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Top 100 cited articles on rheumatoid arthritis
A bibliometric analysis

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Abstract
Background: Rheumatoid arthritis (RA) is a worldwide health issue; although the prospects for most patients are favorable, many still do not respond to the current therapies. Numerous articles related to RA have been published in the past 3 decades; an analysis of the most cited articles in this field was undertaken to identify important articles regarding RA related to pathogenesis, diagnosis, and treatment.

Methods: We searched the Web of Science and collected the general information of the top 100 cited articles. The citation number, publication year, authorship, impact factor (IF) of the journal in the publication year, country origins, article types, and funding source were evaluated.

Results: The total citations of the top 100 articles varied from 11,922 to 556 and were published between 1985 and 2014. These articles were published in 24 journals, led by *Arthritis and Rheumatism* (n = 33), followed by the *New England Journal of Medicine* (n = 15). Most of the articles (n = 80) were produced by ≥5 authors. They were from 34 countries, and the United Stated contributed to most of the articles (n = 58), followed by the United Kingdom (n = 42). The article types were divided into clinical study (n = 55), review (n = 17), meta-analysis (n = 4), clinical guideline (n = 10), and basic science (n = 14). Eighty-seven percent of the articles were supported either by public organizations or medical companies.

Conclusion: This study provided insights into the development of publications and their citations of RA in the past 3 decades. Clinical studies or clinical guidelines published in high-impact journals were more likely to be cited in the field of RA. The latest publications may not be included in the top 100 cited articles, as the more recent studies have not had sufficient time to accumulate the number of citations.

Abbreviations: ACR = American College of Rheumatology, EULAR = European League Against Rheumatism, IF = impact factor, NIH = National Institutes of Health, RA = rheumatoid arthritis, RCT = randomized controlled trial, T100 = top 100 cited.

Keywords: bibliometric analysis, citations, rheumatoid arthritis, web of science

1. Introduction

Rheumatoid arthritis (RA) is a worldwide chronic inflammatory disease; it causes progressive joint damage and even leads to disability.[1] Its onset is closely related to environmental and genetic factors.[2–4] The incidence rate of RA is 0.5% to 1% in industrialized countries, and it is even higher in women and elderly people.[5,6] At present, although the prospects for most patients are favorable, many still do not respond to the current therapies.[6,7] Substantial burden for both individual and society has been caused by RA.[8] Thus, it is urgent to discover new effective treatment strategies of RA.

Bibliometrics are methods which can be used to analyze the scientific production quantitatively and the thematic evolution of a given research field.[9] It mainly contains 2 methods: performance analysis and science mapping analysis.[10,11] The performance analysis is focused on measuring the scientific production with indicators including production indicators, impact indicators based on citations, and indicators based on the impact of the journal.[11] The science mapping analysis is a spatial representation of how disciplines, fields, specialties, and individual articles or authors are related to one another.[12] It was widely used to show and discover the hidden key elements (authors, institutions, topics, among others) in different fields.[11–13]

At present, bibliometric analysis has been applied to identify articles in multiple medical fields such as psoriasis,[14] respiratory diseases,[15] and cardiovascular diseases.[16] As numerous articles related to RA have been published in the past 3 decades, an analysis of the most cited articles in this field was undertaken to identify important articles regarding RA related to pathogenesis, diagnosis, and treatment in this study.

2. Materials and methods

2.1. Search strategy

Web of Science (http://apps.webofknowledge.com) is a database with articles that come from nearly 9000 authoritative journals; in addition to general literature search, it has a function of citation index searching, which may help us evaluate the academic importance of articles in specific field. We searched the Web of Science database for articles related to RA published from 1985 to 31 December 2017. "Rheumatoid arthritis" was used as the search term. Articles were sorted by the "Times cited" option and articles that had more citations were ranked higher. No ethical approval was required as the data were collected from published articles.

2.2. Article selection

Two reviewers (XY and FC) independently screened the abstracts or the full texts to identify the top 100 cited (T100) articles about RA. When there were disagreements between 2 reviewers, a third reviewer (XW) joined and helped achieve consensus. Only articles that focused on the subject of RA were included.

2.3. Data extraction

After all the articles were selected, information about these articles was collected for bibliometric analysis: title, citation number, publication year, number of authors and names of the authors (first author and corresponding author), source journal, impact factor (IF) of the journal in the publication year, country origins of the authors, article types, and funding source. Finally, to adjust for the error of citation number, which may be affected by publication year, a citation index was calculated and defined as citations per year after publication.

2.4. Statistical analysis

Data were presented as median or mean; the Spearman test was used to analyze the correlation between 2 variables with IBM SPSS Statistics 20.0 (IBM Corp., Armonk, NY), and the difference was statistically significant at $P < .05$.

3. Results and discussion

RA was first named in the 1850s, although its classification criteria were developed only 50 years ago.[1] The specialty grew rapidly afterwards, and numerous articles were published. In this study, we focused on the T100 articles on RA by analyzing their total citations, citation index, authors, journals, country origins, contents, and so on. Results of this article gave a brief overview of articles on RA in the past 3 decades.

3.1. Citation number and publication year

Citation analysis is one of the key methodologies in the field of evaluative bibliometrics.[17] Although the value of citation rates has been debated,[18] analysis of citation number can be valuable in identifying important issues and discoveries.[19]

A total of 146,243 articles were identified after searching in the Web of Science database with "Rheumatoid arthritis" for articles published between 1985 and 31 December 2017. The total citations of the T100 articles (Table 1 and supplementary Table S1, http://links.lww.com/MD/C827) varied from 11,922 to 556; the mean citations per article were 1102.2 and median citations numbered 850. Only 13 articles had citations >1500, and most of the articles (n=67) received <1000 citations (range 989–556). The citation index varied from 397.40 to 19.17, with a median index of 56.56. Correlation was significantly strong between the citation index and citation number per article (correlation coefficient=0.683, $P < .001$).

Interestingly, we found that the top-cited article, which was related to the classification criteria of RA and published by the American Rheumatism Association in 1988,[20] had a total number of citations of 11,922. The citation number was far beyond the citation number of the second top-cited article with a citation of 3484, although this number of citations may also be higher than that in many other specialties, such as psoriatic arthritis or ulcerative colitis.[14,21]

Although numerous guidelines that are related to the classification criteria of RA were published in the past 3 decades, the 1987 American College of Rheumatology (ACR) criteria[20] and the 2010 American College of Rheumatology/European League Against Rheumatism (ACR/EULAR)[22] criteria were most cited and ranked the first and the sixth in the T100 articles, respectively. This finding was consistent with the report that the 1987 ACR criteria and the 2010 ACR/EULAR criteria were most widely used for diagnosis of RA worldwide.[23]

The T100 articles were published between 1985 and 2014. Most of the articles (n=77) were published after 1995. The single year with the most cited articles was 2003 (n=9), followed by 2004 (n=8). Figure 1 shows the detailed information about the year and number of published articles. The peak time period of the publication year was 2000 to 2004 with a total number of 30 articles, similar to a bibliometric analysis of acute kidney injury,[24] which may indicate rapid evolution in this field.

As the citation number was closely related to publication year, articles published earlier may have had more citations, the citation index was calculated to measure the true impact of an article independent of short-lived trends.[24] In addition, altmetric scores (Table 1 and supplementary Table S1, http://links.lww.com/MD/C827) were also included to serve as a useful complement to assess the impact of articles included in this study.[25]

Contrary to citation-based metrics, altmetrics measure the impact of an individual article's dissemination promptly by quantifying the discussion of an article on blogs, podcasts, social media platforms, and news media.[26] Altmetrics were considered as measures of "disseminative impact," whereas the citation-based metrics were thought of as measures of "scholarly impact."[27] Although altmetrics address some of the drawbacks of citation-based metrics, limitations persist, a very popular article is not necessarily a high-quality article.[28] Therefore, the citation-based metrics were combined with altmetrics to identify important articles on RA in this study.

Altmetric scores of the T100 articles varied from 485 to 1; the mean altmetric scores per article was 24.38. Most of the articles (n=91) have altmetric scores ≤55; 4 articles (supplementary Table S2, http://links.lww.com/MD/C827) received altmetric scores ≥127, and altmetric scores of the remaining 5 articles were not available from the internet. The result indicated that articles which are related to the management of RA,[29] toxicity of drugs for treating RA,[30] pathogenesis of RA[31,32] were more likely to be discussed on social media.

3.2. Article types and contents

The T100 article types were divided into clinical study, review, meta-analysis, clinical guideline, and basic science (Fig. 2A).

Table 1

General information related to top 20 of the top 100 cited articles on rheumatoid arthritis (sorted by total citations).

| No.	Title	Authors	Journal	Year	Total citation (Web of Science)	Altmetric score	Citation index	Article type
1	The American Rheumatism Association 1987 revised criteria for the classification of rheumatoid arthritis	Arnett et al[20]	Arthritis and Rheumatism	1988	11,922	25	397.4	Clinical guideline
2	Modified disease activity scores that include 28-joint counts development and validation in a prospective longitudinal study of patients with rheumatoid arthritis	Prevoo et al	Arthritis and Rheumatism	1995	3484	15	151.478	Clinical study
3	Comparison of upper gastrointestinal toxicity of rofecoxib and naproxen in patients with rheumatoid arthritis	Bombardier et al[30]	New England Journal of Medicine	2000	2539	127	141.056	Clinical study
4	Infliximab and methotrexate in the treatment of rheumatoid arthritis	Lipsky et al	New England Journal of Medicine	2000	2293	10	127.389	Clinical study
5	Gastrointestinal toxicity with celecoxib vs. nonsteroidal anti-inflammatory drugs for osteoarthritis and rheumatoid arthritis The class study: A randomized controlled trial	Silverstein et al	Journal of the American Medical Association (JAMA)	2000	2160	47	120	Clinical study
6	2010 rheumatoid arthritis classification criteria: An American College of Rheumatology/European League Against Rheumatism collaborative initiative	Aletaha et al[22]	Arthritis and Rheumatism	2010	2036	24	254.5	Clinical guideline
7	American College of Rheumatology. Preliminary definition of improvement in rheumatoid arthritis	Felson et al	Arthritis and Rheumatism	1995	1893	19	82.304	Clinical study
8	Role of cytokines in rheumatoid arthritis	Feldmann et al	Annual Review of Immunology	1996	1875	6	85.227	Review
9	Evolving concepts of rheumatoid arthritis	Firestein	Nature	2003	1862	9	124.133	Review
10	Infliximab (chimeric anti-tumour necrosis factor alpha monoclonal antibody) versus placebo in rheumatoid arthritis patients receiving concomitant methotrexate: A randomised phase III trial	Maini et al	Lancet	1999	1788	21	94.105	Clinical study
11	The shared epitope hypothesis: An approach to understanding the molecule-genetics of susceptibility to rheumatoid arthritis	Gregersen et al	Arthritis and Rheumatism	1987	1770	19	57.097	Review
12	Efficacy of B-cell-targeted therapy with rituximab in patients with rheumatoid arthritis	Edwards et al	New England Journal of Medicine	2004	1562	40	111.571	Clinical study
13	A trial of etanercept, a recombinant tumor necrosis factor receptor: Fc fusion protein, in patients with rheumatoid arthritis receiving methotrexate	Weinblatt et al	New England Journal of Medicine	1999	1522	12	80.105	Clinical study
14	Anti-TNF antibody therapy in rheumatoid arthritis and the risk of serious infections and malignancies: Systematic review and meta-analysis of rare harmful effects in randomised controlled trials	Bongartz et al	Journal of the American Medical Association (JAMA)	2006	1494	19	124.5	Meta-analysis
15	Randomised double-blind comparison of chimeric monoclonal antibody to tumour necrosis factor alpha (cA2) versus placebo in rheumatoid arthritis	Elliott et al	Lancet	1994	1405	12	58.542	Clinical study
16	Rheumatoid arthritis: Pathophysiology and implications for therapy	Harris	New England Journal of Medicine	1990	1398	3	49.929	Review
17	The pathogenesis of rheumatoid arthritis	McInnes and Schett[32]	New England Journal of Medicine	2011	1397	194	199.571	Review
18	A comparison of etanercept and methotrexate in patients with early rheumatoid arthritis	Bathon et al	New England Journal of Medicine	2000	1314	8	73	Clinical study
19	Mechanisms of disease: Cytokine pathways and joint inflammation in rheumatoid arthritis	Choy et al	New England Journal of Medicine	2001	1310	9	77.059	Review
20	Treatment of rheumatoid arthritis with a recombinant human tumor necrosis factor receptor (p75)-Fc fusion protein	Moreland et al	New England Journal of Medicine	1997	1261	17	60.048	Clinical study
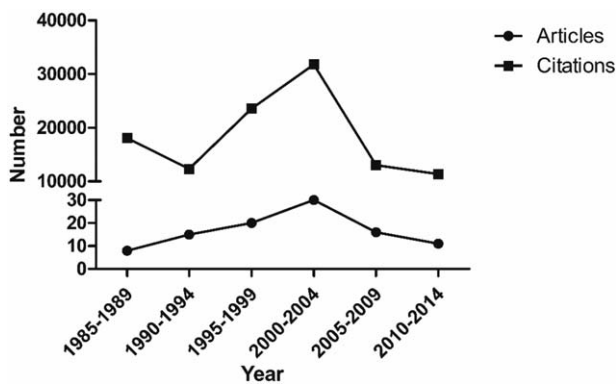
Figure 1. Number of articles and total citations at different periods.

Clinical studies (n = 55) contributed the largest proportion of these articles; they mainly focused on identifying the effectiveness or safety of drug therapy. Among the clinical articles, the most common type was the randomized controlled trial (RCT) (n = 32), followed by prospective-cohort study, case–control study, case series, retrospective-cohort study, and cross-sectional study (Fig. 2B).

Contents of the T100 articles included classification criteria, evaluation of drug therapy, disease activity evaluation, pathogenesis, risk factor, description of epidemiology, and others (Fig. 2C). Evaluation of drug therapy (n = 48) contributed the largest part of these articles and included analysis of the effectiveness of different treatment strategies and the risk of other diseases after treatment.

Clinical guidelines showed us the classification criteria of RA, recommendations for RA management with different kinds of drugs, advice on disease activity evaluation before or after treatment, and cardiovascular risk management in patients with RA. In addition, the risk factors of RA were also explored, such as genetic factors (IL2RA, CCL21, AFF3, and so on).[2,33] This information helped physicians diagnose RA and treat the disease with proper therapies.

By analyzing contents of clinical studies in the past 3 decades, we also found that the diagnosis and treatment of early RA was gradually gaining importance in the rheumatoid field. Thirty-two RCTs were included in the T100 articles; 6 of them were related to the treatment of early RA. There is no single test or criterion standard to confirm the diagnosis; therefore, diagnostic criteria of RA were updated every few years and one of their main goals was to identify RA at an earlier stage.[34] Besides, an abbreviated guideline summary of recommendations for patients with early RA was included in the 2015 ACR guideline for the treatment of RA.[35]

3.3. Source journals

The T100 articles were published in 24 journals (Table 2), which may be more focused than articles published in other fields.[36,37] Among them, *Arthritis & Rheumatism* contributed the most articles (n = 33), with a total citation number of 44,765. Thirty-seven percent of articles were published in high-impact general journals, including the *New England Journal of Medicine* (n = 15), the *Lancet* (n = 12), *Nature* (n = 4), the *Journal of the American Medical Association* (JAMA) (n = 3), *Science* (n = 2),
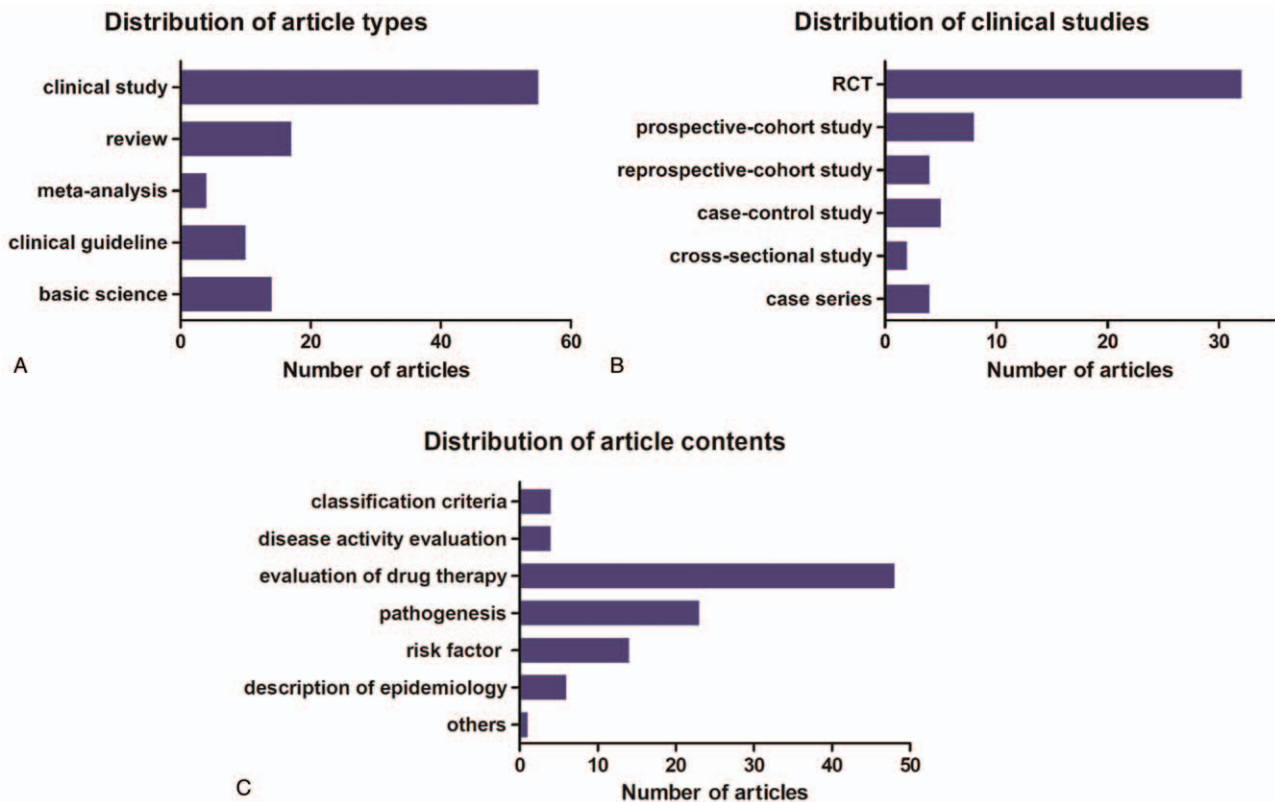

Figure 2. Article types and contents of the top 100 cited articles. (A) Distribution of article types. (B) Distribution of 55 clinical studies. (C) Distribution of article contents.

Table 2

Journals of the T100 articles (n ≥ 2).

Journal	Number of articles
Arthritis & Rheumatism	33
New England Journal of Medicine	15
Lancet	12
Annals of the Rheumatic Diseases	7
Nature	4
Journal of the American Medical Association (JAMA)	3
Journal of Clinical Investigation	3
Annual Review of Immunology	2
Annals of Internal Medicine	2
Journal of Immunology	2
Circulation	2
Nature Genetics	2
Science	2

and *Cell* (n=1). In addition, articles tended to be published in high-impact medical journals in the field of RA such as *Annals of the Rheumatic Diseases* (n=7).

Journal IF plays an important role in quantifying the influence of a journal. Authors' work has increasingly been assessed by the impact of the journal in which it is published.[28] Nowadays, IF was published annually by Thomson Reuters, and calculated (IF=A/B) based on the total number of citations (A) of papers from a particular journal and the total number of papers (B) published in that journal during the past 2 years.[27] In this study, IFs of articles published before 1997 were not available from the Web of Science; IFs of the remaining articles varied from 53.298 to 3.731. The article which had the highest IF was published in the *New England Journal of Medicine*; it was a review related to the pathogenesis of RA.[32]

3.4. Authorship and country origins

Authors of the T100 articles ranged from 90 to 1, but most of these articles (n=80) were produced by ≥5 authors. There were 5 authors who contributed to ≥3 articles and were listed as the first author or corresponding author (Table 3). JS Smolen was the most cited author whose articles were related to clinical guidelines or clinical studies.

Authors of T100 articles were from 34 countries. The United States contributed to most of the articles (n=58), followed by the United Kingdom (n=42), Netherlands (n=29), Canada (n=21), Germany (n=20), and France (n=14); 26 countries contributed ≤8 articles. Authors who contributed to ≥3 articles and were listed as the first author or corresponding author were from the United Kingdom (n=3), the United States (n=1), and Austria (n=1).

Cooperation among authors from different countries was also analyzed. The detailed interactions were shown in Figure 3.

Table 3

Authors contributing to ≥3 articles.

Author	Number of articles	First	Correspond	Total citations
Smolen	5	4	5	4529
Feldmann	4	3	4	4289
Weinblatt	4	3	4	4251
Maini	3	1	3	3162
Elliott	3	3	1	2824

Among the 34 countries included in this study, the majority of them were European countries (the UK, Netherlands, and so on) or American countries (especially the Unites States, Canada), and cooperation between these countries was relatively frequent. Authors from Asian countries or Oceania countries also participated in the publication of articles, at a relatively low number. More cooperation between different countries may be an effective way to promote the development of RA research around the world.

3.5. Funding source

Eighty-seven of the T100 articles stated their funding source, whereas the remaining 13 articles did not reveal it. Among the stated articles, 57 were supported by public organizations, 21 were funded by medical companies, and 9 received support from both. Most of the articles (n=76) were funded by ≤3 organizations. Five articles received support from ≥10 foundations; they were clinical studies, clinical guidelines, meta-analyses, or reviews.

Funding support is an important part of research. Compared to the medical companies, more research was funded by public organizations such as the National Institutes of Health (NIH), ACR, EULAR, the Arthritis Research Campaign of Great Britain, and so on. Among the 21 articles supported by medical companies, 90.5% of them were clinical studies, the rest were clinical guidelines; relatively, contents of articles which were supported by both public organizations and medical companies were more diverse, including clinical study, clinical guidelines, basic science, and review.

3.6. Limitations

Finally, there are some limitations in this study. First, articles included in this study were limited. We only searched the Web of Science. Articles from other databases were not included, and they were all English-speaking; articles published in other languages were not included. Second, some general information was incomplete. IFs of journals before 1997 were not available from the Web of Science, and statistics related to them were removed. Third, this study had methodological limitations. The following caveats must be kept in mind when reviewing the results of this study: articles included in this study were sorted by citation number, which was closely related to publication year; the latest published articles with high academic influence may have been missed in this study. More advanced analysis methods like altmetric score, which could measure the impact of an individual article's dissemination within days of their publication, may solve this problem.[27] In addition, self-citation was not taken into consideration. Despite these limitations, this study gives us a brief overview of articles on RA in the past 3 decades.

4. Conclusions

In this study, we summarized the T100 articles on RA with bibliometric analysis. It provided insights into the development of publications and their citations of RA in the past 3 decades. Articles related to RA were increasing, especially after 1995. Clinical studies or clinical guidelines published in high-impact journals were more likely to be cited in the field of RA. The latest publications may not be included in the T100 articles, as the more recent studies have not had sufficient time to accumulate the number of citations.
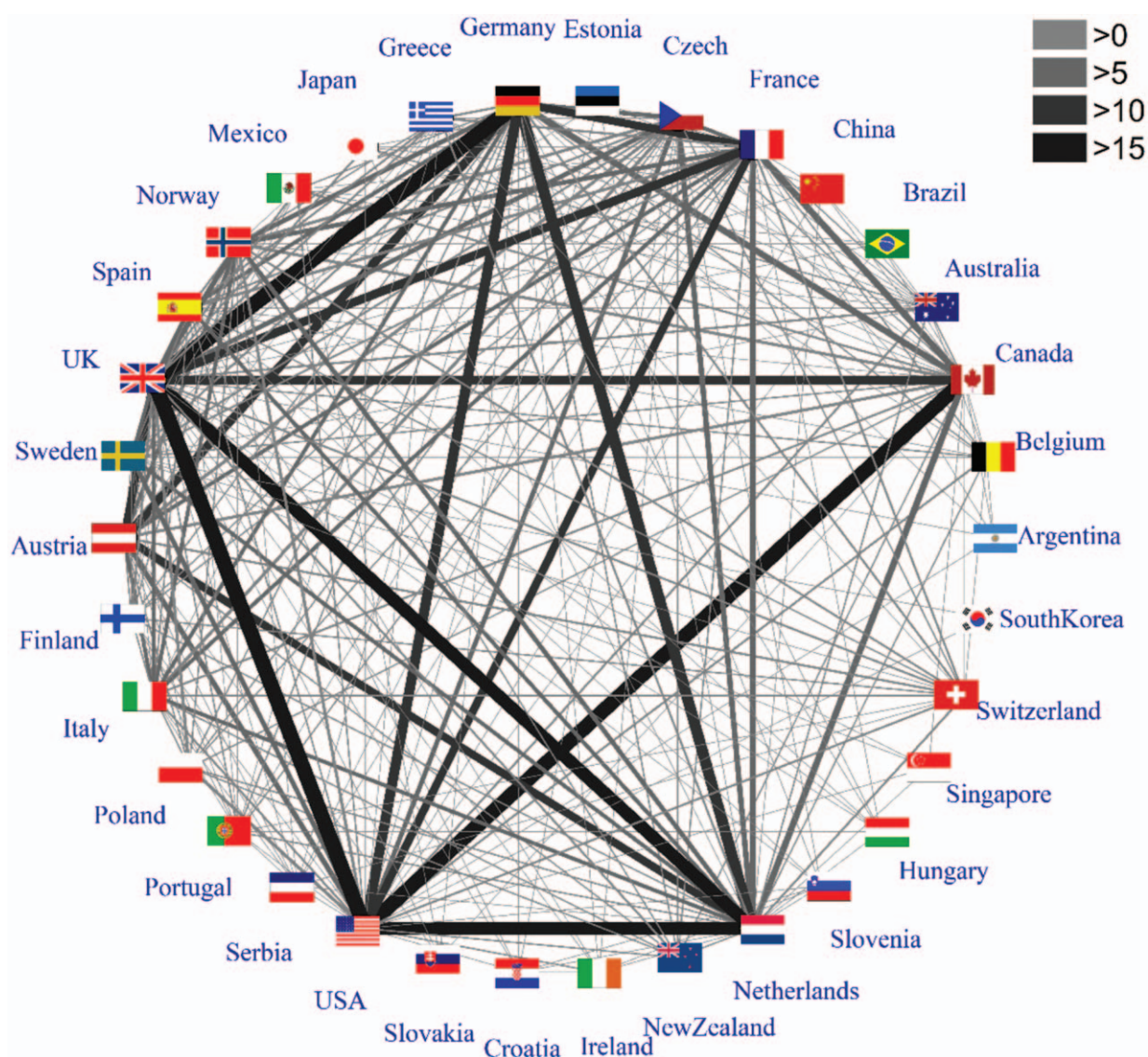
Figure 3. Interactions between countries of the top 100 cited articles.

Author contributions

Data curation: Xiangjun Yin, Fafeng Cheng, Xueqian Wang, Jie Mu, Chongyang Ma, Changming Zhai, Qingguo Wang.
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Writing – review & editing: Xiangjun Yin, Fafeng Cheng, Xueqian Wang, Qingguo Wang.

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