



# Research Status and Future Trends of Angioplasty: A Bibliometric Analysis in CiteSpace

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## Abstract

**Introduction** Angioplasty, with or without stenting, is a nonsurgical procedure to open blocked or narrowed coronary arteries due to underlying atherosclerosis. While there is ample literature on coronary heart disease research, the literature search found no bibliographic studies that quantified angioplasty studies. This study was initiated using bibliometric analysis to identify trends in angioplasty over the past twenty years.

**Methods** The study data was searched from the Web of Science Core Collection (WoSCC). The study data included 11,429 studies published between 2001 and 2021 downloaded from the WoSCC. CiteSpace V.5.8. was used to analyze the intellectual structure and identify upcoming patterns.

**Results** Over the last two decades, the number of publications in this discipline has decreased. Data from 2021 did not exceed (414) and fell by half compared with 2001 (805). The keyword analysis showed that “coronary angioplasty” recorded the strongest citation burst 26.59 for the years 2001 to 2005. For the most recent data from 2018 to 2021, the strongest citation burst was recorded for the keyword “outcome” (25.64).

**Conclusion** This study was an exploratory attempt to identify trends in angioplasty research over the past two decades to deliver relatively unbiased and complete data on the scientific activity performed by authors worldwide. The number and percentage of published articles gradually decrease over time, which is a new finding, highlighting the need for further study of angioplasty, in particular why the trends have decreased over time.

## Keywords

- angioplasty
- endoluminal repair
- percutaneous transluminal angioplasty
- bibliometric analysis
- trends

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## Introduction

Cardiovascular disease (CVD) is a health condition affecting the heart or blood vessels.<sup>1–3</sup> CVD is associated with the accumulation of fatty deposits inside arteries (atherosclerosis), an increased risk of blood clots, and damage to arteries in organs such as the brain, heart, kidneys, and eyes.<sup>4,5</sup> CVDs are the leading cause of death worldwide—17.9 million deaths annually, an estimated 32% of all deaths. In addition, approximately four out of five deaths from CVDs are associated with heart attacks and strokes, and one-third of these deaths occur prematurely in people under 70.<sup>2</sup>

Some of the most significant behavioral risk factors for CVDs include unhealthy diet, physical inactivity, tobacco use, and alcohol abuse.<sup>4–6</sup> Hence, the American Heart Association has suggested seven recommendations to decrease CVD risk: avoiding smoking, being physically active, eating healthy, and keeping normal blood pressure, body weight, glucose, and cholesterol levels.<sup>4,7</sup> In addition, evidence suggests that health policies that create a suitable environment to make healthy choices affordable and accessible are important in motivating people to adopt and maintain healthy behaviors, thereby reducing the risk of morbidity and prevalence of CVD.<sup>3,7</sup> Prevention and treatment of CVDs range from therapeutic strategies such as medical treatment and coronary artery bypass grafting, with angioplasty being the most common procedure.<sup>8</sup>

Angioplasty, with or without stenting, is a nonsurgical procedure to open blocked or narrowed coronary arteries due to underlying atherosclerosis.<sup>8,9</sup> The procedure involves inserting an inflatable balloon catheter through the skin of the extremities and inflating the balloon as it crosses the stenotic artery. It presses the intraluminal plaque of atherosclerosis against the artery wall and widens the luminal diameter, thereby normalizing blood flow to the myocardium.<sup>8,9</sup>

Angioplasty has two main approaches for catheterization: transradial and transfemoral.<sup>8,10,11</sup> Transradial methods are associated with longer procedures, higher irradiation, anatomical variations that may lead to catheterization failure, and radial artery spasms. The transfemoral approach is a more classical procedure associated with easy access and shorter exposure time. At the same time, access site complications are more common, especially in obese patients. Moreover, since the femoral artery is the sole source of blood for the leg, the likelihood of ischemia is higher than with a transradial approach.<sup>8,10,11</sup>

While angioplasty is a breakthrough in reducing morbidity and mortality from CVD, as with all types of surgery, this procedure carries the risk of complications during or after angioplasty.<sup>3,8</sup> For instance, bleeding or bruising under the skin where the catheter was inserted. More serious but less common complications include damage to the artery into which the sheath was inserted, an allergic reaction to the contrast agent used during the procedure, damage to an artery in the heart, excessive bleeding requiring a blood transfusion, heart attack, stroke, or death. Another rare but serious complication of angioplasty is iatrogenic coronary

artery perforation due to the main complex lesion, which occurs in 0.1 to 0.8% of the total number of angioplasty cases.<sup>8,12,13</sup>

In the past few years, there has been significant interest in angioplasty research, but only a few review articles on angioplasty procedures and outcome measures have been published worldwide. Given that the number of CVDs continues to grow, it is necessary to analyze the research on angioplasty and its impact on coronary heart disease research.<sup>2,5,6</sup> One of the consequential assessment methods in applied science can be bibliometric analysis, a rigorous method for examining and analyzing large amounts of scientific data to identify new and emerging data in an area of research interest.<sup>14,15</sup> As such, while there is ample literature on coronary heart disease research, the literature search found no bibliographic studies that quantified angioplasty studies. Consequently, this study was initiated using bibliometric analysis to identify trends in angioplasty over the past 20 years.

## Materials and Methods

The database was searched between December 2020 and June 2021. The study data was searched from the Web of Science Core Collection between 2001 and 2021. CiteSpace was used to analyze and visualize patterns in scientific literature derived from WoS. This is a Java-based application for analyzing knowledge maps consisting of nodes and links. This analysis gives a complete picture of the overall development of a particular research area of interest, thus creating networks.

This view of the flow of periodical literature was already advocated over 40 years ago by Price.<sup>16</sup> Hence, defining articles as nodes or vertices, and citations as links or edges of a network allows graph theory methods to be applied to bibliometrics. Different nodes in a map represent elements such as country, cited journals, keywords, authors, and cited authors. The CiteSpace parameters were as follows: time slice (2001–2021), years per slice (1), term source (all selections), node type (select one at a time), crop (navigator), and visualization (cluster view, static, show internetwork).

All databases were searched using Boolean operators (AND, OR, NOT) expressed in English through a combination of words in a single search (► **Table 1**).

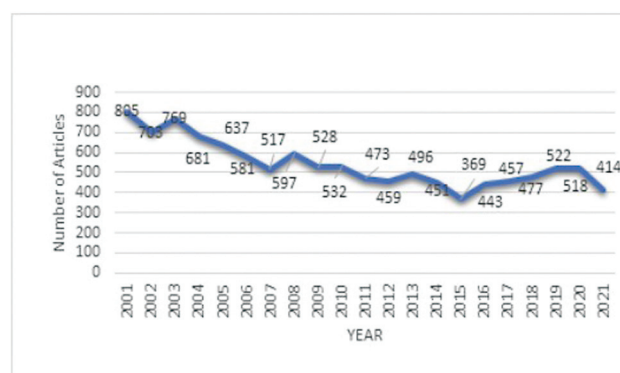
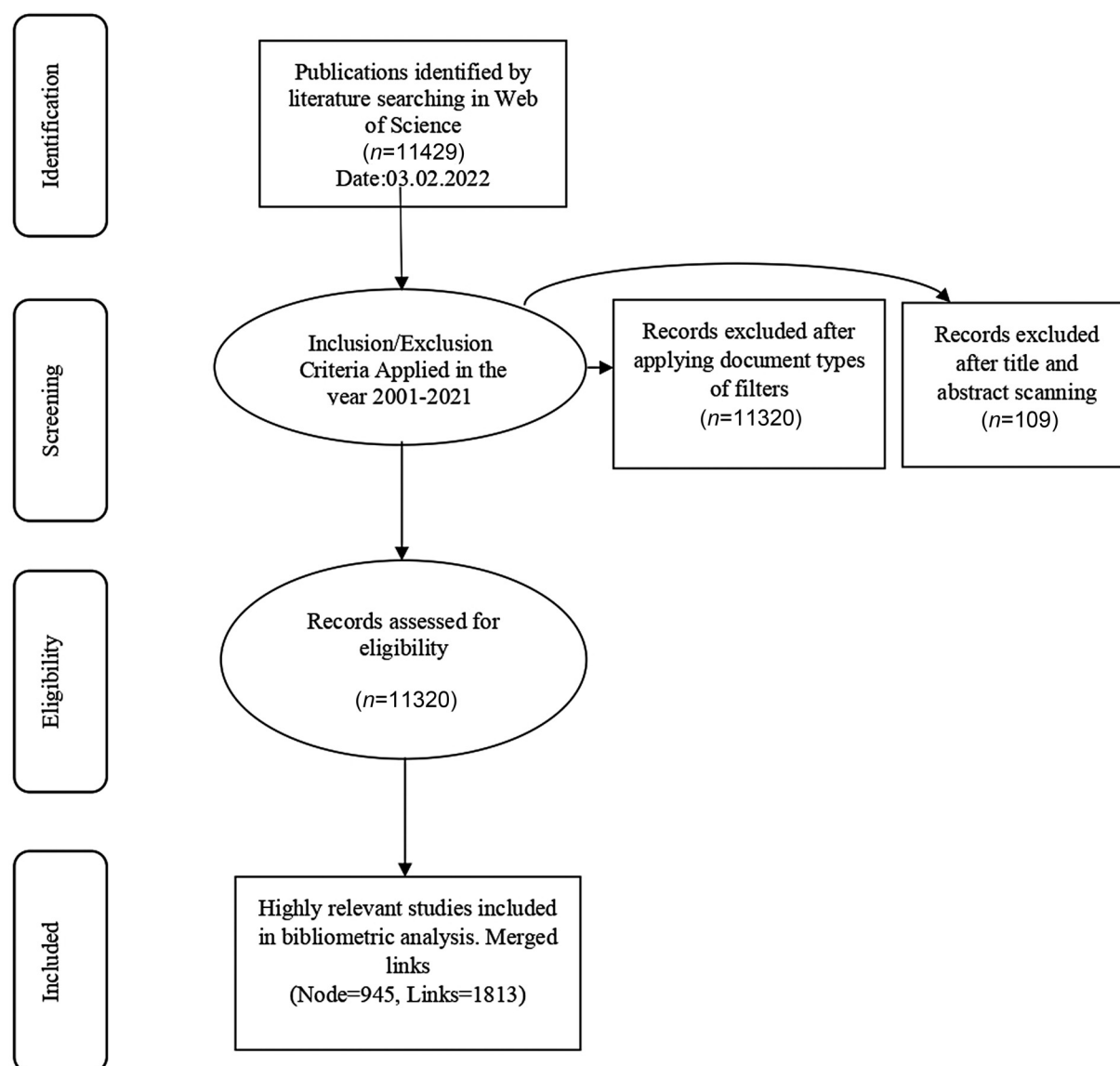
## Results

With the aim of knowing the research to identify trends in angioplasty research over the past 20 years, a total number of 11,429 publications were obtained from the WOS database between 2000 and 2021 (► **Fig. 1**).

► **Fig. 2** shows publication trends from 2001 to 2021. Although the number of publications was declining from 2001 to 2015, since 2016 the number of publications has started to increase slightly. However, data from 2021 did not exceed (414) and fell by half compared with 2001 (805).

**Table 1** Web of science core collection keyword search for articles

Date	December 2021 and February 2022
Publication dates	2001 to 2021
Language	English
Search string	Angioplasty (Title) or Endoluminal Repair (Title) or Endoluminal Repairs (Title) or Percutaneous Transluminal Angioplasty (Title) or Angioplasty (Title) or Percutaneous Transluminal (Title) or Transluminal Angioplasty (Title) or Transluminal Angioplasty (Title) and 2021 or 2020 or 2019 or 2018 or 2017 or 2016 or 2015 or 2014 or 2013 or 2012 or 2011 or 2010 or 2009 or 2008 or 2007 or 2006 or 2005 or 2004 or 2002 or 2003 or 2001 (Publication Years)

**Fig. 2** Publication trends from 2001 to 2021.**Fig. 1** Four-phase flow diagram of data extraction and filtration process of angioplasty literature.

**Table 2** Top 20 highly cited references

Burst	Degree	Cent	Author	Year	Source	Vol	Half-life
134	50.81	34	Keeley EC	2003	Lancet	361	1.5
105	47.2	33	Yadav JS	2004	New Eng J Med	351	2.5
98	42.26	15	Norgren L	2007	J Vasc Surg	45	2.5
95	40.65	46	Galie N	2016	Eur Heart J	37	2.5
94	36.28	30	Stone GW	2002	New Eng J Med	346	1.5
80	35.45	33	Tepe G	2015	Circulation	131	3.5
77	41.24	12	Katsanos K	2018	J Am Heart Assoc	7	1.5
72	31.94	26	Grines CL	1999	New Eng J Med	341	2.5
70	29.11	44	Brown MM	2001	Lancet	357	2.5
62	34.17	30	Mizoguchi H	2012	Circ-Cardiovasc Inte	5	3.5
61	28.51	36	Rosenfield K	2015	New Eng J Med	373	3.5
60	29.37	11	Van de Werf F	2008	Eur Heart J	29	2.5
59	30.39	9	Steg PG	2012	Eur Heart J	33	2.5
58	27.1	26	Ringleb PA	2006	Lancet	368	2.5
57	26.63	23	Mas J	2006	New Eng J Med	355	1.5
57	21.39	16	Morice M	2002	New Eng J Med	346	1.5
57	26.41	28	Bradbury AW	2005	Lancet	366	3.5
57	23.67	25	Montalescot G	2001	New Eng J Med	344	2.5
55	20.77	18	Andersen HR	2003	New Eng J Med	349	1.5
52	24.28	21	Schillinger M	2006	New Eng J Med	354	2.5

\*Burst—Citation burst is a measure of the most active research area, indicating that a particular publication is associated with a citation burst over the course of several years or 1 year.

\*\*Degree—The degree of a node in a network is the number of connections or edges the node has to other nodes.

\*\*\*Half-life is the median age of the citations produced by a journal during the *Journal Citation Reports* (JCR) year.

► **Table 2** shows the top 20 cited references ranked by citation burst being more than 52. The most highly cited reference was by Keeley EC (2003) a quantitative review of 23 randomized trials looking into primary angioplasty versus intravenous thrombolytic therapy for acute myocardial infarction. The article was published in the *Lancet*, with the citation half-life being 1.5 at the degree of 50.81. This article was then followed by the study of Yadav JS (2004), a randomized control trial looking into protected carotid-artery stenting versus endarterectomy in high-risk patients. The manuscript was published in the *New Eng J Med* with a citation burst being 105 at a degree of 47.2. As it can be further seen in ► **Table 2**, the most cited eight references were articles published in the *New Eng J Med*, followed by the *Lancet* with four references.

► **Table 3** and ► **Fig. 3** summarize the list and map of the top 15 co-citation networks of journals, with *Circulation* recording 4406 co-citation networks, followed by *J Am Coll Cardiol* 3753, and *New Eng J Med* 3458 with a citation half-life being 7.5 years. Generating a co-citation journal map using CiteSpace resulted in 47 highest degree for the *Circulation* journal (► **Table 3**). However, as shown in ► **Fig. 3**, there was not much difference in the degree of co-citations between the journals. The lowest co-citation networks were recorded for the journal *Heart* with a citation half-life being 8.5 years.

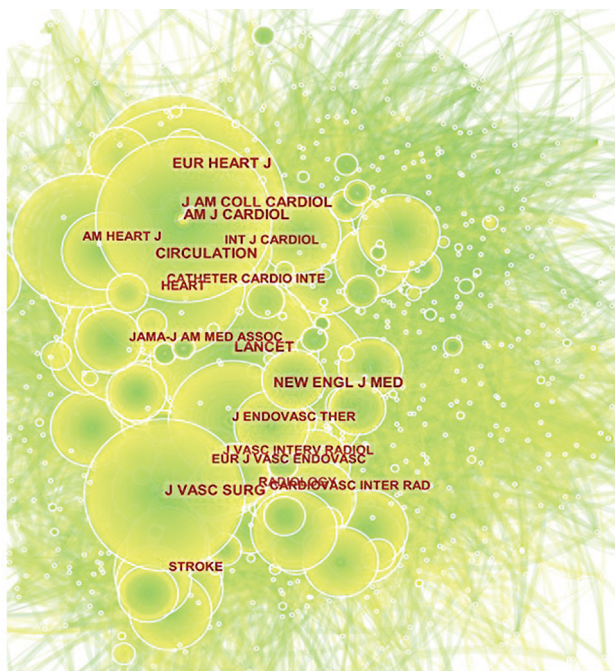
The overall citation half-life data for the journal co-citation network was as low as 5.5 years and as high as 10.5 for the year 2001 the most active year of published papers.

An analysis in terms of co-occurrence frequency and centrality revealed that the hot keywords were “Balloon angioplasty” (716), followed by “Disease” (679) and “Intervention” (536), with “Trial” and “Percutaneous transluminal angioplasty” having the same frequency of 505 (► **Table 4**). The lowest frequency for the keywords was related to the terms “surgery,” “artery disease,” and “metanalysis.”

Further keyword analysis included looking into the top 20 keywords with the strongest citation burst, words that were frequently cited over a period of time. The analysis showed that “coronary angioplasty” recorded the strongest citation burst 26.59 for the years 2001 to 2005. For the years 2015 to 2021, the strongest citation bursts were recorded for the keywords “drug-coated balloon” (33.22) followed by “balloon pulmonary angioplasty” (32.48). For the most recent data from 2018 to 2021, the strongest citation burst was recorded for the keyword “outcome” (25.64). Based on the evolution of keyword bursts and the end of the year shown by the red segment, future research directions in this field will be related to coronary angioplasty, thrombolytic therapy, and transluminal coronary angioplasty (► **Table 5**).

**Table 3** Journal co-citation network

Sl. no	Freq	Degree	Year	Source	Half-life
1	4406	47	2001	Circulation	7.5
2	3753	38	2001	J Am Coll Cardiol	7.5
3	3458	35	2001	New Eng J Med	7.5
4	2630	30	2001	Am J Cardiol	5.5
5	2318	23	2001	Lancet	7.5
6	2099	44	2001	J Vasc Surg	9.5
7	2048	33	2001	Eur Heart J	9.5
8	1795	26	2001	Am Heart J	6.5
9	1727	28	2001	Catheter Cardio Inte	9.5
10	1431	19	2001	Jama-J Am Med Assoc	7.5
11	1269	32	2001	Radiology	7.5
12	1201	35	2001	J Vasc Interv Radiol	9.5
13	1145	40	2001	J Endovasc Ther	10.5
14	1130	39	2001	Eur J Vasc Endovasc	9.5
15	1049	30	2001	Heart	8.5

**Fig. 3** Journal co-citation map related to angioplasty research from 2001 to 2021.

The analysis of the highly productive authors showed that GW Stone was the most productive with 105 papers, followed by CL Grines with 91 papers, and DA Cox with 66 papers. In contrast, although G De Luca had half as many papers (55) as GW Stone, the citation half-life was higher at 5.5 years compared with 1.5 years for GW Stone (►Table 6 and ►Fig. 4). This was true also for the papers of Al Qureshi, who produced 45 papers with a citation half-life being 3.5. The overall analysis of citation half-life for the most produc-

tive authors ranged from 1.5 years to 5.5 years, with the vast majority recording 1.5 years.

The final stage of analysis as part of this bibliometric study included the author co-citation data, with GW Stone being the most co-cited author (542) with a half-life citation at 6.5 years since 2001. This was followed by PW Serruys with 369 co-citations and half-life citations in 2.5 years since 2001. In comparison, while the papers of Zeller T were among the least co-cited papers (209), the half-life citation was 10.5 years since 2006. The least co-citation frequency was recorded by G Tepe with 207 frequency and citation half-life being 6.5 years since 2011 (►Table 7, ►Fig. 5).

## Discussion

The bibliometric analysis performed in this study was an exploratory attempt to identify trends in angioplasty research over the past two decades to deliver relatively unbiased and complete data on the scientific activity performed by authors worldwide, thereby providing insight into current research and major scientific trends. The results of this study showed that the number and percentage of published articles gradually decrease over time. One possible explanation may be related to the official guidelines of the American College of Cardiology/American Heart Association, where primary angioplasty is currently considered an alternative to thrombolysis.<sup>17</sup> Nevertheless, the findings of the current analysis showed some controversy. Thus, in some studies, primary angioplasty was superior to thrombolysis only in high-risk patients, while other studies showed a benefit of primary angioplasty in low-risk patients. Further findings of this study related to the most cited reference. A paper by Keeley EC (2003) was the most cited reference; a quantitative review of 23 randomized trials looking into primary angioplasty versus intravenous










**Table 4** Top 30 most frequently used keywords during 2001–2021

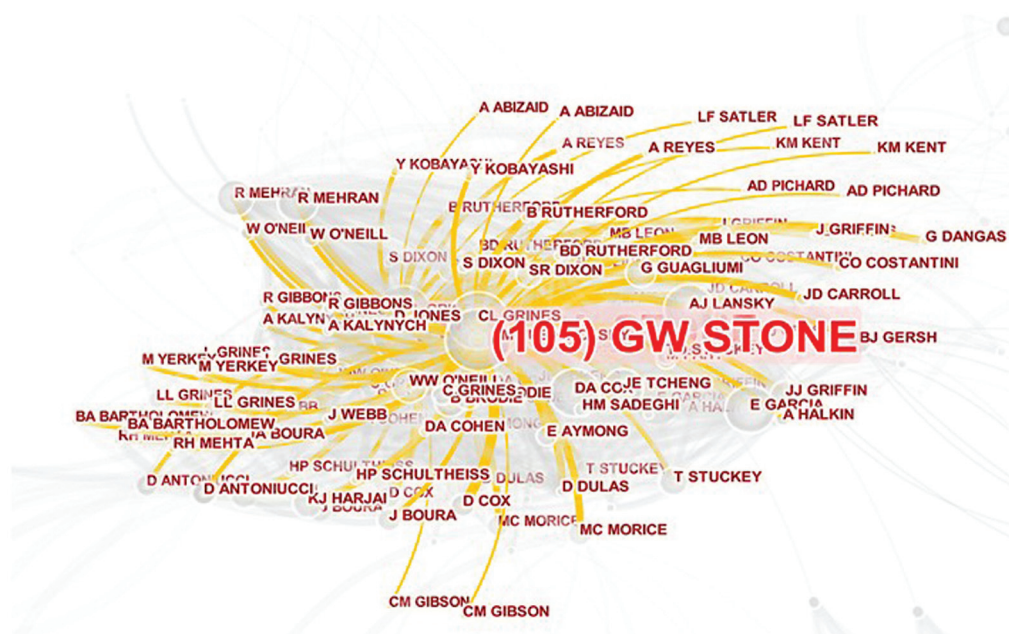
Sl. no	Freq	Keyword	Sl. no	Freq	Keyword
1	716	Balloon angioplasty	16	384	Follow-up
2	679	Disease	17	365	Risk
3	536	Intervention	18	362	Mortality
4	505	Trial	19	351	Endarterectomy
5	505	Percutaneous transluminal angioplasty	20	321	Coronary angioplasty
6	496	Restenosis	21	307	Implantation
7	495	Percutaneous coronary intervention	22	286	Randomized trial
8	463	Outcome	23	285	Reperfusion
9	459	Acute myocardial infarction	24	271	Experience
10	456	Management	25	245	Lesion
11	438	Myocardial infarction	26	236	Placement
12	425	Revascularization	27	226	Predictor
13	425	Stenosis	28	224	Surgery
14	418	Therapy	29	219	Artery disease
15	394	Artery	30	214	Metanalysis

**Table 5** Top 20 keywords with the strongest citation bursts

Keywords	Strength	Begin	End	2001 to 2021
Coronary angioplasty	26.59	2001	2005	
Thrombolytic therapy	25.71	2001	2005	
Transluminal angioplasty	22.77	2001	2006	
Transluminal coronary angioplasty	20.02	2001	2004	
Smooth muscle cell	17.43	2001	2004	
Injury	17	2001	2003	
Percutaneous coronary intervention	19.17	2010	2015	
Elevation myocardial infarction	21.77	2011	2017	
Endovascular treatment	20.32	2012	2021	
Paclitaxel	22	2013	2021	
Bare metal stent	18.54	2013	2018	
Drug-eluting balloon	16.54	2013	2019	
Peripheral artery disease	27.7	2014	2021	

**Table 5** (Continued)

Keywords	Strength	Begin	End	2001 to 2021
Arteriovenous fistula	21.72	2014	2021	
Chronic thromboembolic pulmonary hypertension	17.88	2014	2021	
Pulmonary hypertension	17.03	2014	2021	
Drug-coated balloon	33.22	2015	2021	
Balloon pulmonary angioplasty	32.48	2015	2021	
Chronic thromboembolic pulmonary hypertension	16.21	2015	2021	
Outcome	25.64	2018	2021	



**Fig. 4** The map of highly productive authors.

thrombolytic therapy for acute myocardial infarction.<sup>18</sup> Nevertheless, given the controversy, there is a need for further study of angioplasty and its trends in comparison with other methods of treatment. Moreover, it can be considered that the initial literature on angioplasty has reached a saturation point. This means that the most important questions have been answered, and further research may yield additional results with diminishing returns. As a result, researchers may decide to explore other areas that offer greater opportunities for discovery or impact in this medical intervention.

The summary of the co-citation network showed that *Circulation*, *J Am Coll Cardiol*, and *New Eng J Med* reported the strongest co-citation network. Although there is no one formula for good and bad journals, some of the key indicators of journal quality are the scientific rigor of the

publications published in the journal, the editorial quality of the publications, and the journal's history.<sup>19</sup> *Circulation* is a scientific journal published by Lippincott Williams & Wilkins for the American Heart Association since the 1950s with an impact factor of 29.69. *J Am Coll Cardiol* has been spanning the entire field of cardiovascular medicine, keeping investigators, clinicians, and specialists up to date on the latest practice-changing science since 1983 with an impact factor of 24.09. The third leading journal in the co-citation network was *New Eng J Med* published by the Massachusetts Medical Society with over two centuries of history and an impact factor of 91.24. This summary of journals suggested that the criteria for identifying quality journals suitable for publication papers on angioplasty were transparency on the part of the journal about its aims and scope,

**Table 6** Top 15 highly productive authors

Sl. no	Freq	Burst	Author	Half-life
1	105	27.72	GW STONE	1.5
2	91	28.52	CL GRINES	1.5
3	66	20.78	DA COX	1.5
4	64	18.07	H SURYAPRANATA	2.5
5	58	16.69	MJ DE BOER	2.5
6	55	19.36	R MEHRAN	1.5
7	55	15.51	AJ LANSKY	1.5
8	55	15.9	E GARCIA	1.5
9	55	20.16	GREGG W STONE	1.5
10	53	19.49	G DE LUCA	5.5
11	50	14.77	F ZIJLSTRA	1.5
12	48	13.52	JCA HOORNTJE	2.5
13	47	20.11	ROXANA MEHRAN	1.5
14	45	14.7	JP OTTERVANGER	2.5
15	45	18.48	ADNAN I QURESHI	3.5

**Table 7** Author co-citation analysis

Sl. no	Freq	Degree	Author	Year	Half-life
1	542	49	Stone GW	2001	6.5
2	369	33	Serruys PW	2001	2.5
3	313	43	Norgren L	2007	6.5
4	293	50	Grines CI	2001	2.5
5	272	44	Keeley EC	2003	4.5
6	245	36	Schillinger M	2003	8.5
7	243	30	Topol EJ	2001	1.5
8	239	50	De Luca G	2005	4.5
9	239	44	Ellis SG	2001	3.5
10	237	66	Yadav JS	2001	5.5
11	230	59	Kastrati A	2001	4.5
12	223	61	Rutherford RB	2001	7.5
13	221	79	Taylor DW	2001	4.5
14	209	50	Zeller T	2006	10.5
15	207	46	Tepe G	2011	6.5

editorial board, indexing status, the peer review process, reputation, and policies for authors.

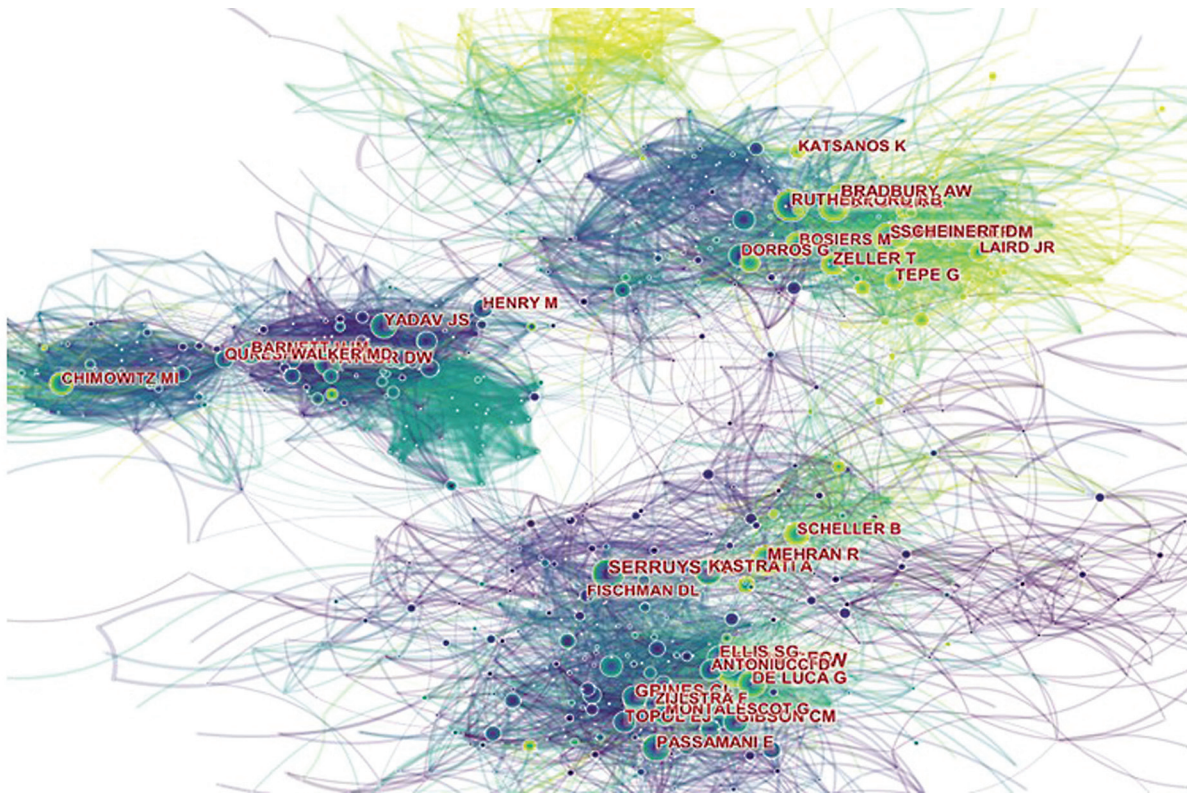
Keyword analysis can identify current hot research topics and future orientation. Consequently, keyword analysis has been used in this research to identify the evolving frontiers of research related to the subject area. As such, it was found that from 2001 to 2021, “coronary angioplasty,” “drug-coated balloon,” “pulmonary balloon angioplasty,” and “outcome” were the most commonly used terms with the future trends of research relating to “coronary angioplasty,” “thrombolytic therapy,” and “transluminal coronary angioplasty.”

In terms of the productivity of the authors, GW Stone has been the most co-cited author with 542 citations. He has

been the principal investigator in over 80 national and international multicenter randomized trials. In addition, his contribution has been influential in shaping the field of interventional cardiology. Dr. Stone has been involved in research related to transcatheter aortic valve replacement, a minimally invasive procedure used to replace the aortic valve in patients with severe aortic stenosis. With a 2018 H-factor of 152, Nature Medicine recently listed Dr. Stone as one of the most prolific authors in science.<sup>20,21</sup>

This bibliometric study is the first to identify and characterize angioplasty research that provides a clear visual analysis of quantity, quality, citation, and keyword analysis. This is a good example of visualization to study angioplasty and related





**Fig. 5** A co-citation map related to angioplasty from 2001 to 2021.

research. A summary of the results of this bibliometric analysis and a brief discussion of the findings showed that, despite declining publication trends, angioplasty research continues to be of interest to leading researchers worldwide. To conclude, while this study looked at general trends in angioplasty, it is recommended that future studies examine the comparison between radial and femoral approaches and their relevance in publication trends, as well as bibliometric relevance.

## Conclusion

This bibliometric study is the first to identify and characterize angioplasty research that provides a clear visual analysis of quantity, quality, citation, and keyword analysis. This study has become an example of visualization to study angioplasty and related research, demonstrating that despite a decline in publications, angioplasty continues to be of interest to leading researchers worldwide. This study will be a benchmark study where researchers and institutions can compare citation rates, collaboration patterns, and publication profiles in their field. This will provide insight, identify areas for improvement, or track progress over time, which may increase the amount of new work done on angioplasty to overcome the lack of literature published over the past decade.

### Authors' Contributions

M.I. was involved in conceptualization, methodology, and software; A.W. contributed to data curation, visualization,

writing-reviewing and editing; M.R. was involved in writing-original draft preparation, visualization, and investigation; S.A. contributed to supervision, methodology, software, and validation.

### Compliance with Ethical Principles

An ethics statement is not applicable because this study is based on published literature.

### Availability of Data and Material

All data generated or analyzed during this study are included in this published article.

### Funding and Sponsorship

The authors have no relevant financial or nonfinancial interests to disclose. All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest or nonfinancial interest in the subject matter or materials discussed in this manuscript.

### Conflict of Interest

None declared.

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