 to 2022 from 66 countries/regions were identified: 637 (32.78%) were conducted in China and 360 (18.53%) in the United States; 152 (cited frequency 941) were conducted by Capital Medical University and 107 (cited frequency 370) by Fujian Medical University. The *Journal of Cardiac Surgery* was the most frequently published journal (143 publications, cited frequency 695). The highest citation and co-cited journal was the Annals of Thoracic Surgery (cited frequency 3,888, co-cited frequency 6,224). We identified 8,050 authors among which Lizhong Sun (61 publications, cited frequency 721) had the largest number of publications, and Nienaber Christoph A (cited frequency 1,536, co-cited frequency 392) was co-cited most often. Meanwhile, the most common keywords were acute type A aortic dissection (occurrences, 1,211), surgery (occurrences, 657), repair (occurrences, 404), and management (occurrences, 386). The earliest and latest used keywords were "axillary artery" (average publication year: 2011.23) and "inflammation" (average publication year: 2019.09), respectively. The keyword "surgical treatment" (strength 12.31) and the co-cited reference "Evangelista A, 2018, *Circulation*" (strength 28.55) had the highest citation bursts. The keywords "impact" and "acute kidney injury" remained high citation bursts. The co-cited references with the largest and smallest size clusters were "cerebral protection" (#0, size = 126) and "pregnancy" (#12, size = 11). The reference "Hagan PG, 2000, *JAMA*" (cited frequency, 350) had the highest co-citations.

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Conclusions: The bibliometric and visualized analysis generated objective evidence for a comprehensive understanding and evaluation of ATAAD research.

1. Introduction

Aortic dissection (AD) is a catastrophic cardiovascular surgical emergency that results in rapid hemodynamic deterioration after onsets, such as cardiac tamponade-induced severe circulatory failure, aortic rupture, and poor perfusion-caused multi-organ failure [1]. The annual incidence of AD was approximately 3–6/100,000 people [2]. According to the Stanford classification system, acute type A aortic dissection (ATAAD) is defined as the intimal tear occurred in the ascending aorta. ATAAD is caused by the degeneration or cystic necrosis of the middle layer of the aorta, with blood pouring through the intimal tear, forming a false lumen between the intima and the middle layer [3]. The main clinical manifestation of ATAAD is tear-like pain in the chest and back. Studies have shown that smoking, hypertension, lipid disorders, and genetic predisposition were the common risk factors of aortic degeneration and increased the fragility of the aortic wall, ultimately causing the aorta unable to defend blood flow and leading to ATAAD [4,5]. The development of ATAAD involves three main pathological processes: inflammatory response, disruption of the extracellular matrix (ECM), and loss of vascular smooth muscle cells [6,7]. The prognosis of ATAAD after pharmacological treatment was poor, while surgery significantly prolonged the medium-term survival for patients with ATAAD [8]. Non-surgically treated ATAAD patients had a death rate of 1%–2% per hour after onset and up to 90% within 90 days [9]. Currently, open surgical treatment of ATAAD is the most effective in reducing the risk of aortic dissection.

With the accumulation of clinical experience and the advancement of scientific research, studies on ATAAD have been published in many peer-reviewed journals and reported in academic conferences. For clinicians and researchers, quick and accurate access to research hotspots and the latest advances in ATAAD research will help determine research direction and guide clinical practice. However, a quantitative analysis of publications on ATAAD research has not yet been conducted.

Conventionally, systematic reviews have been the main method of literature mining, requiring a lot of human effort to read and extract useful information, while a certain degree of omission and bias may exist. A comprehensive understanding of the current situation is paramount to obtaining the most valuable content and contributes to the advancement of aortic dissection research. Bibliometric analysis is widely utilized to explore the research frontiers in various research fields [10,11], which plays an increasingly vital role in resolving current research contradictions and finding new research hotspots. It has provided clear insights into many areas of medicine. By reading relevant publications, readers can obtain statistical information about the distribution of publications across countries, institutions, authors, and journals [12].

In the present study, we searched for publications on ATAAD between 2002 and 2022 from the Web of Science Core Collection (WoSCC) and analyzed them quantitatively and visually to identify research hotspots and future research directions for ATAAD to facilitate the development of future research and clinical practice. Researchers can utilize the study to set research directions and partners quickly, while supporters and policymakers can allocate scientific and clinical resources efficiently.

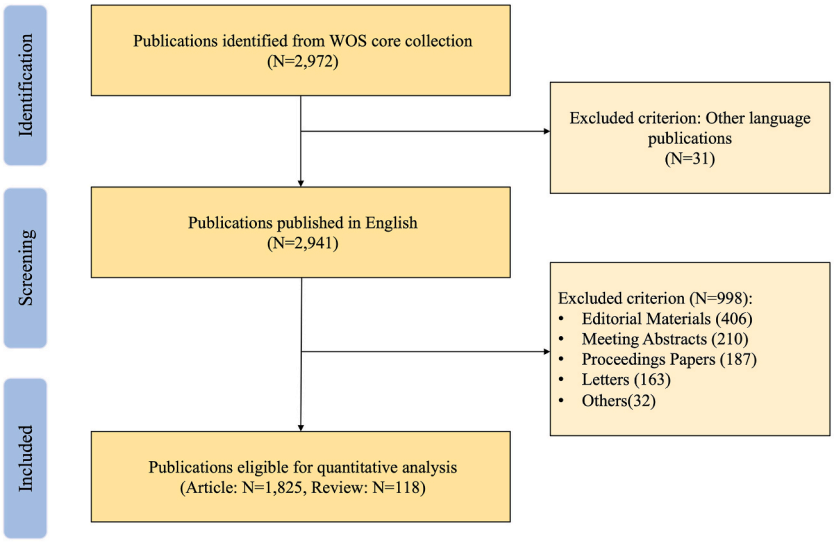


Fig. 1. Flow chart of screening and included publications.

2. Methods

2.1. Data collection and searching strategies

Relevant publications were searched through the Science Citation Index Expanded (SCI-expanded) database of WoSCC using the following search strategy: TS = ("type A aortic dissection") OR TS = ("type I aortic dissection") OR TS = ("type II aortic dissection") AND PY = (2002–2022) AND LA = (English). The search results were refined by document type (original article and review). The literature search and raw data download were completed on March 19, 2023 to avoid bias caused by constant database updates. Following the search strategy, 2,972 publications were identified and further screened. After removing duplicate entries, we retrieved 1,943 publications (1,825 articles and 118 reviews) that were eligible for further bibliometric analysis (Fig. 1).

Two investigators (Zhen Qi and Ri Tang) independently conducted the primary literature search. The retrieved publications with complete records and cited references were saved in plain text, BibTeX, and tab-separated file formats for further bibliometric analysis. For analysis of collaboration between countries, the Online Analysis Platform of Bibliometric (https://bibliometric.com) was employed.

2.2. Bibliometric analysis

The publications on ATAAD research were analyzed and visualized using CiteSpace (6.2.1), VOSviewer (1.6.18), and Microsoft Excel 2022. CiteSpace was used for visual network analysis of the cooperative relationship between state institutions and authors, considering its interactive visualization function. The main parameters were as follows: time slices from January 2002 to December 2022 (1 year for each slice), selection criteria (g-index, k = 25), pruning method (pathfinder and pruning sliced networks), and visualization method (cluster view-static and merged network). Notably, each node represents an item, such as country, institution, keyword, and so on. The link describes the relationship of co-citation or co-occurrence between nodes, and the thickness of a line is positively correlated with co-occurrence and co-reference relationships [13]. The concept of betweenness centrality introduced by the American sociologist Freeman was used to identify pivotal points [14]. The betweenness centrality is defined as the following

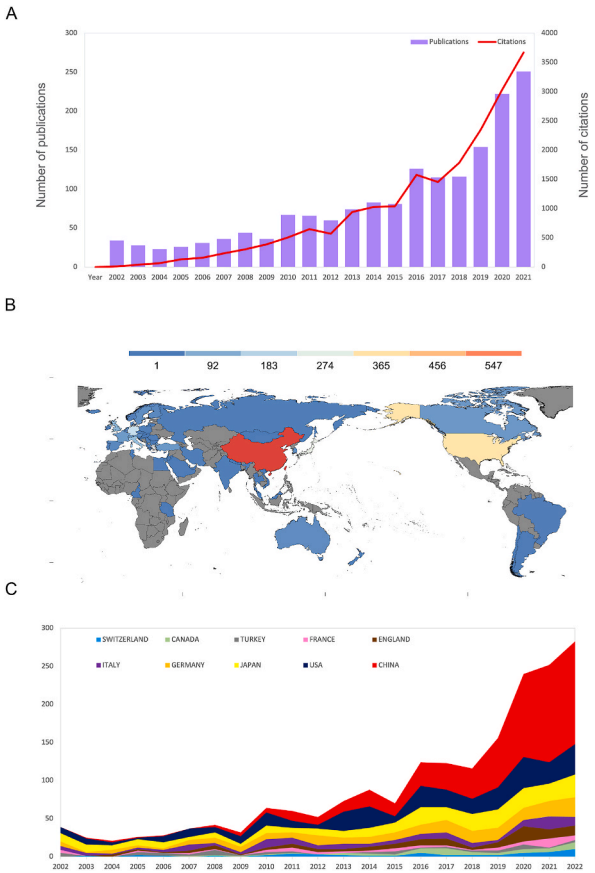


Fig. 2. Annual publications and citations, global map of authorship distribution, and the top 10 countries/regions for ATAAD publications from 2002 to 2022. (A) The number of annual publications and citations worldwide. (B) The publication density map. (C) The number of annual publications of the top 10 countries/regions. China demonstrated the fastest growth in publications among the top 10 countries/regions in recent years.

equation:

$$Centrality(node_i) = \sum_{i \neq j \neq k} \frac{\rho_{jk}(i)}{\rho_{jk}}$$

In this equation, ρ_{jk} represents the number of shortest paths between node j and node k, and $\rho_{jk}(i)$ is the number of those paths that pass through node i. The indicator betweenness centrality can be used to assess the significance of each publication at the level of a co-citing network [15]. VOSviewer is another bibliometrics software, its main function is to create and visualize scientific knowledge maps, density color visualization, item cluster analysis and so on [16]. It was used to detect co-citation and collaborations between authors, institutions, and countries and to analyze co-occurrence between journals and keywords. The polynomial function for the prediction model, as well as the time trends of publications and citations, were analyzed using Microsoft Excel 2022.

3. Results

3.1. An overview of acute type a aortic dissection publications

3.1.1. Growth trend of publications

The results showed that the growth of ATAAD research could be generally divided into two main time periods (Fig. 2A). In the early phase (2002–2009), the number of publications fluctuated below 50. However, it increased rapidly during the next 13 years, indicating that ATAAD was becoming a hotspot in cardiovascular research. These publications achieved a total of 24,574 citations, with an average of 12.65 citations, showing a gradually increasing trend. Based on the highest R^2, the polynomial function was used to fit the prediction model as follows: $y = 0.057\ x^3 - 342.95\ x^2 + 688240x - 5\ E{+}08$, which suggested that there will be nearly 425 articles published on ATAAD in the year 2025.

3.1.2. Analysis of countries/regions and institutions

The 1,943 ATAAD publications came from 1,657 institutions in 66 countries/regions. Global contributions to ATAAD research are depicted on a world map based on the number of publications (Fig. 2B). The top 10 countries/regions publishing the majority of ATAAD publications each year are shown in Fig. 2C. Ranking by number of publications are China (637, 32.78%), the United States (360, 18.53%), Japan (282, 14.51%), Germany (215, 11.07%), and Italy (129, 6.64%), respectively. Table 1 lists the 10 most productive countries/regions in terms of their contribution to ATAAD research. Overall, ATAAD research publications of these countries/regions were steadily increasing.

3.1.3. Analysis of scientific collaboration networks

Collaborations on ATAAD research between countries/regions are shown in Fig. 3A. The most collaborative country with other countries in ATAAD research is the United States. Purple circles are often used to identify nodes with a betweenness centrality greater than 0.1 [17]. China, the United Kingdom, Italy, and the United States had high betweenness centralities (Fig. 3B), indicating that they are in the core position in this field and serve as bridges connecting academic exchange and collaborations in this field.

The collaboration network knowledge map based on institutions exhibited 469 institutions and 984 collaborations, and the density was 0.009 (Fig. 3C). The most productive research institutions were Capital Medical University (152 publications, 7.82%), followed by Fujian Medical University (107 publications, 5.50%), Fudan University (81 publications, 4.16%), and University of Michigan (64 publications, 3.29%) (Table 1). Notably, eight of the top 10 institutions are from China, one from the United States, and one from Japan. Although the numbers of publications of Yale University, University of Michigan, Harvard University, and the University of Pennsylvania were not as large as the Chinese institutions, their collaborations with other institutions was very active. Among them, The University of Pennsylvania showed the highest centrality (0.13).

Table 1
The top 10 countries/regions, institutions, and authors of publications on ATAAD.

Rank	Country/region	Publications	Citations	Institution	Publications	Citations	Author	Publications	Citations
1	CHINA	637	4,329	Capital Med Univ	152	941	Lizhong Sun	61	721
2	USA	360	7,318	Fujian Med Univ	107	370	Liangwan Chen	43	317
3	JAPAN	282	4,792	Fudan Univ	81	422	Junming Zhu	39	459
4	GERMANY	215	6,121	Univ Michigan	64	2,357	Dongjin Wang	35	130
5	ITALY	129	4,039	Nanjing Univ	55	203	Cuntao Yu	34	242
6	ENGLAND	113	1,812	Chang Gung Univ	51	236	Yongmin Liu	33	458
7	FRANCE	60	902	Chinese Acad Med Sci	46	592	Jun Zheng	32	510
8	TURKEY	54	459	Cent South Univ	44	72	Hongjia Zhang	28	190
9	CANADA	56	905	Jichi Med Univ	44	393	Chunsheng Wang	26	163
10	SWITZERLAND	50	951	Nanjing Med Univ	37	85	Czerny Martin	25	780

ATAAD：Acute Type A Aortic Dissection; Capital Med Univ: Capital Medical University; Fujian Med Univ: Fujian Medical University; Fudan Univ: Fudan University; Univ Michigan: University of Michigan; Nanjing Univ: Nanjing University; Chang Gung Univ: Chang Gung University; Chinese Acad Med Sci: Chinese Academy of Medical Sciences & Peking Union Medical College; Cent South Univ: Central South University; Jichi Med Univ: Jichi Medical University; Nanjing Med Univ: Nanjing Medical University.

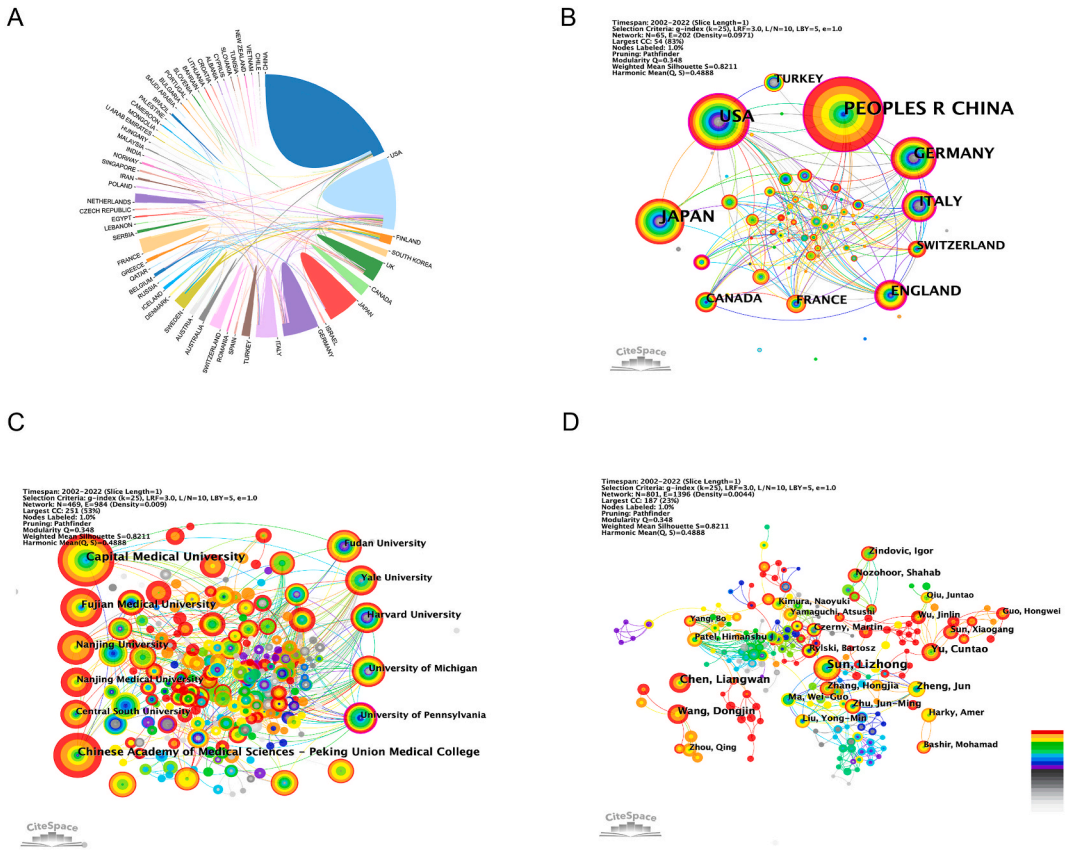


Fig. 3. Collaboration relationship among countries/regions, institutions, and authors involved in ATAAD research from 2002 to 2022. (A) Collaborations between countries/regions based on the data from https://bibliometric.com. The size of the plates indicates the number of publications in corresponding country/region, and the lines between the plates indicate the intensity of collaboration between them. (B) Visualization of country/regional collaborations networks. N = 65, E = 202. (C) Visualization of institutional collaborations networks. N = 469, E = 984. (D) Visualization of author collaborations networks. N = 801, E = 1,396. The size of the circle reflects the frequency of co-occurrence, and the thickness of the line indicates the co-occurrence relationship. (N: the number of nodes. E: the number of links.)

A total of 8,050 authors worldwide had made outstanding contributions to ATAAD research. The knowledge map of the collaborative network based on the authors demonstrated 801 authors and 1,396 collaborations, and the density was 0.004 (Fig. 3D). Lizhong Sun, the most productive author from China, published 61 publications, followed by Liangwan Chen (43 publications),

Table 2
The top 10 productive and co-cited journals.

Rank	Journal	Publications	Citations	IF (2022)	JCR quantile	Rank	Co-cited Journal	Citations	IF (2022)	JCR quantile
1	J Card Surg	143	695	1.778	Q3	1	Ann Thorac Surg	6,224	5.102	Q1
2	Ann Thorac Surg	140	3,888	5.102	Q1	2	J Thorac Cardiovasc Surg	5,349	6.439	Q1
3	J Thorac Cardiovasc Surg	116	3,683	6.439	Q1	3	Eur J Cardiothorac Surg	3,251	4.534	Q1
4	Eur J Cardiothorac Surg	116	2,483	4.534	Q1	4	Circulation	2,975	39.918	Q1
5	Interact Cardiovasc Thorac Surg	103	1,088	1.978	Q3	5	J Vasc Surg	1,216	4.86	Q1
6	J Cardiothorac Surg	98	467	1.522	Q4	6	J Am Coll Cardiol	1,054	27.203	Q1
7	J Thorac Dis	59	342	3.005	Q3	7	Interact Cardiovasc Thorac Surg	642	1.978	Q3
8	Front Cardiovasc Med	52	48	5.846	Q2	8	Eur Heart J	613	35.855	Q1
9	Heart Surg Forum	45	93	0.699	Q4	9	Am J Cardiol	600	3.133	Q3
10	J Cardiothorac Vasc Anesth	37	265	2.894	Q3	10	Ann Cardiothorac Surg	599	4.617	Q1

Junming Zhu (39 publications), and Dongjin Wang (35 publications), whereas the top three most cited authors were Eagle Kim A (1,657 citations), Isselbacher Eric M (1,554 citations), and Nienaber Christoph A (1,536 citations) (Table 1). As shown in Fig. 3D, Lizhong Sun cooperated closely with Junming Zhu, Jun Zheng, Weiguo Ma, and Yongmin Liu. In addition, Eagle Kim A collaborated frequently with Nienaber Christoph A, Bo Yang, and Patel Himanshu J. The co-citation analysis found that Nienaber Christoph A had the highest co-citations (392), followed by Rylski B (379), and Hagan Peter G (352).

3.2. Analysis of journals and Co-cited journals

A total of 314 journals contributed to the ATAAD publications, nine of which exceeded 40 publications. Impact factors (IF) and journal quartiles were analyzed according to Journal Citation Reports 2022. Table 2 lists the top 10 journals with the most ATAAD publications and co-citations. The top three prolific journals were *Journal of Cardiac Surgery* (IF 1.778), *Annals of Thoracic Surgery* (IF 5.102), and *Journal of Thoracic and Cardiovascular Surgery* (IF 6.439). However, the top three journals with the highest citations and co-citations were *Annals of Thoracic Surgery* (3,888 citations, 6,224 co-citations), followed by *Journal of Thoracic and Cardiovascular Surgery* (3,683 citations, 5,349 co-citations), and *European Journal Cardio-thoracic Surgery* (2,483 citations, 3,251 co-citations) (Fig. 4A).

Among the top ten most prolific and co-cited journals, *Circulation* had the highest IF of 39.918, and *Annals of Thoracic Surgery* had the highest citation and co-cited (3,888, 6,224). Most of the journals in Table 2 were classified as Q1 journals, indicating that these journals have high credibility and quality. The dual map overlay of journals was visualized using Citespase to illustrate the subject

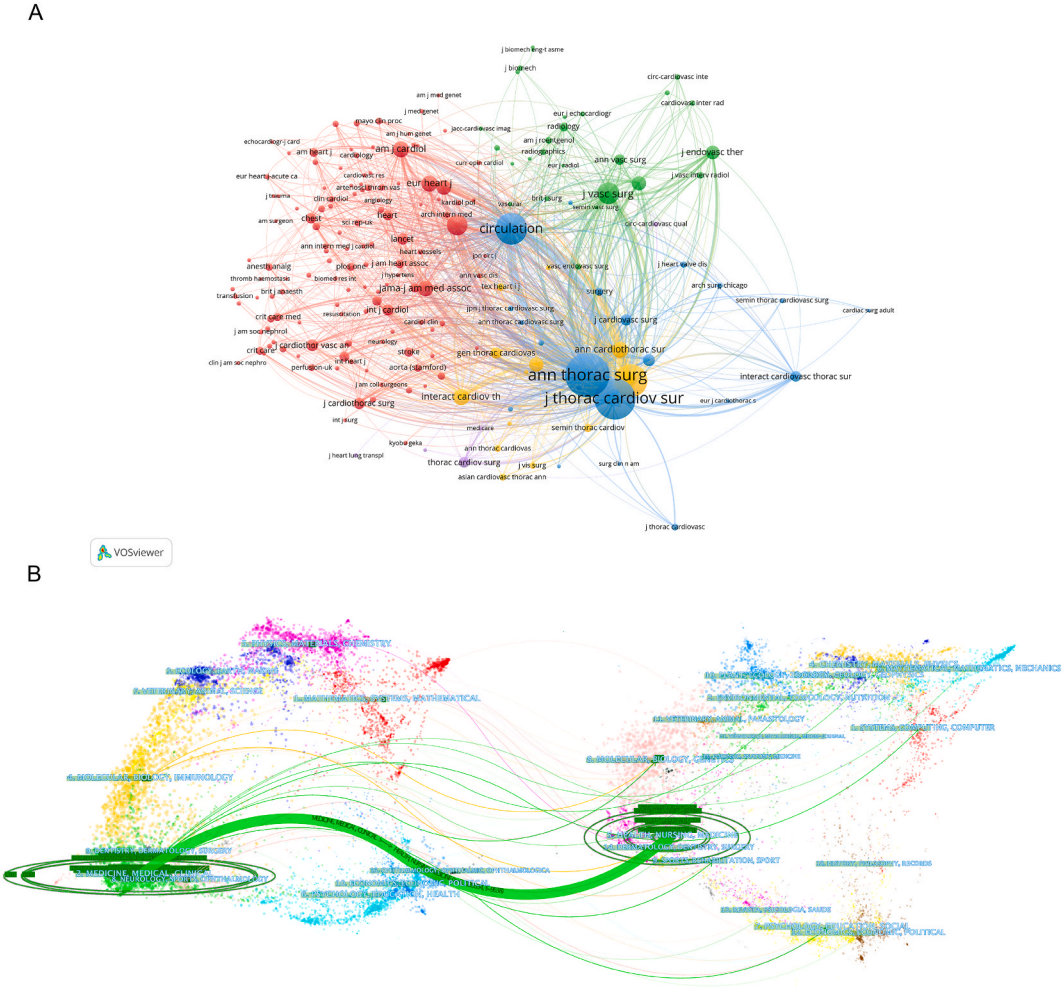


Fig. 4. The visualization of the co-occurrence network of journals and the dual map overlay of journals on ATAAD research from 2002 to 2022. (A) Visualization of the journal co-occurrence network. The different colors indicated various clusters. The strongest co-citation links between journals are represented by lines. (B) Dual map overlay of journals. Citing journals are presented on the left, cited journals are on the right, and the colored paths represent the citation relationships. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

distribution of academic journals [18]. The mapping identifies a colored primary citation pathway, demonstrating that ATAAD publications in health, nursing, and medicine journals were primarily cited by publications in medicine, medical, and clinical journals, respectively (Fig. 4B).

3.3. Keyword Co-occurrence analysis of acute type a aortic dissection research hotspots

Keyword co-occurrence analysis was utilized to detect research themes hotspots shifting and emerging topics of research frontiers in the ATAAD research [19]. A total of 3,583 keywords were extracted from the 1,943 publications after merging synonyms. The top 20 keywords are listed in Table 3 by occurrence and total link strength. Among these keywords, "acute type A aortic dissection", "surgery", and "repair" had been used in over 400 publications, suggesting that surgical repair remains the main treatment measure and research frontier of ATAAD. As shown in Fig. 5A, VOSviewer identified 100 keywords (Author keywords and Keywords Plus) with more than 18 occurrences and classified them into 5 categories based on their common attributes, namely ATAAD, stent graft placement, surgery, total arch replacement, and outcomes.

The overlay visualization of the 100 keywords was used to show the thematic trends of the ATAAD research during different periods (Fig. 5B). The earliest commonly used keyword was "axillary artery" (7 publications, average publication year: 2011.23), while the latest commonly used keyword was "inflammation" (43 publications, average publication year: 2019.09). Supplementary Table S1 summarizes the top ten earliest and latest commonly used keywords. The terms with the highest usage frequency were "echocardiography" (26 publications, average publication year, 2013.36) among the earliest commonly used keywords and "impact" (121 publications, average publication year, 2019.26) among the latest commonly used keywords. Density visualization shows the keywords mapped by their usage frequency (Fig. 5C and D). The keywords "acute type A aortic dissection", "surgery", "repair", "management", "IRAD", and "outcomes" were most commonly used in ATAAD publications.

3.4. Time evolution analysis and citation burstness analysis of keywords in ATAAD publications

Co-occurring keywords were mapped to the time axis using clusters of keywords created using CiteSpace software which consists of 621 keywords and 2,755 co-occurrence relationships (Fig. 6A). As shown in Fig. 6A, nine of the 10 clusters (except "aortic dissection") are still in progress. Among them, "frozen elephant trunk" is the biggest cluster, followed by "outcomes", "hypothermic circulatory arrest", and "in-hospital mortality".

A keyword burst was defined as a large number of frequently cited keywords over a period of time. Keyword bursting is a bibliometric algorithm that identifies new hot spots in a given field based on the strength value and duration time of the burst [20]. From 2002 to 2022, "surgical treatment", "ascending aorta", and "aneurysms" were the top three terms with burst strength values of 12.31, 10.7, and 10.1, respectively. Our results showed that the top 25 keywords with the strongest citation bursts since 2010 may better reflect the current research trend. From 2010 to 2022, the top three terms with the strongest burst strength were "impact", "regurgitation", and "acute kidney injury" (strength = 9.35, 5.51, and 5.49, respectively) (Fig. 6B).

3.5. Co-citation and clustered visualization network of Co-cited reference

CiteSpace was used for co-citation and clustering network analysis of 17,701 citations. The results of mean silhouette S (score = 0.8796) and the overall modularity Q (score = 0.7377) proved that the clustering was thought to be efficient and compelling, with efficient features and definitions for each subdomain. Fig. 7A shows the visual network diagram of the co-cited publications, with a total of 990 nodes and 2,350 links. The top three co-citation ATAAD publications with a high centrality were "Girdauskas E, 2009" (centrality 0.23), "Chiappini B, 2004" (centrality 0.14), and "Santini F, 2007" (centrality 0.13) (Table 4). The most co-citations were P G Hagan in *JAMA* (350), followed by Raimund Erbel in *Eur Heart J* (164). Co-cited ATAAD publications were clustered into 13 main clusters (Fig. 7B), including cerebral protection, aorta and great vessels, aneurysm - false, endograft, frozen elephant trunk, acute kidney injury, stent graft, ascending thoracic aorta, stents, neuroprotection, coagulation, recombinant factor VIIa, pregnancy. The largest 6 clusters are listed in Table 5. Co-cited reference time evolution analysis demonstrated that the cluster "cerebral protection" had the highest degree of citation bursts. Since 2010, "aorta and great vessels", "frozen elephant trunk", and "acute kidney injury" had

Table 3
Top 20 keywords in ATAAD publications from 2002 to 2022.

Rank	Keyword	Occurrences	Total link strength	Rank	Keyword	Occurrences	Total link strength
1	acute type an aortic dissection	1,211	5,488	11	aorta and great vessels	165	962
2	surgery	657	3,664	12	ascending aorta	163	899
3	repair	404	2,284	13	diagnosis	156	828
4	management	386	2,150	14	experience	147	856
5	irad	384	2,240	15	aortic arch	142	837
6	aortic aneurysm	380	1,815	16	impact	121	759
7	total arch replacement	377	2,255	17	endovascular aortic repair	114	634
8	outcomes	368	2,144	18	cardiac surgical procedures	110	510
9	risk factor	317	1,751	19	malperfusion syndrome	108	580
10	mortality	233	1,410	20	stent graft placement	107	590

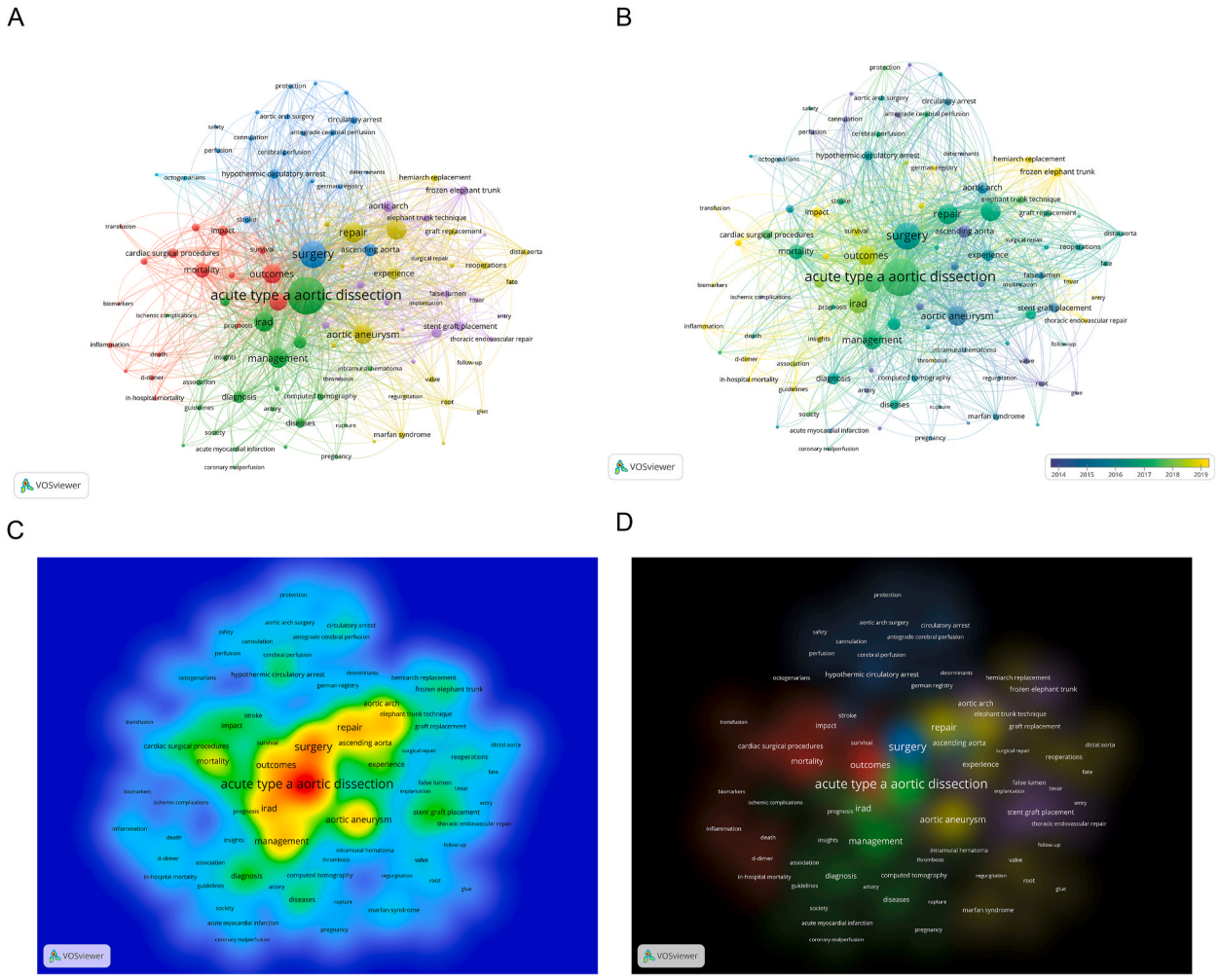
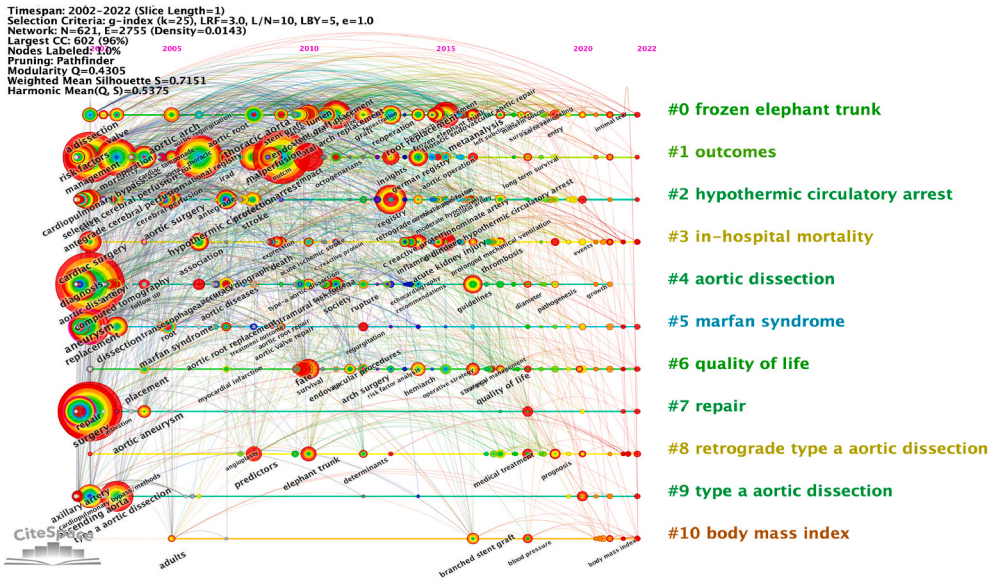


Fig. 5. The visualization of the co-occurrence network and overlay analysis of keywords for ATAAD publications from 2002 to 2022. (A) Visualization of the keyword co-occurrence network. The 100 keywords were divided into five clusters in red, green, yellow, blue, and purple. Each cluster represents a research direction; the size of the circle inside the cluster represents the number of occurrences of the keyword; and the thickness of the lines represents the intensity of its previous connections. (B) Overlay visualization of keyword co-occurrence network. The overlay keyword co-occurrence visualization colors the different clusters according to the timeline. The purple nodes indicate that the keywords have been used in early publications. As time passes, the yellow nodes indicate that the keywords have been commonly used in recent publications. (C) The item density visualization map. The red nodes represent commonly used keywords. (D)The cluster density visualization map. The depth of color nodes represents commonly used keywords. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

been extensively cited and remained citation hotspots. The research seemed to focus on the application of frozen elephant trunks and the protection of vital organs such as the brain and kidneys (Fig. 7C). The top 25 co-cited ATAAD publications with the strongest bursts from 2002 to 2022 are summarized in Fig. 7D. The strongest burstness (strength = 28.55) is an authoritative article entitled "Insights From the International Registry of Acute Aortic Dissection: A 20-Year Experience of Collaborative Clinical Research" [21], published in the *Circulation* by Arturo Evangelista et al., in 2018, with citation burstness from 2020 to 2022.

A search of the *ClinicalTrials.gov* website on March 21, 2023, found 61 ongoing studies related to Acute type A aortic dissection. After excluding all irrelevant publications, a total of 14 publications were screened and are listed in Table 6. Among the 14 studies topics, the clinical trials NCT05346497, NCT05044494, NCT05409469, NCT02164201, NCT05482555, NCT05409677, and NCT04408404 focused on investigating the effects of different surgical procedures on ATAAD. The clinical trials NCT05126771 and NCT03885635 were consistent with the co-citation reference cluster analysis result "frozen elephant trunk", which explored the effect of arch replacement surgery on ATAAD. The clinical trial NCT05039814, which is consistent with the co-citation references cluster analysis result "acute kidney injury", aimed to explore the predictive value of the preoperative level of cystatin C in the occurrence of postoperative acute kidney injury. The clinical trials NCT04962646 and NCT05151536 were consistent with the co-citation reference cluster analysis result "cerebral protection" and "neuroprotection". They aimed to explore postoperative neurological injury in patients

A



B

Top 25 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	2002 - 2022
surgical treatment	2002	12.31	**2002**	2014	
ascending aorta	2002	10.7	**2002**	2012	
aneurysms	2002	10.1	**2002**	2014	
operations	2002	8.8	**2002**	2013	
arch	2002	7.88	**2002**	2007	
axillary artery	2002	6.25	**2002**	2009	
placement	2004	5.08	**2004**	2013	
marfan syndrome	2005	6.12	**2005**	2011	
perfusion	2005	5.51	**2005**	2008	
cannulation	2002	5.44	**2005**	2014	
transesophageal echocardiography	2006	4.99	**2006**	2018	
hypothermic circulatory arrest	2007	6.58	**2007**	2012	
thoracic aorta	2008	7.9	**2008**	2014	
replacement	2002	5	**2008**	2014	
complications	2002	4.5	**2008**	2014	
selective cerebral perfusion	2003	5.42	**2009**	2015	
aortic diseases	2007	4.71	**2010**	2015	
stent graft placement	2011	4.99	**2011**	2014	
regurgitation	2012	5.51	**2012**	2016	
root	2005	5.29	**2013**	2014	
computed tomography	2003	4.99	**2013**	2018	
false lumen	2010	4.5	**2016**	2019	
registry	2013	4.54	**2018**	2019	
impact	2010	9.35	**2019**	2022	
acute kidney injury	2015	5.49	**2020**	2022	

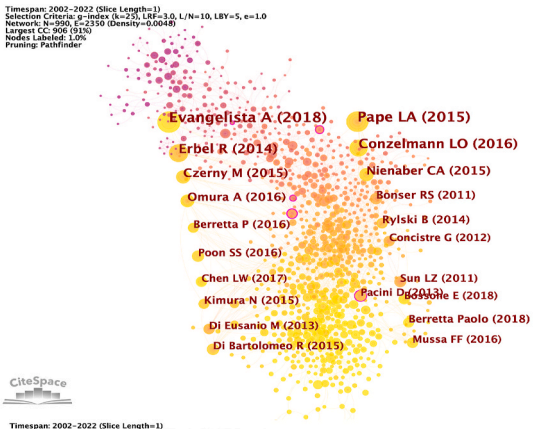
Fig. 6. Time evolution analysis of keywords and the keywords with the strongest citation bursts in ATAAD publications from 2002 to 2022. (A) Visualization map of timeline viewer related to ATAAD research. N = 621, E = 2,755. (B) The top 25 keywords with the strongest citation bursts in ATAAD publications. The length of the red line represents the duration of the burst. The burst strength indicates that the keyword is the main research hotspot in the field of ATAAD. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

with ATAAD. The clinical trials NCT05174767 and NCT03894033 were consistent with the co-citation reference cluster analysis result "stent graft", "stents", and "endograft", and aimed to investigate the effect of stent implantation on dissected aorta repair.

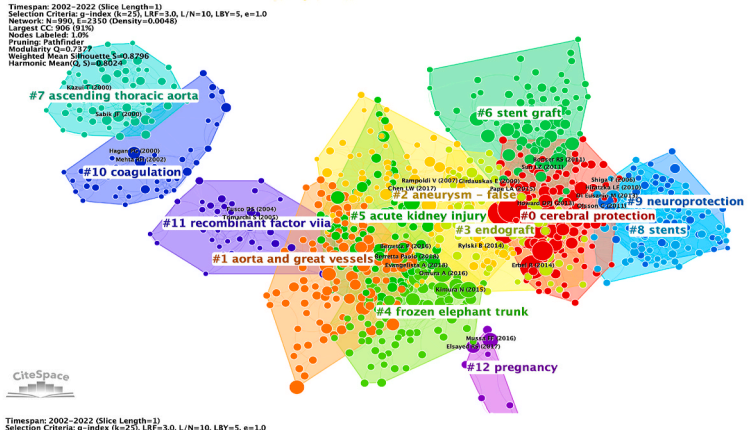
4. Discussion

In an era of knowledge explosion, bibliometric analysis allows new researchers to quickly understand the background, present state, hotspots, and research directions of a particular field. However, to date, no study has provided a comprehensive bibliometric overview of ATAAD research. Therefore, we aimed to quantitatively analyze and visualize 20 years of publications in the ATAAD field using bibliometric tools. This study will help researchers understanding the current status of ATAAD research and what is hot for

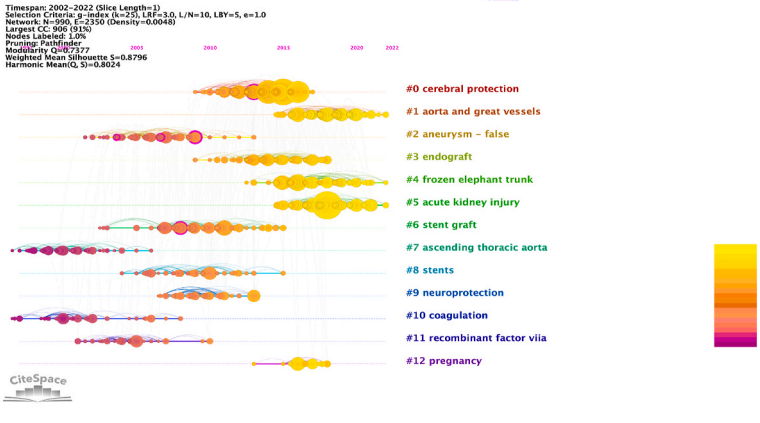
A



B



C



D

Top 25 References with the Strongest Citation Bursts

Type	References	Year	Strength	Begin	End	2002 - 2022
Article	Hagan PG, 2000, JAMA-J AM MED ASSOC, V283, P897, DOI 10.1001/jama.283.7.897, DOI	2000	9.56	2002	2005	
Article	Trimarchi S, 2005, J THORAC CARDIOV SUR, V129, P112, DOI 10.1016/j.jtcvs.2004.09.005, DOI	2005	12.31	2006	2010	
Article	Rampoldi V, 2007, ANN THORAC SURG, V83, P55, DOI 10.1016/j.athoracsur.2006.08.007, DOI	2007	11.55	2008	2011	
Article	Halstead JC, 2007, J THORAC CARDIOV SUR, V133, P127, DOI 10.1016/j.jtcvs.2006.07.043, DOI	2007	10.54	2008	2012	
Article	Zierer A, 2007, ANN THORAC SURG, V84, P479, DOI 10.1016/j.athoracsur.2007.03.084, DOI	2007	8.87	2008	2012	
Article	Geirsson A, 2007, ANN THORAC SURG, V84, P1955, DOI 10.1016/j.athoracsur.2007.07.017, DOI	2007	9.74	2009	2012	
Article	Girdauskas E, 2009, J THORAC CARDIOV SUR, V138, P1363, DOI 10.1016/j.jtcvs.2009.04.059, DOI	2009	9.11	2010	2014	
Review	Hiratzka LF, 2010, CIRCULATION, V121, PE266, DOI 10.1161/CIR.0b013e3181d4739e, DOI	2010	11.18	2011	2015	
Article	Uchida N, 2009, ANN THORAC SURG, V87, P773, DOI 10.1016/j.athoracsur.2008.11.061, DOI	2009	9.29	2011	2014	
Article	Trimarchi S, 2010, J THORAC CARDIOV SUR, V140, P784, DOI 10.1016/j.jtcvs.2009.11.014, DOI	2010	8.62	2011	2015	
Article	Bonser RS, 2011, J AM COLL CARDIOL, V58, P2455, DOI 10.1016/j.jacc.2011.06.067, DOI	2011	14.49	2013	2016	
Article	Sun LZ, 2011, CIRCULATION, V123, P971, DOI 10.1161/CIRCULATIONAHA.110.015081, DOI	2011	11.57	2013	2016	
Article	Concistre G, 2012, ANN THORAC SURG, V93, P450, DOI 10.1016/j.athoracsur.2011.10.059, DOI	2012	9.6	2013	2017	
Article	Rylski B, 2014, ANN SURG, V259, P598, DOI 10.1097/SLA.0b013e3182902cca, DOI	2014	9.44	2014	2019	
Article	Pacini D, 2013, EUR J CARDIO-THORAC, V43, P820, DOI 10.1093/ejcts/ezs500, DOI	2013	9.38	2014	2018	
Article	Easo J, 2012, J THORAC CARDIOV SUR, V144, P617, DOI 10.1016/j.jtcvs.2011.07.066, DOI	2012	8.76	2014	2017	
Review	Erbel R, 2014, EUR HEART J, V35, P2873, DOI 10.1093/eurheartj/ehu281, DOI	2014	23.69	2015	2019	
Article	Howard DPJ, 2013, CIRCULATION, V127, P2031, DOI 10.1161/CIRCULATIONAHA.112.000483, DOI	2013	8.51	2015	2018	
Article	Pape LA, 2015, J AM COLL CARDIOL, V66, P350, DOI 10.1016/j.jacc.2015.05.029, DOI	2015	25.51	2016	2020	
Article	Czerny M, 2015, J AM COLL CARDIOL, V65, P2628, DOI 10.1016/j.jacc.2015.04.030, DOI	2015	15.37	2017	2020	
Article	Nienaber CA, 2015, LANCET, V385, P800, DOI 10.1016/S0140-6736(14)61005-9, DOI	2015	12.18	2017	2020	
Article	Conzelmann LO, 2016, EUR J CARDIO-THORAC, V49, P644, DOI 10.1093/ejcts/ezv356, DOI	2016	15.16	2018	2022	
Article	Poon SS, 2016, ANN CARDIOTHORAC SUR, V5, P156, DOI 10.21037/acs.2016.05.06, DOI	2016	8.85	2018	2020	
Article	Evangelista A, 2018, CIRCULATION, V137, P1846, DOI 10.1161/CIRCULATIONAHA.117.031264, DOI	2018	28.55	2020	2022	
Review	Mussa FF, 2016, JAMA-J AM MED ASSOC, V316, P754, DOI 10.1001/jama.2016.10026, DOI	2016	8.68	2020	2022	

(caption on next page)

Fig. 7. The co-cited reference clustering and time evolution analysis on ATAAD research from 2002 to 2022. (A) Visualization map of co-citation of references on ATAAD research. Nodes marked with purple circles (centrality >0.1) are significant in this co-citation visualization network map. (B) Clustering network visualization of co-citation literature. (C) Timeline visualization view of co-citation clusters identified using CiteSpace. (D) The top 25 most cited publications with the strongest citation bursts on ATAAD research. The length of the red line represents the duration of the burst. The burst strength indicates that the literature is of great significance to the study of the ATAAD field. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 4
The top 10 co-cited publications in ATAAD from 2002 to 2022.

Rank	Title	First author	Journal	Year	Cited frequency	DOI
1	The International Registry of Acute Aortic Dissection (IRAD) - New insights into an old disease	P G Hagan	JAMA	2000	350	10.1001/jama.283.7.897
2	2014 ESC Guidelines on the diagnosis and treatment of aortic diseases	Raimund Erbel	Eur Heart J	2014	164	10.1093/eurheartj/ehu281
3	Presentation, Diagnosis, and Outcomes of Acute Aortic Dissection: 17-Year Trends From the International Registry of Acute Aortic Dissection	Linda A Pape	J Am Coll Cardiol	2015	152	10.1016/j.jacc.2015.05.029
4	Contemporary results of surgery in acute type A aortic dissection: The International Registry of Acute Aortic Dissection experience	Santi Trimarchi	J Thorac Cardiovasc Surg	2005	148	10.1016/j.jtcvs.2004.09.005
5	Predicting death in patients with acute type an aortic dissection	Rajendra H Mehta	Circulation	2002	131	10.1161/hc0202.102,246
6	Total Arch Replacement Combined With Stented Elephant Trunk Implantation A New "Standard" Therapy for Type A Dissection Involving Repair of the Aortic Arch?	Lizhong Sun	Circulation	2011	115	10.1161/circulationaha.110.015081
7	Insights From the International Registry of Acute Aortic Dissection: A 20-Year Experience of Collaborative Clinical Research	Arturo Evangelista	Circulation	2018	106	10.1161/CIRCULATIONAHA.117.031264
8	2010 ACCF/AHA/AATS/ACR/ASA/SCA/SCAI/SIR/STS/SVM guidelines for the diagnosis and management of patients with Thoracic Aortic Disease	Loren F Hiratzka	Circulation	2010	104	10.1161/cir.0b013e3181d4739e
9	Simple risk models to predict surgical mortality in acute type A aortic dissection: The International Registry of Acute Aortic Dissection score	Vincenzo Rampoldi	Ann Thorac Surg	2007	101	10.1016/j.athoracsur.2006.08.007
10	Mortality in patients with acute aortic dissection type A: analysis of pre- and intraoperative risk factors from the German Registry for Acute Aortic Dissection Type A (GERAADA)	Lars Oliver Conzelmann	Eur J Cardiothorac Surg	2016	88	10.1093/ejcts/ezv356

Table 5
Summary of the largest 6 clusters.

Cluster ID	Size	Silhouette	Average Year	Label (LLR)
0	126	0.806	2013	cerebral protection (14.08, 0.001)
1	104	0.876	2018	aorta and great vessels (10.99, 0.001)
2	86	0.845	2006	aneurysm - false (6.11, 0.05)
3	81	0.841	2014	endograft (9.61, 0.005)
4	77	0.894	2017	frozen elephant trunk (42.55, 1.0E-4)
5	76	0.814	2018	acute kidney injury (27.18, 1.0E-4)

determining research directions as well as guiding clinical practice.

4.1. Status quo of ATAAD research

In this study, the VOSviewer and CiteSpace software were used to visualize the development trends and hotspots of ATAAD research. Based on the data published in the WoSCC database from 2002 to 2022, we identified 1,943 original articles and reviews. Before 2009, the number of publications in this field was very low, less than 50 papers per year. The most prolific country, institution, and journal were Japan (54, 24.32%), Michigan University (7, 0.36%), and *Ann Thorac Surg* (54, 2.78%). In the early years, there was a lack of understanding of the pathogenesis and treatment standards for ATAAD, and there was less funding for ATAAD research. A period of rapid development followed. In the following 13 years, the number of publications in this field increased rapidly. The most prolific country, institution, and journal were China (630, 36.61%), Capital Medical University (102, 5.25%), and *J Card Surg* (131, 6.74%). The quantity of publications supported by funding exhibited a gradual increase, with China emerging as the country with the

Table 6
Fourteen clinical trials exploring acute type A aortic dissection that were registered with ClinicalTrials.gov.

NCT number	Status	Study title	Conditions	Sample size (n)	Study type	Study design
NCT05346497	Completed	Surgical Management of the Aortic Root and Long-term Outcomes For Acute Type A Aortic Dissection	Type A Aortic Dissection	1,600	Observational	Observational Model: Case-Control Time Perspective: Retrospective
NCT05044494	Completed	Surgery for Delay-recognized or Defer-operated Type A Aortic Dissection	Aortic Dissection	68	Observational	Observational Model: Cohort Time Perspective: Retrospective
NCT05126771	Completed	Learning Curve of Aortic Arch Replacement Surgery in Chinese Mainland With Stanford Type A Aortic Dissection	Cumulative Sum Learning Curves Stanford Type A Aorta Dissection	139	Observational	Observational Model: Other Time Perspective: Retrospective
NCT05409469	Completed	Clinical Characteristics, Management Patterns and Outcomes of Type A Aortic Dissection: A Sino-US Comparative Cohort Analysis	Aortic Dissection	11,550	Observational	Observational Model: Cohort Time Perspective: Other
NCT05039814	Completed	Prediction of Postoperative Acute Kidney Injury in Patients With Acute Type A Aortic Dissection Using Cystatin C	Aortic Dissection Acute Kidney Injury	249	Observational	Observational Model: Case-Control Time Perspective: Retrospective
NCT04962646	Recruiting	Carbon Dioxide Flooding to Reduce Postoperative Neurological Injury Following Surgery for Acute Type A Aortic Dissection	D000784 D020521	80	Interventional	Allocation: Randomized Intervention Model: Parallel Assignment Intervention Model Description:Prospective, randomized, controlled, patient- and reviewer blinded interventional study. Masking: Double (Participant, Outcomes Assessor) Primary Purpose: Prevention
NCT02164201	Completed	Post Market Surveillance Study Evaluating BioFoam Surgical Matrix in Cardiovascular Surgery	Cardiovascular Procedures; Thoracic Aortic Aneurysm; Aortic Valve Replacement; Type A Aortic Dissection	75	Observational	Observational Model: Cohort Time Perspective: Prospective
NCT05482555	Recruiting	Percutaneous Plug-based Femoral Arteriotomy Closure Device Use in Surgery for Acute Type A Aortic Disection	Aortic Dissection	200	Observational	Observational Model: Cohort Time Perspective: Prospective
NCT05409677	Completed	Perioperative Eosinophils Their Recovery in Type An Acute Aortic Dissection Prognosis	Acute Aortic Dissection	274	Observational	Observational Model: Cohort Time Perspective: Retrospective
NCT04408404	Completed	Factors Influencing Perioperative Mortality in Type An Acute Aortic Dissections Operated at Dijon University Hospital	Aortic Dissection	230	Observational	Observational Model: Cohort Time Perspective: Retrospective
NCT05174767	Recruiting	PERSEVERE- A Trial to Evaluate AMDS in Acute DeBakey Type I Dissection	Acute Aortic Dissection	93	Interventional	Allocation: N/A Intervention Model: Single Group Assignment Masking: None (Open Label) Primary Purpose: Treatment
NCT05151536	Completed	Effects of Different Doses of Epinephrine on Biomarkers of Nervous System Ischemia-reperfusion Injury in Patients with Stanford Type A Dissection	Adrenaline; Aortic Dissection; Drug Dose; Nervous System; Ischemia Reperfusion Injury	132	Observational	Observational Model: Other Time Perspective: Retrospective
NCT03885635	Recruiting	Hemiarch vs Extended Arch in Type 1 Aortic Dissection	Aortic Dissection	182	Interventional	Allocation: Randomized Intervention Model: Parallel Assignment Intervention Model Description: Hemiarch vs. extended arch repair in the setting of acute DeBakey type 1 aortic dissections Masking:

(*continued on next page*)

Table 6 (*continued*)

NCT number	Status	Study title	Conditions	Sample size (n)	Study type	Study design
NCT03894033	Recruiting	Dissected Aorta Repair Through Stent Implantation (DARTS): A POST-MARKET REGISTRY	Aortic Dissection Acute DeBakey I Dissection Acute Type A Dissection	100	Observational	None (Open Label) Primary Purpose: Treatment Observational Model: Cohort Time Perspective: Prospective

highest number of publications (Supplementary Fig. S1). Advances in medical and critical care technology, improved surgical protocols, and increased research grants led to a flood of innovative research. Based on the Polynomial function fitting prediction model indicated that nearly 425 articles related to ATAAD will be published in 2025. Thus, we can speculate that research on ATAAD will remain a hotspot in the future.

4.2. Major contributing countries/regions, institutions, authors, and journals

In terms of countries/regions, the analysis results demonstrated significant differences in the number of articles published between countries, with only six countries exceeding 100 publications. China published the largest number of publications. However, the citation rate of its publications was lower than that of other countries such as the United States, Japan, Germany, and Italy. Interestingly, the United States was about twice as much cited as China (Table 1). China had more ATAAD publications than the United States, probably because Lizhong Sun optimized the treatment of ATAAD with the frozen elephant trunk stent and promoted it throughout China so that related clinical studies and clinical trials were conducted on a large scale. Chinese researchers have developed great enthusiasm for the study of ATAAD, and China has paid more attention to the treatment and funding of this disease. The number of citations is a strong indicator of research quality [22]. Notably, Germany and Japan have fewer publications, but their publications are cited more often than those of China. The above results suggest that the quantity of publications should be increased along with the quality of publications. In the following years, these high-yield nations could consider translating their large number of publication sizes into high-impact studies. According to the visualized network diagram (Fig. 3B), the United Kingdom, Italy, and the United States were working very closely with other countries and benefited from exchange and collaborations. Therefore, academic barriers between countries/regions should be removed and collaborations should be strengthened to promote the progress of ATAAD research.

In terms of institutions, Capital Medical University and Fujian Medical University had made great contributions to ATAAD research. Capital Medical University had published the largest number of research results and made extensive domestic collaborations but lacked international collaborations. Interestingly, the analysis of co-cited authors showed that Christoph A Nienaber, the most cited author (392 citations), was from the Royal Brompton & Harefield NHS Foundation Trust, London, United Kingdom. The second and third most co-cited authors were Bartosz Rylski and P G Hagan from the University Heart Center Freiburg, Germany, and the University of Pennsylvania, the United States, respectively. However, the most frequently co-cited literature was by P. G. Hagen, indicating that he has a comparatively authoritative academic status in the field.

Journal publication and co-citation analysis can provide a strategy for researchers to select appropriate journals for submission, so that their research can be received more quickly, thus promoting the progress of research in the field. The majority of relevant papers were published in Q1 journals, with more co-citations appearing in internationally renowned journals, such as *Ann Thorac Surg*, *Circulation*, *J Am Coll Cardiol*, *JAMA*, and *Eur Heart J*. The journal with the highest citation and co-citation rate was *Ann Thorac Surg* (IF = 5.102, JCR Q1), indicating high authority and credibility. However, there is only a 40% match rate between the top ten most cited and most prolific journals, indicating that there is an imbalance between the quantity and quality of ATAAD research, so strengthening international collaboration among scholars is the cornerstone of improving quality.

4.3. Knowledge base

Among the top 10 co-cited references, two are referred to practice guidelines in the diagnosis and treatment of aortic diseases [1, 23], one is related to the process improvement of aortic dissection surgery [24], one is related to death prediction based on institutional data from the German Registry for Acute Aortic Dissection Type A (GERAADA) [25], and notably, six were contributed by the International Registry of Acute Aortic Dissection (IRAD). IRAD is the world's largest and best-known aortic dissection database, including 55 active sites in 12 countries, and has become the benchmark and paradigm for aortic dissection research. The most cited publication is the article published in JAMA entitled "The International Registry of Acute Aortic Dissection (IRAD) - New insights into an old disease", a multicenter study showed that the clinical manifestations of acute aortic dissection were varied. Only 31.6% of patients had aortic regurgitation, and 15.1% had pulse insufficiency. Therefore, it is necessary to be highly suspicious of ATAAD in patients with related symptoms. At the same time, despite surgical advances, in-hospital mortality (26%) remains high [26].

In the last two decades, only 2 practice guidelines on aortic disease have been published [1,23], and both were proposed at least 8 years ago. Recently, a new guideline entitled "2022 ACC/AHA Guideline for the Diagnosis and Management of Aortic Disease" proposed by the American Heart Association makes the following key points: 1) recommending immediate operative repair of the

ascending aorta for ATAAD patients with renal, mesenteric, or lower extremity malperfusion; 2) recommending aortic valve resuspension rather than replacement for ATAAD patients without significant aortic valve leaflet pathology; 3) recommending aortic valve replacement with a mechanical or biological valve conduit for conditions such as extensive aortic root disruption, root aneurysm, or known genetic disease; 4) recommending open distal anastomosis for ATAAD patients undergoing aortic repair to prolong survival and increase false lumen thrombosis rates; 5) recommending Hemiarch repair rather than more extensive arch replacement for ATAAD patients without an arch intimal tear or significant arch aneurysm [27]. It's worth noting that the update of aortic disease guidelines has been relatively slower than that of other cardiovascular diseases, possibly because aortic dissection is an urgent and lethal condition that prevents clinical trials from being conducted.

4.4. The hotspots and trending

Keywords co-occurrence (Table 3, Supplementary Table S1, and Fig. 5) was used to illustrate the hotspots in a professional field [28], and the timeline view (Fig. 7) was used to show the evolution of new hotspots [29]. Table 3 and Fig. 5 show commonly used keywords in ATAAD research, including acute type A aortic dissection, surgery, repair, management, IRAD, aortic aneurysm, total arch replacement, outcomes, risk factor, and mortality, which were regarded as the research hotspots in ATAAD. With the deepening of research on ATAAD, new topics emerge in an endless stream, which to some extent represents the future research direction (Fig. 6). In the germination stage (2002–2005), rising terms included surgical treatment, ascending aorta, and aneurysm. Next, in the stable-growth stage (2005–2016), the emerging keywords are more focused on the research of related diseases, vital organ protection, and the improvement of surgical procedures, including Marfan syndrome, perfusion, hypothermic circulatory arrest, selective cerebral perfusion, stent graft placement. After a long period of clinical practice to further the understanding mechanism of ATAAD, emerging keywords have the strongest citation bursts for terms such as registry, impact, and acute kidney injury (2018–2022). According to the cluster analysis in the ATAAD field, the five top keyword clusters are the frozen elephant trunk, outcomes, hypothermic circulatory arrest, in-hospital mortality, and repair, which are mainly related to the surgical treatment and clinical prognosis of ATAAD (Fig. 6A). In just 70 years, surgical procedures for the treatment of ATAAD have advanced tremendously. Back in the 1950s, De Bakey et al. carried out the first replacement of the aortic arch with a homograft prosthesis, laying the foundation for the surgical treatment of AD [30]. In 1983, the use of a two-stage elephant trunk stent (traditional elephant trunk stent) for the treatment of aortic aneurysms was proposed by Borst et al. [31]. However, this elephant trunk stent has many limitations, such as the free-floating of the graft segment forming the trunk within the descending aortic lumen, which hinders thrombosis between the graft segment and the aneurysmal aortic wall, further affecting vascular remodeling. The elephant trunk prosthesis must be attached directly to the distal descending portion of the aorta or needs to be enlarged to the desired level, thus, requiring a second surgery. However, inserting the prosthetic graft into the true lumen of the ATAAD is very difficult [32]. At the same time, deaths from intraoperative residual aortic aneurysm rupture have been reported [33]. In 2003, Karck et al. suggested the application of a self-expanding stent to preserve the distal end of the elephant trunk and avoid the complications associated with traditional elephant trunk stent surgery [34]. However, the self-expanding stent only preserved the distal end of the elephant trunk, meanwhile, it was difficult to choose the appropriate size [35]. What's more, it may cause a high risk of intimal injury. Lizhong Sun combined the advantages of open surgery and interventional surgery to optimize the frozen elephant trunk stent, which is why this procedure is called "Sun's surgery" [36]. Sun et al. demonstrated that this procedure may be a new standard therapy for ATAAD [24]. According to accumulated evidence from clinical studies, hypothermic circulatory arrest [37] and anterograde cerebral perfusion [38] may play an important role in reducing complications, reducing mortality, and improving prognosis. Despite the fact that the utilization of total arch replacement (TAR) in conjunction with frozen elephant trunk (FET) represents the most efficacious therapeutic approach for ATAAD, there is still controversy regarding the optimal strategy for hypothermia, cerebral perfusion, and vital organ protection. A new strategy was called the "brain-heart-first" for the surgical treatment of ATAAD in which the cardiac ischemic time was reduced and better protection for the brain was achieved by changing the anastomosis order and optimizing the management of the cardiopulmonary bypass [39]. Compared with the conventional method, this strategy is more effective in reducing operative difficulty, postoperative complications, and 30-day mortality.

Keyword co-occurrence analysis demonstrated that the foci of research have gradually shifted to focus on surgical procedures such as frozen elephant trunks, biomarkers such as D-dimer, poor multiorgan perfusions such as renal, mesenteric, or lower extremity malperfusion, and inflammation mechanism of ATAAD in recent years (Supplementary Table S1 and Fig. 5B). Feng et al. demonstrated that an D-dimer level was an independent risk factor for acute kidney failure, MODS (multiple organ dysfunction syndrome), gastrointestinal bleeding, and mortality (D-dimer >14.5 mg/ml) [40]. Liu et al. also found that an elevated D-dimer level at the time of admission was associated with the risk of postoperative complications occurred within 90 days in patients with ATAAD who underwent TAR and FET [41]. Zhang et al. constructed Nomogram images in the perioperative period to predict acute kidney injury after ATAAD [42]. Wang et al. demonstrated that the uric acid-to-albumin ratio was an independent predictor for long-term mortality of patients with ATAAD (sensitivity = 69.6%, specificity = 51.8%) [43]. These results indicate that the search for effective serologic markers is of great importance for the diagnosis and prognosis prediction of ATAAD and is also the foci of ATAAD research in the future. Inflammation has been reported to be associated with the main pathological process of ATAAD [44–46]. Lian et al. showed that metabolic reprogramming of macrophages activated HIF-1α and promoted aortic dissection progression through the HIF-1α-ADAM17 pathway, suggesting that inhibiting HIF-1α in macrophages may be a potential therapeutic strategy for aortic dissection [47]. Liu et al. illustrated that the use of methylprednisolone-loaded stent prevented aortic degradation by regulating inflammation in AD [48]. The management of ATAAD involves many aspects [49]. Meanwhile, epidemiology, pathological mechanism, prevention, diagnosis, and perioperative management need more attention.

The emerging themes of a field could also be characterized by the publications with wide citations [50]. The ATAAD publication

with the strongest citation burstness is entitled "Insights from the International Registry of Acute Aortic Dissection: A 20-Year Experience of Collaborative Clinical Research" [21] published by Arturo Evangelista et al. in the *Circulation* in 2018, with citation burstness from 2020 to 2022. This systematic review will provide strong evidence for clinical decision-making and management of aortic dissection by summarizing the key lessons learned from IRAD over the past 20 years. More importantly, in addition to the review just mentioned, two other papers are among the top 25 with the strongest citation burstness (Fig. 7). These papers deserve further discussion because they represent the most recent emerging topics in the field of ATAAD [51]. The first article (burst strength = 15.16) was published in 2016 in the *European Journal of Cardio-Thoracic Surgery* by Lars Oliver Conzelmann et al. The citation burst lasted for 4 years (2018–2022). In combination with age, coma, or cardiopulmonary resuscitation, 30-day mortality was increased (all $P < 0.0001$). Meanwhile, the risk of death was also increased in patients with multi-organ malperfusion ($P < 0.0001$). The ATAAD publication with the second strongest citation burstness was published in *JAMA* by Firas F Mussa et al., in 2016 (strength = 8.68, 2020–2022). This review concluded that the presence of acute aortic syndrome (AAS) should be considered in patients with acute chest or back pain, based on 82 studies (2 randomized clinical trials and 80 observational studies) involving 57,311 patients. However, given the high mortality and the proximity of the aortic valve and large vessels (with the potential for dissecting complications like tamponade), ATAAD requires immediate open surgery to replace the ascending aorta.

ATAAD is the most lethal aortic disease with high morbidity and mortality. Saving patients' lives is the first priority in the treatment of ATAAD [52]. The most effective approach is to take a pathology-oriented approach with the total or partial replacement of the ascending aorta according to the tearing site [53]. However, there are many pressing challenges in the management of ATAAD, such as total *vs* hemi-arch replacement, unilateral *vs* bilateral perfusion, and optimal temperature of hypothermic circulatory arrest.

With the deepening of knowledge and technological development of ATAAD, we identified some new surgical techniques such as "arch-first" and "brain-heart-first" through bibliometric analysis, some new diagnostic biomarkers such as d-dimer, ST2, and IL33 [54], and potential therapeutic targets such as inflammation, apoptosis, and ferroptosis [6,55]. From the above analysis, clinical studies accounted for the majority of the retrieved literature, while basic studies were relatively few. The top 10 most cited publications and the top 10 most used keywords were all related to clinical research. The current clinical research was mainly focused on the study of surgical procedures. Changes in surgical procedure (e.g., "brain-heart-first") will improve postoperative patient survival and reduce complications. Although many clinical trials related to ATAAD are ongoing, most studies have focused on the effect of surgical approach on patient prognosis. Although surgery is the main treatment for ATAAD, we should actively search for the pathogenesis of ATAAD to fundamentally inhibit and alleviate ATAAD. More attention should be paid to the pathogenesis of ATAAD, such as smooth muscle cell death and phenotypic transformation, involvement of immune cells in inflammatory mechanisms, and hemodynamic effects. Although ATAAD-funded research is increasing year by year, it is mainly focused on clinical aspects, and more funding is needed for basic research in the future. Currently, there are no effective molecular or pathway-targeted interventions for the treatment of ATAAD. Future scientific research should invest more in basic research.

4.5. Limitations

Although the use of bibliometric tools allows for more objective analysis and quantitative results on current hotspots and trends of ATAAD research compared to traditional reviews. However, the present study still has limitations. Only English-language documents were included in our study. Some non-English literature on ATAAD research tends to be neglected, such as some German articles and Spanish articles. They may contain a lot of important research and knowledge but are overlooked because of language barriers. The non-English language publications of ATAAD research were listed in Supplementary Table S2. In addition, owing to limitations of the CiteSpace software, we have only included articles from WoSCC. Although most ATAAD publications are included in WoSCC, other public databases like Embase, Scopus, and PubMed are also considered authoritative by researchers [56–59]. Because the proportion of articles in this section is not high, we believe that these articles do not affect the main findings of this study. Finally, articles that are highly cited or from high-impact journals may have some bias effect on bibliometric analysis, because these articles are more likely to receive attention and be recognized by the researchers, thus increasing their citations.

5. Conclusion

The present study systematically analyzed ATAAD using the bibliometric method. Over the past 20 years, ATAAD research has evolved significantly, with a roaring trend gradually. The increasing number of ATAAD publications in prestigious international journals indicates an increasing importance of ATAAD research. China and the United States are the major contributors to this field of research, while collaborations and communication among countries and institutions still need to be strengthened. In addition, ATAAD research is mainly focused on clinical trials; extensive basic research is needed to explore the pathophysiological mechanisms of ATAAD and promote the clinical translation of its research results. Currently, ATAAD research is focused on surgical replacement, postoperative inflammation, and outcomes, which are pivotal to the improvement of treatment efficacy and prognosis prediction for patients with ATAAD. The theoretical basis for targeting inflammation in the treatment of ATAAD needs further research.

Data Availability Statement

The original data in this article will be available from corresponding author.

Author contributions

Zhen Qi: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Ri Tang: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper. Qiuguo Wang; Yifan Zeng: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data. Ling Tan; Hao Tang: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Additional information

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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