

Visual and bibliometric analysis of Chronic Rhinosinusitis and Nasal Polyps

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Abstract

Background: Chronic rhinosinusitis (CRS) is a heterogeneous disease characterized by persistent sinonasal inflammation and sinus microbiome dysbiosis. Nasal polyps (NPs) is one of the main manifestations which cause diverse clinical symptoms of CRS. We conducted a bibliometric and visual analysis of CRS and NPs articles published between 2003 and 2022 to provide researchers with the current state of research and potential directions. **Method:** We used a systematic search strategy to search relevant articles in the databases of the Web of Science from 2003 to 2022. VOSviewers, Bibliometrix R package, and CiteSpace were used to perform the bibliometric analysis. **Results:** 3,907 publications, including 3,266 “articles” and 641 “reviews” were retrieved. The USA made the highest contributions to global research, followed by China; furthermore, Northwestern University, Capital Medical University, and Sun Yat-Sen University had the highest number of publications. A total of 12,894 authors participated in this research, with the most published author being Bachert C., followed by Schleimer Robert P. and Schlosser Rodney J.. And the authors with the most co-citations were Bachert C., Fokkens W.J., and Gevaert P. 428 journals had published the articles of this research. Moreover, the journal with the most publications was the *International Forum Of Allergy & Rhinology* and the *Journal Of Allergy And Clinical Immunology* received the most citations. “Covid-19”, “biologic”, and “type 2 inflammation” were the top current research hotspots. **Conclusion:** The United States and Northwestern University were the leading country and institution in researching CRS and NPs. And Bachert C. is the most influential expert. The *International Forum Of Allergy & Rhinology* published the most articles, and the *Journal Of Allergy And Clinical Immunology* got the highest number of citations. Moreover, “Covid-19”, “biologic”, and “type 2 inflammation” were the trending topics.

Introduction

Chronic rhinosinusitis (CRS) is a heterogeneous disease characterized by persistent sinonasal inflammation and sinus microbiome dysbiosis, affecting 5-12% of the population of most countries^[1]. And nasal polyps (NPs) is one of the main manifestations which cause diverse clinical symptoms of CRS. As one of the most common diseases in most countries, the disease seriously affects the quality of patients’ daily life and burdens society and families. The dominant symptoms of CRS are nasal congestion, mucopurulent nasal discharge, facial pain/pressure/fullness, and decreased sense of smell^[1]. Currently, the primary treatment modalities include nasal or systemic glucocorticoid, antibiotics, and endoscopic sinus surgery (ESS)^[1-5]. In recent years, new treatments have emerged, and clinical research has progressed rapidly. Therefore, it is essential to grasp the current status and potential research directions.

Bibliometrics is a statistical method to identify and summarize articles on a selected area in a systematic manner. Many medical fields now use bibliometrics for in-depth analysis^[6-11]. It is helpful for researchers in related fields to accurately grasp the current research trends by analyzing the publication. Recently,

multiple bibliometric software tools have been developed, such as VOSviewer^[12-13], CiteSpace^[14-15], and Bibliometrix R package^[16-17]. Researchers can analyze, compare, and visualize results across these tools and obtain information, including authors, countries, institutions, journals, and references in the area of interest. However, bibliometrics has not been applied in the CRS and NPs study.

In this study, we used the Web of Science (WoS) database to perform a bibliometric analysis of articles related to CRS and NPs from 2003 to 2022 and utilized VOSviewer, CiteSpace, and Bibliometrix R package to perform a visualization analysis. We summarized the significant contributors of CRS and NPs in the past 20 years and discussed the trending topics and hotspots in this field. We hope this article will reference the researchers and drive progress in the research of CRS and NPs.

Methods

Search Strategy

The Web of Science (WoS) database (<https://www.webofscience.com/wos/woscc/basic-search>) was used as the data source. The retrieval time of databases was as of January 2023. The search formula was (TS=("chronic rhinosinusitis") OR TS=("chronic sinusitis") OR TS=("chronic nasosinusitis")) AND (TS=("nasal polyp") OR TS=("nasal polyps") OR TS=("nasal polyposis")), LA = (English), and the type of documents was set to "articles" and "review".

Data Analysis

Considering the respective properties and advantages, we simultaneously used VOSviewer, the Bibliometrix R package, and CiteSpace.

VosViewer (version 1.6.18) is a bibliometric analysis software that can be used for network construction and visualization based on publications, countries and institutions, journals and co-cited journals, authors and co-cited authors or keywords^[12-13]. In the visual network diagram built by this software, a circle represents an analytical item, such as a country, institution, journal, or author. The size of the circle depicts the number of this item. Circles' colors represent different clusters. The thickness of the lines between the circles reflects the degree of cooperation or co-citation between the analyzed items. Bibliometrix R package (version 4.2.1) (<https://www.bibliometrix.org>) was used to conduct the bibliometric and visualized analysis. Besides, we used Bibliometrix to build the Bradford's Law diagram, publications geographic distribution maps, trend topic analysis, and the Sankey diagram^[14-15].

Bibliometric software CiteSpace (version 6.1.R3) was used to draw the dual map of the journal^[16-17]. In addition, Microsoft Office Excel 2019 was used to graph the quantitative analysis of the publication.

Results

Annual Publication and Major Research Directions

There were 3,907 studies on CRS and NPs between 01 /01/ 2003 and 31/ 12/ 2022, including 3,266 "articles" and 641 "reviews". The number of publications on CRS and NPs steadily increased in the past two decades.

As shown in Figure 1A, this field attracted the attention of scientific researchers at an early stage. Of the studies, 27 were published in 2003. From 2003 to 2020, the number of publications increased rapidly. The publications increased by 133.3% (27 in 2003, 387 in 2020). Starting from 2020, the publication trend in the last three years (2020-2022) had been relatively stable, which may mean that the number of studies temporarily peaked.

We classified the 3907 studies on CRS and NPs (Figure 1B), and found that "Otorhinolaryngology", "Immunology", and "Immunology" were the three primary research directions in the research.

Most influential country and institution

These publications came from 82 countries and 3,139 institutions. We set the publication threshold to 10 publications, and 43 countries met the criteria. The top 10 countries were distributed in Asia, North America,

and Europe, mainly in Europe ($n=5$), with the United States having the highest number of publications ($n=1248$, 33.5%), followed by China ($n=631$, 17.0%), Korea ($n=293$, 7.9%), and Belgium ($n=272$, 7.3%). During these 20 years, the total number of citations of publications published in the USA ranked first with 39027 (Table 1).

Based on the selection criteria, we visualized the number of publications and inter-country collaboration networks for these 82 countries (Figure 2A). For example, The United States had close collaborative relationships with Canada, England, and Germany. In addition, we also mapped the geographical distribution of inter-country collaborations (Figure 2B) and the publication density (Supplementary figure 1).

As with the above criteria, 190 of the 3,139 institutions met our criteria. The top 10 institutions were also located in Asia, North America, and Europe, mainly in the United States ($n=3$) and China ($n=3$). Northwestern University ($n=1248$) was the top institution in terms of the number of publications, followed by Capital Medical University ($n=631$) and Sun Yat-sen University ($n=293$). Meanwhile, Northwestern University also achieved the highest citations. We analyzed the average year of the publications for the top 10 institutions, with larger values for Harvard Medical School (2019.4316), Capital Medical University (2018.4385), and Karolinska Institutet (2018.043), implying that these three institutions may have invested more in this research of CRS and NPs in recent years (Supplementary table 1).

Similarly, we constructed a collaboration network among the 190 institutions and visualized the average year of the publications from different institutions (Figure 2C). Most institutions with high publication volume collaborated with other institutions, especially within the same country. Some had many collaborating institutions, such as Sun Yat-sen University.

Most impactful authors

A total of 12,894 authors had published in the research of CRS and NPs in the past two decades. Among them, 265 authors had published ≥ 10 publications. We analyzed the core authors in this field according to Price's law ($m_p = 0.749 \cdot \sqrt{n_{pmax}}$). In this law, m_p is the minimum number of articles published by core authors in the statistical period, and n_{pmax} is the number of articles published by the authors with the most significant number of publications in the statistical period. Through calculation, $m_p = 9.41$, and 265 core authors with publications ≥ 10 were counted. Supplementary table 2 shows the top 5 authors regarding the number of publications. The author with the most publications was Prof. Bachert Claus, who had published 158 articles cited 10,093 times. Furthermore, we noted that Prof. Zhang Luo had a significantly later average publication year than the other four professors and remained active in CRS and NPs-related research in recent years.

We drew a visualized collaboration network of these 265 authors (Figure 2D). The same color represents a cluster of authors with collaborative relationships, such as the collaboration between Bachert Claus, Wang chengshuo, Lou hongfei, and others.

Authors with ≥ 50 co-citations were screened. The most co-cited author was Bachert, C ($n=2808$), followed by Fokkens, WJ ($n=1767$) and Gevaert, P ($n=1061$) (Supplementary table 3). Close collaboration among the co-cited authors was prevalent (Supplementary figure 2).

Most impactful journals

A total of 428 journals published publications related to CRS and NPs, and we filtered them by the number of publications ≥ 5 and citations ≥ 50 , and a total of 83 journals were eligible.

The journal with the highest number of publications was *the International Forum Of Allergy & Rhinology* ($n=365$), with an average publication year of 2016.7671, followed by the *American Journal Of Rhinology & Allergy* ($n=318$), *Journal Of Allergy And Clinical Immunology* ($n=188$) and *Rhinology* ($n=188$) (Supplementary table 4). Among the top 10 journals with the most publications, *the Journal Of Allergy And Clinical Immunology-in Practice* ($n=2019.6389$), *International Forum Of Allergy & Rhinology* ($n=2016.7671$), *European Archives Of Oto-Rhino-Laryngology* ($n=2016.0061$) had an average later year of publication. These

journals produced more cutting-edge articles in recent years. In addition, according to our screening criteria, the most cited journal was the *Journal Of Allergy And Clinical Immunology* (n=13739), with an average of 73 citations per article, followed by *the International Forum Of Allergy & Rhinology* (n=7813) (Table 2).

We plotted the inter-journal citation network of these 83 journals and distinguished their average publication year by color, showing the citation relationship between different journals (Supplementary figure 3). Such as *the International Forum Of Allergy & Rhinology* and *the European Archives Of Oto-Rhino- Laryngology* had a strong citation relationship.

According to Bradford's Law^[18-19], evidence of the regularity of the distribution of scientific journals, it is always a small number of journals that contribute to the core sources in a field. We used the Bibliometrix R package to calculate the leading contributing journals in the research of CRS and NPs. They were the *International Forum Of Allergy & Rhinology*, *American Journal Of Rhinology & Allergy*, *Journal Of Allergy And Clinical Immunology*, *Rhinology*, *Laryngoscope*, *European Archives Of Oto-Rhino- Laryngology* (Figure 3A).

We constructed the dual-map overlay of journals using CiteSpace software (Figure 3B). It showed the citation relationships between journals and co-cited journals, with clusters of citing journals on the left and clusters of cited journals on the right. For example, Molecular/ Biology/ Immunology was often cited by Molecular/ Biology/ Genetics, Dentistry/ Dermatology/ Surgery was often cited by Molecular/ Biology/ Genetics, and Medicine/ Medical/ Clinical was often cited by Molecular/ Biology/ Genetics.

Most widely cited references

From 2003 to 2022, there were 58,708 co-cited references in studies related to CRS and NPs, and we screened 241 references using a co-citation count of [?]50 as the screening criterion.

We listed the top 10 most co-cited references (Supplementary table 5). The highest number of co-citations was published in *Rhinology* by Fokkens WJ et al., *European Position Paper on Rhinosinusitis and Nasal Polyps 2012* (EPOS 2012)^[20], with 1323 co-citations. In 2020, this article was updated and is now the *European Position Paper on Rhinosinusitis and Nasal Polyps 2020* (EPOS 2020)^[1], the most authoritative and complete guide in CRS. It provides a research base for researchers worldwide. Followed by articles published by Lund Valerie J et al.^[21] (n=459) and Van Zele T et al.^[22] (n=428), both of which were published earlier, in 1993 and 2006. They illustrated the staging in rhinosinusitis and the differences in the cellular and media profiles of different types of CRS, respectively. These are both seminal studies in the research of CRS and NPs, focusing on the endophenotypic and immunological features of CRS. At the beginning of global scientific work, they showed the most fundamental elements of CRS to a wide range of scholars. The article with the fourth highest number of co-citations was published in 2016, the most recent of the top 10 co-cited references. Researchers analyzed IL-5, IFN- γ , IL-17A, TNF- α , IL-22, IL-1 β , IL-6, IL-8, eosinophilic cationic protein, myeloperoxidase, TGF- β 1, IgE, specific IgE and albumin in the patient tissue samples and classified the inflammatory endotype of CRS by immunomarkers^[23]. This article generated discussion throughout the CRS and NPs fields about further refining the CRS immunophenotypic delineation and remained impactful worldwide.

The top 10 co-cited references had a profound impact on the fundamental research. Interestingly, these ten publications originated from only four journals, with *the Journal Of Allergy And Clinical Immunology* (IF=14.29, Q1) accounting for 5. At the same time, *Rhinology* (IF=6.634, Q1) published the two references with the highest number of co-citations. We constructed a co-cited reference relationship network with co-cited citations [?] 50 times (Supplementary figure 4).

Keywords, Hotspots, and Trend Topics

Author keywords and keywords plus for 3907 publications were included in our analysis.

By analyzing the author keywords of the publications of CRS and NPs during the past 20 years, we obtained 5138 author keywords, of which 233 appeared ten times or more. Then, we sorted these author keywords

according to the average publication year of the corresponding articles and counted the occurrences and the average citations (Supplementary table 6). Based on these, we made a reasonable judgment of the frontiers and hotspots in the research of CRS and NPs.

As shown in the table, we presented the 20 author keywords with the latest average publication year, which represented the frontiers of research in this field in the last three years, with "Covid-19", "Biologic", "Benralizumab", "Dupilumab", and "Reslizumab" in the top 5. Covid-19 attracted significant attention throughout the medical field as a currently prevalent infectious disease. In addition, the other four author keywords in the top 5 indicated that the research of CRS and NPs focused on biologic treatments. Benralizumab, dupilumab, and reslizumab are monoclonal antibodies to IL-5R, IL-4R, and IL-5, respectively, the biologics currently approved worldwide for allergic diseases such as asthma and atopic dermatitis [24-25]. It proved that biologics and monoclonal antibodies were attracting much attention from researchers in CRS and NPs [26-27]. In addition, we highlight the author keywords with >50 occurrences. We found that "biologics" (n=84), "crswnp" (n=82), "dupilumab" (n=77), "type 2 inflammation" (n=69), "omalizumab" (n=55) showed a high number of occurrences in the frontier articles, which may mean that these are the hotspots of research in recent years.

We plotted the hotspot diagram of author keywords with [?]10 occurrences (Supplementary figure 5) and the relationship network diagram between these keywords (Figure 4A). The hotspot diagram can visually determine the frequency of keyword occurrences, with darker colors representing higher occurrences. In the keywords network diagram, a thicker line means a stronger connection between the two, and the color represents the average occurrence year of that keyword.

In addition, we organized trend topics based on authors' keywords (Supplementary figure 6) to visualize how research trends had changed over the 20 years, with the size of the circles representing the frequency of the corresponding topics. As we can see, "type-2 inflammation", "patient-reported outcomes", "nasal polyp score," and "biologics" were the latest trend topics.

Beyond that, we added the objective keywords plus analysis (Supplementary figure 7) to provide a more comprehensive analysis of keywords. The keywords plus can exclude authors' subjective factors and reflect the main elements discussed in the publication. As shown in Supplementary figure 7, "asthma", "expression", "inflammation", and "endoscopic sinus surgery" were the most discussed keywords in publications during the 20 years. The trending topics analysis was built based on the keywords plus (Figure 4B). The most recent trending topics were "biologics", "type-2 inflammation", "hypereosinophilic", "mepolizumab", and others (more information can be found in the table.) Combining the results above, "biologics" and "type-2 inflammation" were mentioned many times, and the importance of these topics deserves attention.

We combined affiliations, authors, and keywords plus to draw a Sankey diagram (Supplementary figure 8). The Sankey diagram can show the relationship between these three topics. The lines' thickness represents the connection between the two; for example, Bachert B. mainly worked with Ghent University, Ghent University Hospital, and Karolinska Institute. Northwestern University had more studies on nasal polyps.

Discussion

General Information

In the present study, we reviewed the current research in the research of CRS and NPs by bibliometrics for the first time and analyzed the publications in the last 20 years (2003 to 2022) to obtain a comprehensive overview of this research. We observed that: (1) The United States and Northwestern University were the most influential country and institution with the most articles and the highest citations. (2) Bachert C. was the scholar with the most articles and the highest co-cited citations. (3) The *International Forum Of Allergy & Rhinology* had the highest number of articles, and the *Journal Of Allergy And Clinical Immunology* had the highest number of citations. (4) The endotype and immune characteristics of CRS and NPs had received long-term and extensive attention. (5) "Covid-19", "biologic", and "type 2 inflammation" were currently the top research hotspots. These findings are helpful for researchers to understand the current state and

grasp potential directions and trending research topics on CRS and NPs.

Results Interpretation and Research Directions Mining

Development Situation

This research chose to analyze the Web Of Science database because it is one of the most authoritative databases. CRS and NPs had received attention from researchers at an early stage, which may be related to the prevalence of this disease. From 2003 to 2020, global research on CRS and NPs grew substantially, with a generally stable growth rate. The average annual increase in publications for these 18 years was 20, with an annual average of 175.1 publications. Moreover, from 2020-2022, the growth reached a plateau with an annual average of 380.7 publications. The peak and plateau of publication over the past three years indicated that the study was receiving sustained attention from researchers and was in a steady state of development and research.

The main subject areas related to CRS and NPs were not only otolaryngology but also immunology and allergology. The immunological mechanisms of CRS and NPs had received much attention from scholars, which may bring reference to some researchers.

Major Contributing Units

The major contributors to this research were the United States and China, with the United States accounting for 33.5% of publications and China for 17.0% over the 20 years. Among the top 10 institutions with the most publications, the United States and China account for three each. Northwestern University had the highest publication volume and citations in the area worldwide. In CRS and NPs research, cooperation and linkages between countries were already intense. All countries with more than ten publications were involved in international collaboration. Undoubtedly, it promoted the flourishing of CRS and NPs research. Although European countries had fewer publications than the United States and China, their contribution to the research cannot be ignored. Of the ten institutions with the most publications, three were from Europe. And the Ghent University Hospital received the second most citations, following Northwestern University.

Of those institutions with more than ten publications, we found that Chang Gung University, Padova University, and Chung Shan Medical University had never collaborated with other institutions, which may affect the continued development of these institutions. We call for broader collaboration among countries and institutions, leading to more CRS and NPs research breakthroughs.

A total of 428 journals published research on CRS and NPs over the 20 years, and the International Forum Of Allergy & Rhinology (IF=5.426, Q1) had the most publications, indicating that it is the most popular journal in this research. After compiling the top 10 journals regarding the number of publications, we noted that six journals are Q1 and four are Q2. The top 3 journals with the most citations were all high-impact journals in Q1. Although CRS and NPs belong to rhinological diseases, many articles were published in allergy and basic medicine journals in addition to rhinology journals.

Leading experts and related directions

The five authors with the most publications in this study were Bachert Claus, Schleimer Robert P, Schlosser Rodney J, Zhang Luo, and Kern Robert C, with over 80 publications. We searched that Prof. Bachert Claus also focused on biological studies in 2022, and the latest article in which he participated showed that Omalizumab's effectiveness is independent of Staphylococcal Enterotoxin sensitization^[28]. Moreover, he also published as the first author of the study of the therapeutic effect of Dupilumab and Mepolizumab in CRS patients^[27,29]. In addition, he constructed a decision tree model through the combination of nasal secretion biomarkers and clinical characteristics of CRS patients to accurately define type 2 CRSwNP patients in a non-invasive way to give more rational treatment to patients in the clinic^[30]. Prof. Bachert Claus' group has focused on various directions, including endotypes clustering of CRS patients based on different molecules, surgery, biological therapies, pathophysiological mechanisms, and so on^[28-35]. Recently, Prof. Schleimer Robert P has focused on frontier molecules and treatments such as Retinoic acid, Nasal secretion tissue

plasminogen activator, and oral CRTH2 antagonist [36-38]. On the other hand, Prof. Schlosser Rodney J focused more on olfaction and the surgical treatment of CRS [39-41].

Prof. Bachert Claus was the author with the highest number of co-citations, followed by Prof. Fokkens WJ. and Prof. Gevaert P. A high number of co-citations often means that the author has a large amount of seminal research in the field that has been cited several times by subsequent researchers. They were all involved in compiling the most co-cited publication in research of CRS and NPs: European Position Paper on Rhinosinusitis and Nasal Polyps 2012. Interestingly, all three authors had recently published research on biologics as first authors^[27,29, 42-43]. As mentioned in the previous article, this fact reaffirmed the importance of biologics research in CRS and NPs research.

Highly cited articles and current hotspots

Studies with high co-citation counts often represent fundamental and fundamental research in the field and are generally published earlier. Except for the EPOS, we summarized the nine most co-cited articles, which can be divided into three categories: immune features and endotypes, clinical applications, and epidemiological analyses. Of these nine articles, 6 explored the inflammatory patterns in CRS in different countries or different endotypes, and they collectively focused on the cell expression profile and immune marker profile of CRS patients, such as T(H)1/ T(H)2 skewed inflammation^[21-23,44-46]. In addition, two publications focused on clinical applications, respectively evaluating the effectiveness of SNOT-22 (a derivative of SNOT-20), a quality-of-life questionnaire for patients with CRS^[47], and the clinical efficacy of Omalizumab^[48]. Moreover, the last publication was the European international multicentre prevalence study of CRS^[49]. It should be noted, however, that the value of an article is not reliably measured by co-citation alone, as the newly published articles will rank lower when analyzed in terms of citations independently. In contrast, many incoming articles have significantly impacted frontier research.

By analyzing the timing and frequency of keyword appearances, we could obtain the current frontier research about CRS and NPs. Subsequently, we grouped the current frontier research hotspots into three sections: monoclonal antibodies and biologics, Covid-19, Inflammatory response, and endotypes.

Limitations and shortcomings

The limitations of our study included that the analysis was performed using the "Web of Science" database and the language "English," meaning that some publications from other databases and non-English publications were not included in our data analysis. It would cause us to omit parts of the publication and may impact the results. But this is unlikely to change the main trends described in this article.

Conclusions

This study provided an overview of studies on CRS and NPs from a bibliometric perspective for the first time. The number of relevant publications grew dramatically over 20 years, representing many scholars' increasing interest in the area. The United States was the primary leader in this research. Northwestern University and Bachert C. were the most prolific institutions and authors, respectively. The *International Forum Of Allergy & Rhinology* published the most articles, and the *Journal Of Allergy And Clinical Immunology* was the most cited. Researchers can stay updated with the latest trends in this research by following them. Our study concluded that "Covid-19", "biologic," and "type 2 inflammation" were current research hotspots. These directions deserve attention from scholars. We expect that our study will facilitate closer communication and collaboration among scholars from different countries to jointly promote this scientific area's progress.

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Tables and Figure legends

Table 1. Top 10 countries in terms of the number of publications and citations.

Rank	Country	Documents	Citations
1	The United States (North America)	1248	39027
2	China (Asia)	631	11065
3	South Korea (Asia)	293	5276
4	Belgium (Europe)	272	17501
5	Japan (Asia)	257	7726
6	Italy (Europe)	247	6129
7	England (Europe)	237	12219
8	Germany (Europe)	217	8170
9	Canada (North America)	173	6273
10	Sweden (Europe)	145	8381

Rank	Journal	IF (Q)	Documents	Citations	Avg. pub. year
1	journal of allergy and clinical immunology	14.29 (Q1)	188	13739	2015.9628
2	international forum of allergy & rhinology	5.426 (Q1)	365	7813	2016.7671
3	allergy	14.71 (Q1)	118	6880	2014.5254
4	laryngoscope	2.97 (Q2)	180	6621	2013.2167
5	american journal of rhinology & allergy	2.300 (Q3)	318	6177	2015.1761
6	rhinology	6.634 (Q1)	188	4994	2015.0638
7	otolaryngology-head and neck surgery	5.591 (Q1)	102	3333	2012.8725
8	american journal of rhinology	/	58	2481	2006.6207
9	current allergy and asthma reports	4.919 (Q2)	83	1986	2014.012

Rank	Journal	IF (Q)	Documents	Citations	Avg. pub. year
10	clinical and experimental allergy	5.401 (Q2)	54	1915	2014.7963

Supplementary table 1. Top 10 institutions in terms of the number of publications, the citations, and the average year of publication.

	Institution	Documents	Citations	Avg. pub. year
1	Northwestern University (The United States)	191	8916	2016.2775
2	Capital Medical University (China)	130	3068	2018.4385
3	Sun Yat-sen University (China)	123	2314	2017.9268
4	Ghent University (Belgium)	116	7107	2017.5172
5	Ghent University Hospital (Belgium)	111	8459	2014.2072
6	Harvard Medical School (The United States)	95	1684	2019.4316
7	Karolinska Institutet (Sweden)	93	5343	2018.043
8	Oregon Health and Science University (The United States)	84	2852	2015.2976
9	Seoul National University (South Korea)	78	1633	2016.9872
10	Huazhong University of Science and Technology (China)	77	2440	2016.4805

Supplementary table 2. Ranking of authors by the number of publications.

Author	Documents	Citations	Avg. pub. year
Bachert, Claus	158	10093	2016.6266
Schleimer, Robert P.	85	4629	2016.4824
Schlosser, Rodney J.	85	1922	2016.1765

Zhang, Luo	84	2522	2019.0238
Kern, Robert C.	80	3989	2016.0125

Supplementary table 3. Ranking of co-cited authors.

Co-Cited Author	Citations
Bachert, C	2808
Fokkens, WJ	1767
Gevaert, P	1061
Van zele, T	1009
Hopkins, C	852
Bhattacharyya, N	760
Soler, ZM	672
Stevens, WW	667
Lund, VJ	665
Fokkens, W	627

Supplementary table 4. Ranking of journals (in descending order by documents).

Rank	Journal	IF (Q)	Documents	Citations	Avg.
1	international forum of allergy & rhinology	5.426 (Q1)	365	7813	2016.
2	american journal of rhinology & allergy	2.300 (Q2)	318	6177	2015.
3	journal of allergy and clinical immunology	14.29 (Q1)	188	13739	2015.
4	rhinology	6.634 (Q1)	188	4994	2015.
5	laryngoscope	2.97 (Q2)	180	6621	2013.
6	european archives of oto-rhino-laryngology	3.236 (Q2)	164	1803	2016.
7	allergy	14.71 (Q1)	118	6880	2014.
8	otolaryngology-head and neck surgery	5.591 (Q1)	102	3333	2012.
9	current allergy and asthma reports	4.919 (Q2)	83	1986	2014.
10	journal of allergy and clinical immunology-in practice	11.022 (Q1)	72	1577	2019.

Supplementary table 5. Ranking of co-cited references.

Rank	Co-cited reference	Citations
1	Fokkens WJ, 2012, Rhinology, V50, P1, DOI 10.4193/rhin20.600	1323
2	Lund Valerie J., 1993, Rhinology (utrecht), V31, P183	459
3	Van Zele T, 2006, Allergy, V61, P1280, DOI 10.1111/j.1398-9995.2006.01225.x	428
4	Tomassen P, 2016, J Allergy Clin Immun, V137, P1449, DOI 10.1016/j.jaci.2015.12.1324	365
5	Cao PP, 2009, J Allergy Clin Immun, V124, P478, DOI 10.1016/j.jaci.2009.05.017	344
6	Zhang N, 2008, J Allergy Clin Immun, V122, P961, DOI 10.1016/j.jaci.2008.07.008	337
7	Hastan D, 2011, Allergy, V66, P1216, DOI 10.1111/j.1398-9995.2011.02646.x	305
8	Bachert C, 2001, J Allergy Clin Immun, V107, P607, DOI 10.1067/mai.2001.112374	286
9	Hopkins C, 2009, Clin Otolaryngol, V34, P447, DOI 10.1111/j.1749-4486.2009.01995.x	286
10	Gevaert P, 2013, J Allergy Clin Immun, V131, P110, DOI 10.1016/j.jaci.2012.07.047	261

Supplementary table 6. Author Keywords Statistics.

Keyword	Occurrences	Avg. pub. year	Avg. citations
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covid-19	12	2021.1667	12.6667
biologic	10	2021.1	12.6
benralizumab	28	2020.8929	11.5357
dupilumab	77	2020.8442	14.1039
reslizumab	13	2020.6154	17.8462
biologics	84	2020.6071	16.119
type-2 inflammation	10	2020.6	13.4
type 2 inflammation	69	2020.5652	24.4638
monoclonal antibody	15	2020.2667	7.8667
patient-reported outcome measure	10	2020	9.7
severe asthma	31	2020	15.129
mepolizumab	42	2019.9048	28.4286
crswnp	82	2019.8902	11.7073
crssnp	16	2019.875	18.9375
endotypes	39	2019.8462	40.9487
chronic rhinosinusitis with nasal polyps (crswnp)	19	2019.8421	13.7895
monoclonal antibodies	22	2019.7727	12.5455
medical therapy of chronic rhinosinusitis	11	2019.7273	11.8182
omalizumab	55	2019.7273	18.5636
biologicals	13	2019.6923	24.3846

Figure 1. Publications output over 20 years.

(A) Annual publication number of research of CRS and NPs. (B) The number and proportion of publications in different research categories.

Figure 2. The collaborative networks between different units.

Inter-country cooperation network. The color represents the cluster. (B)

Geographical distribution of inter-country cooperation. Each connecting line represents 5 collaborative publications between two countries. The color represents the number of publications. (C) Inter-institutional cooperation network. The color represents the average year of publication. (D) Author collaboration network.

Figure 3. The core sources journals and the citation relationships between journals.

Core sources journals according to Bradford's law. (B) The dual-map overlay of journals. The connecting line represents the citation relationship.

Figure 4. Inter-keywords network and trend topics.

The relationship network between authors' keywords. (B) Trending topics analysis based on keywords plus.

Supplementary figure 1. Country publication density map.

The color represents the number of publications.

Supplementary figure 2. A collaborative network of co-cited authors.

Supplementary figure 3. Inter-journal citation network.

Supplementary figure 4. Co-cited reference relationship network.

Supplementary figure 5. The hotspot map of author keywords.

The shade of the color represents the frequency of occurrence.

Supplementary figure 6. Trending topic analysis based on author keywords.

Supplementary figure 7. Keywords plus tree.

Supplementary figure 8. Sankey diagram for the authors-authors-keywords plus network.

The middle field is the affiliation, the left field is the author, and the right field is the keywords plus.

A

PUBLICATIONS



B

Publications categories

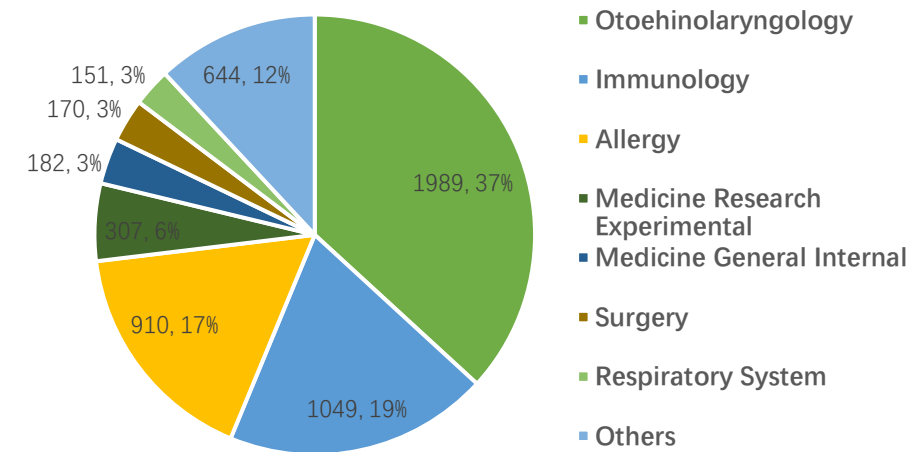
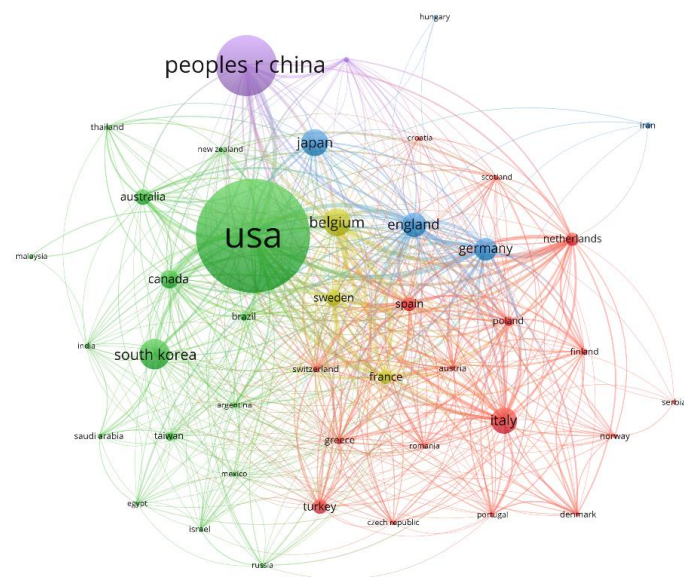


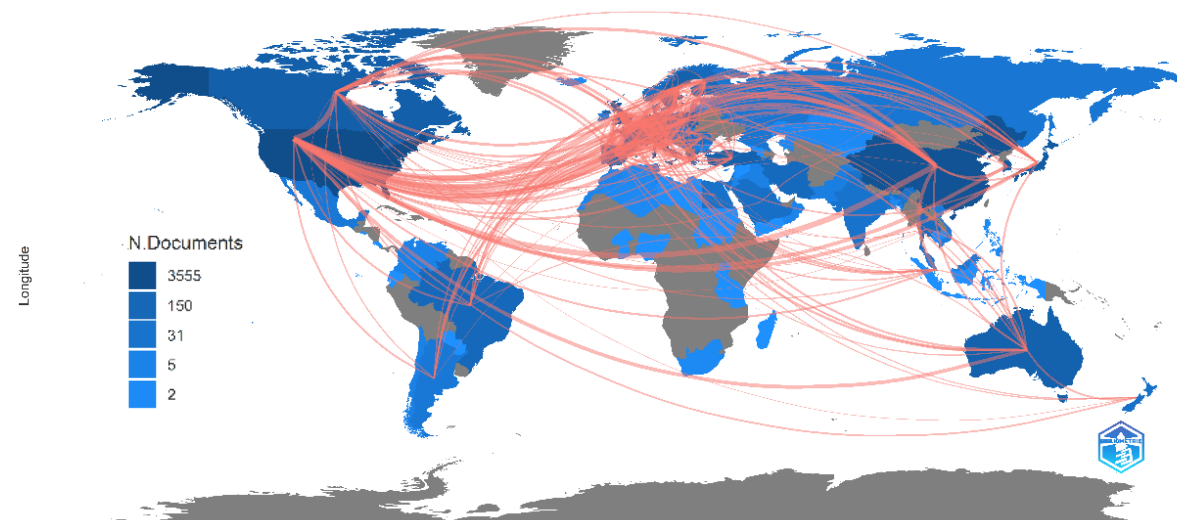
Figure 1

A

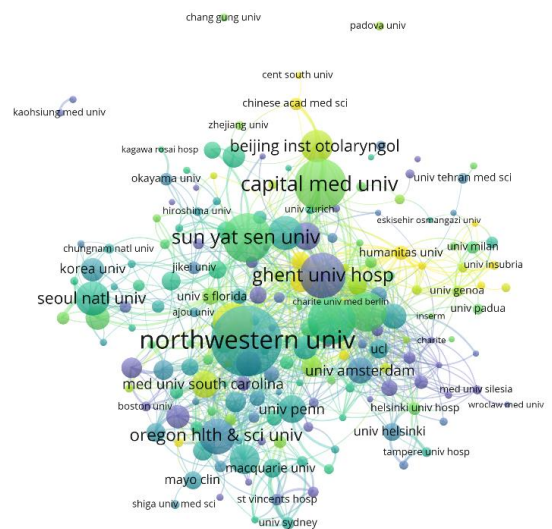


B

Country Collaboration Map



C



D

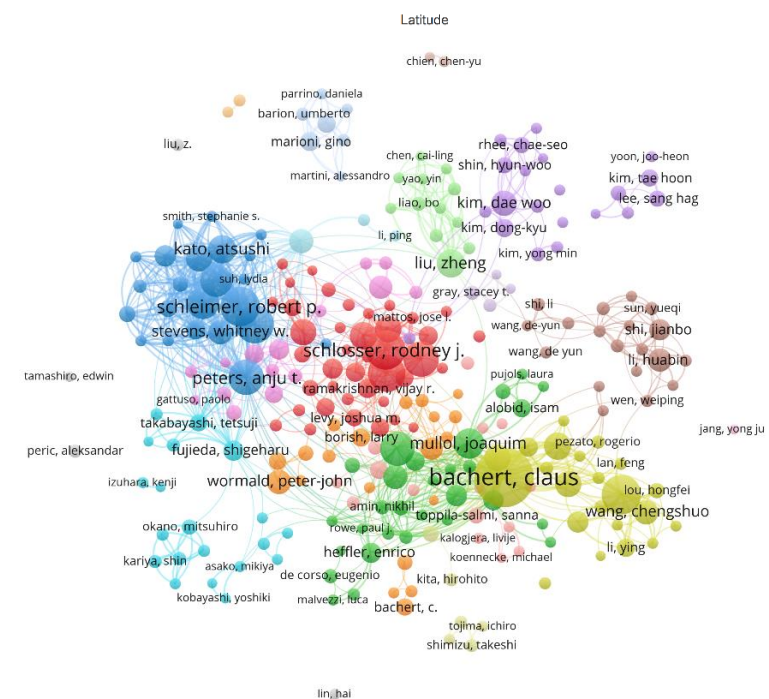
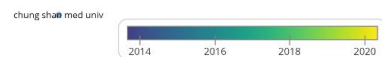
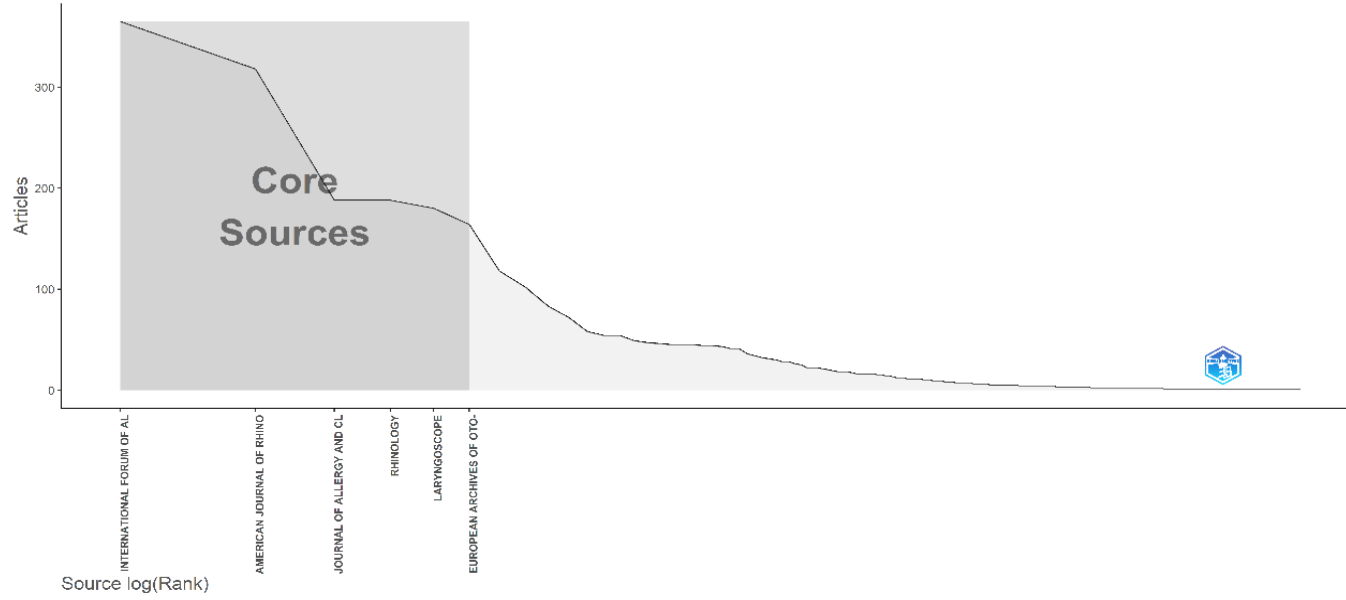


Figure 2



A



B

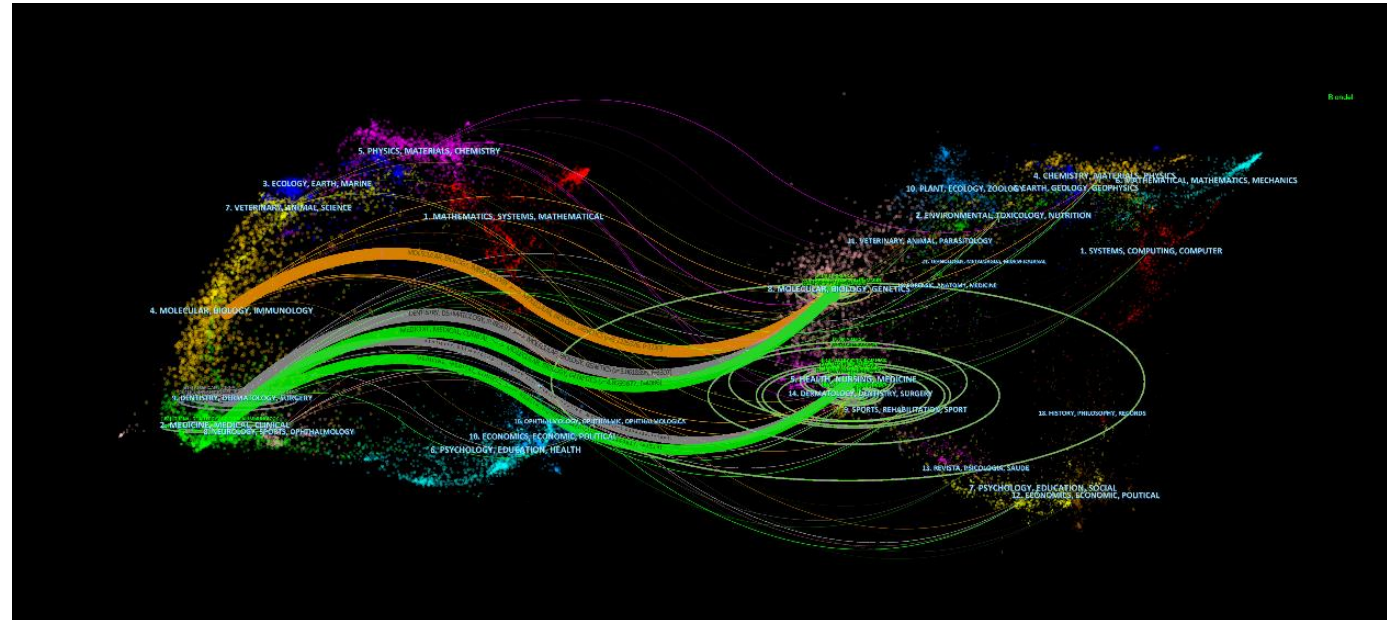
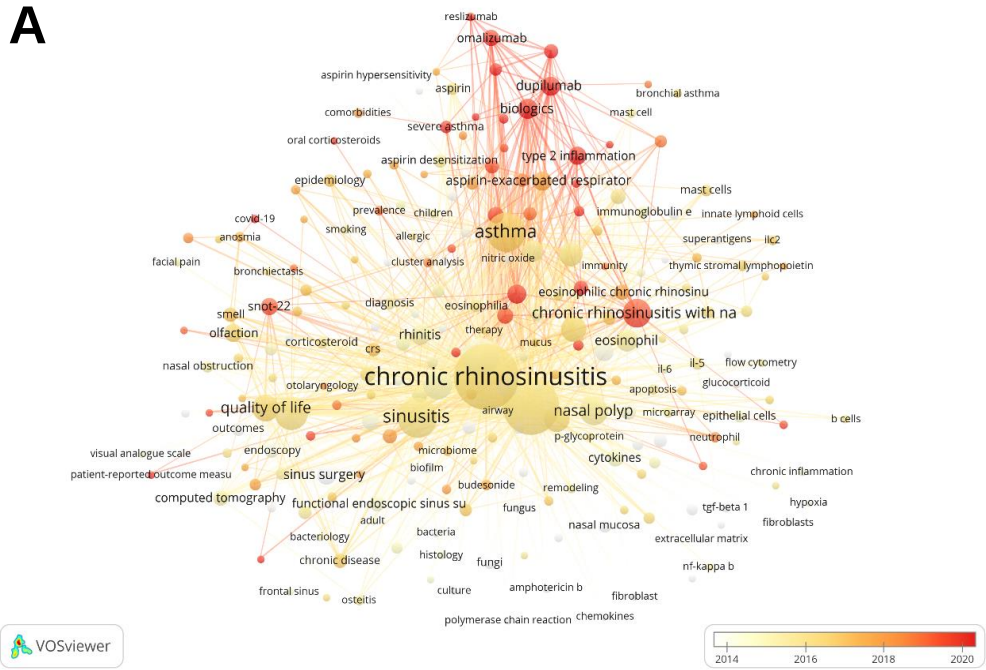


Figure 3

A



B

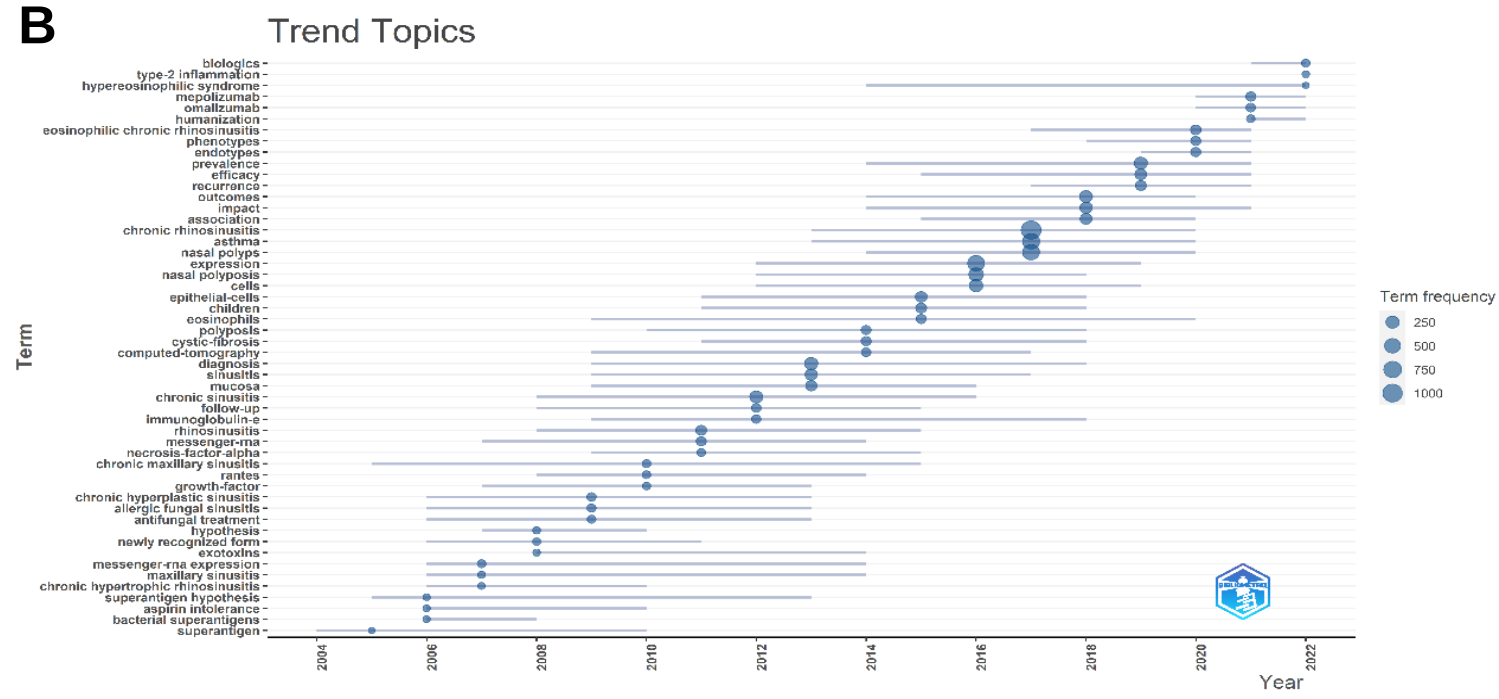
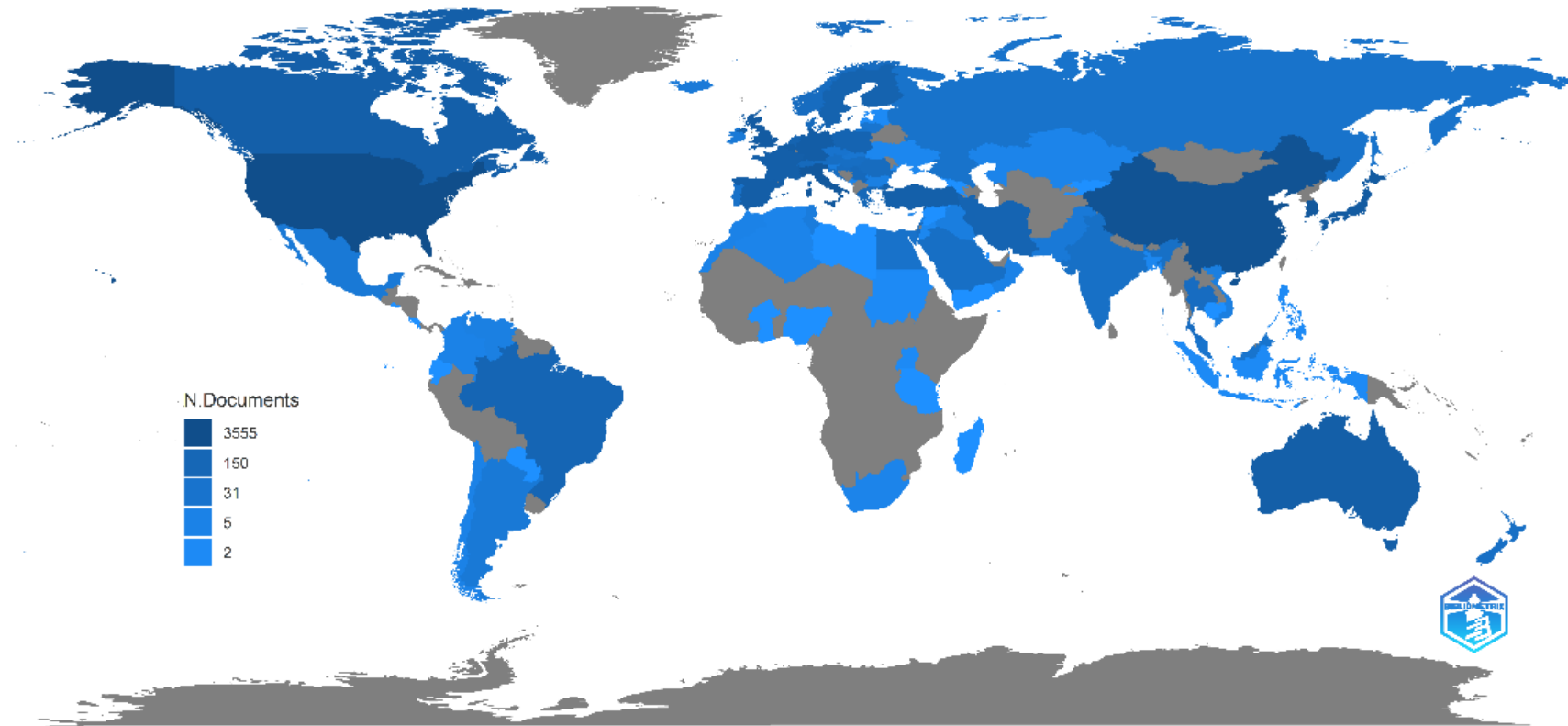
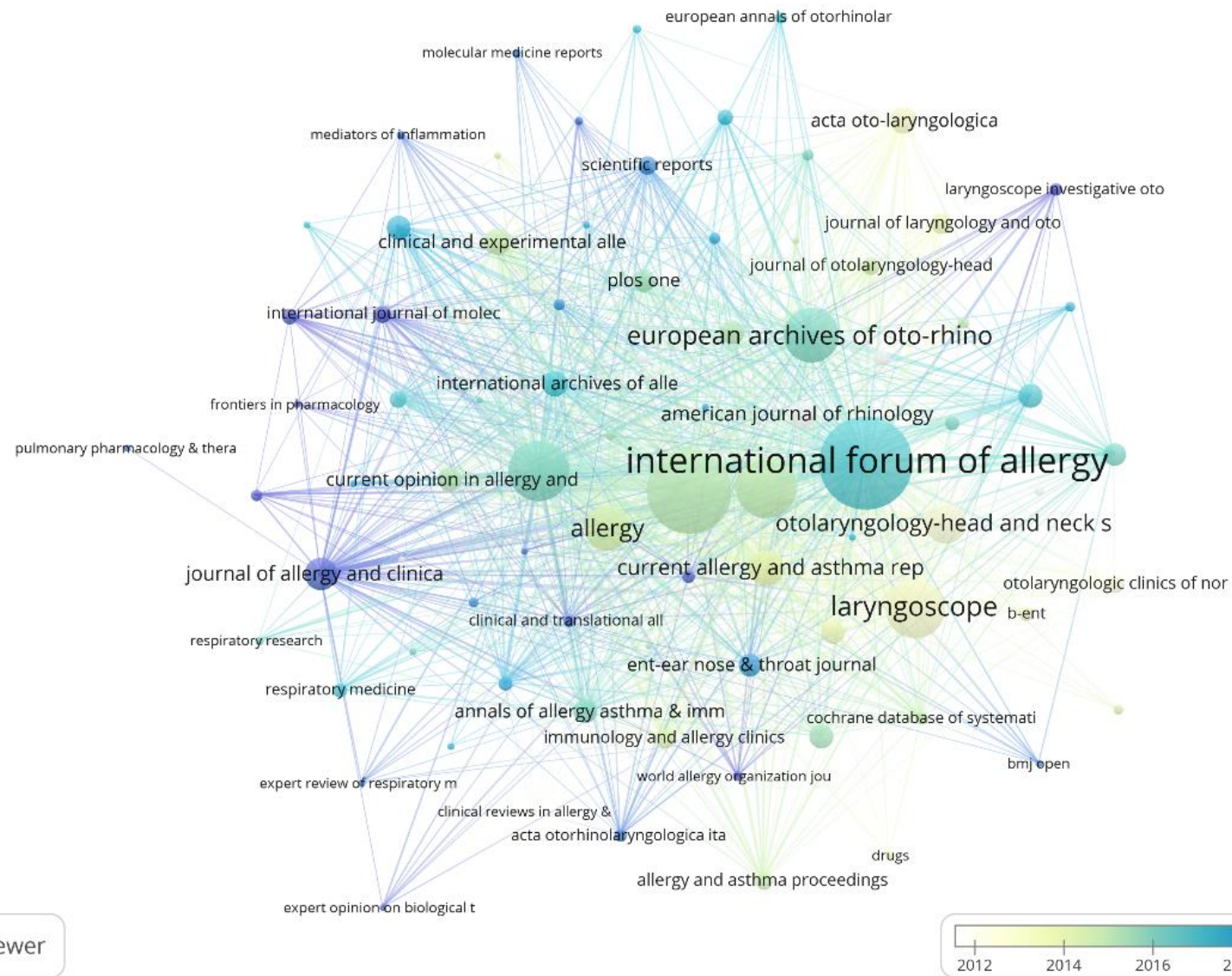


Figure 4

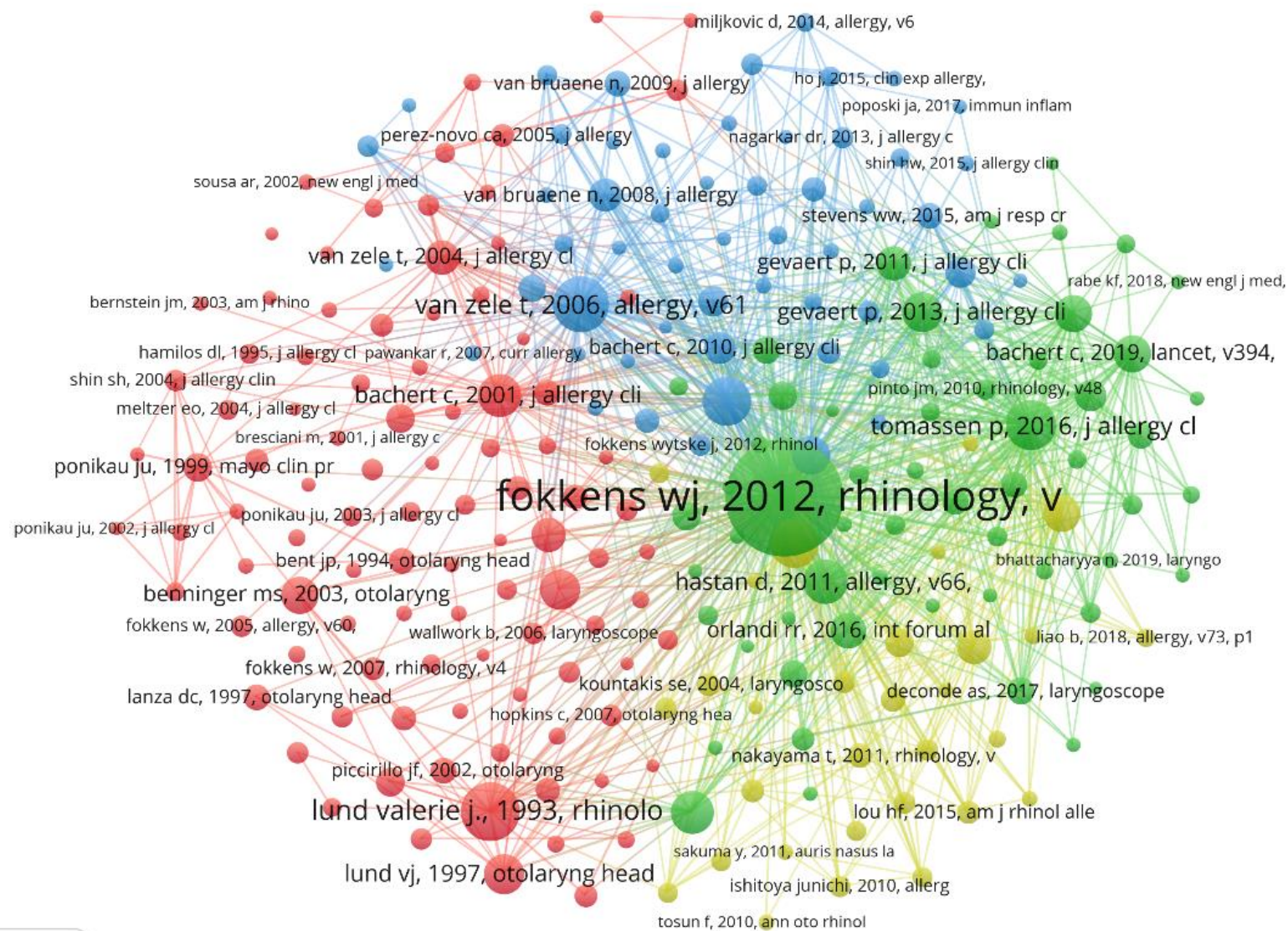
Country Scientific Production



Supplementary figure 1

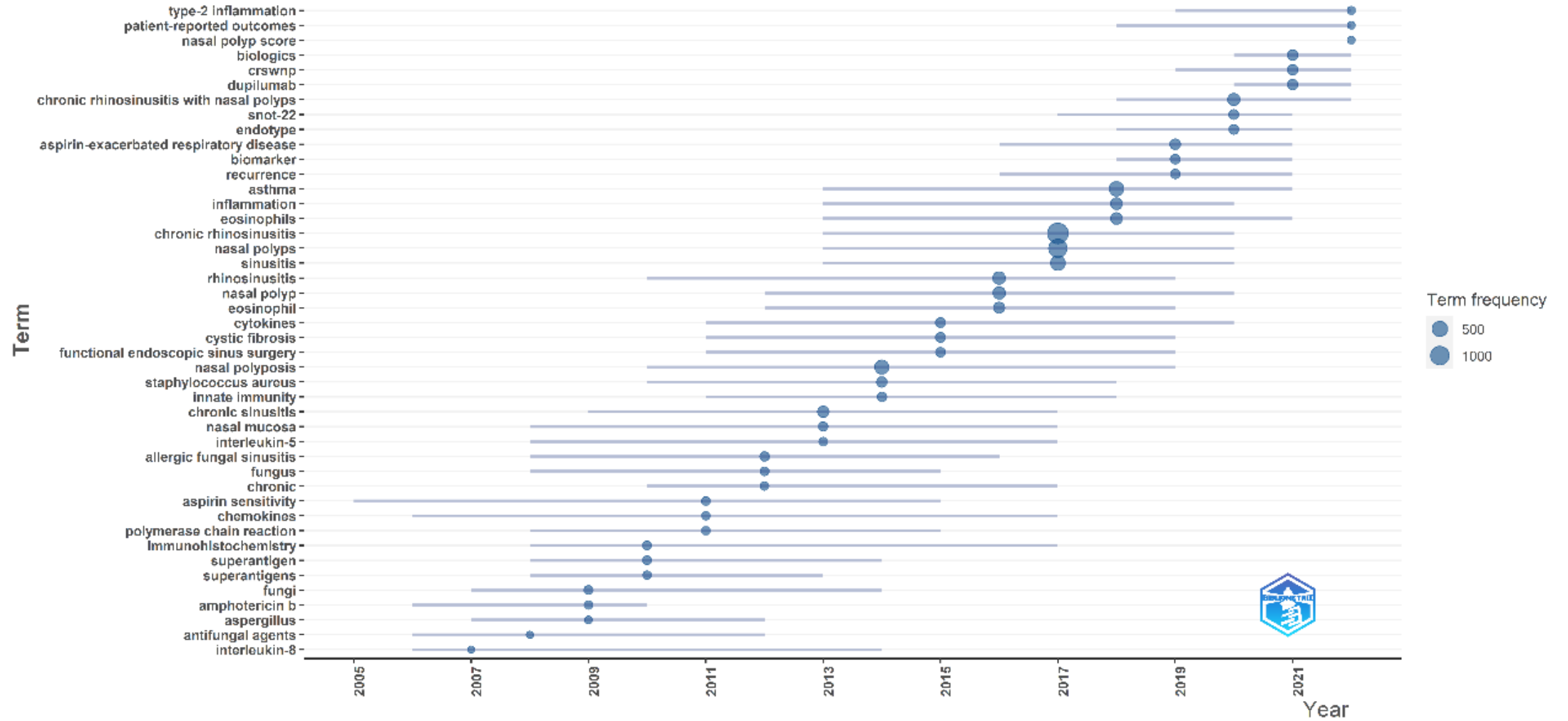


Supplementary figure 3



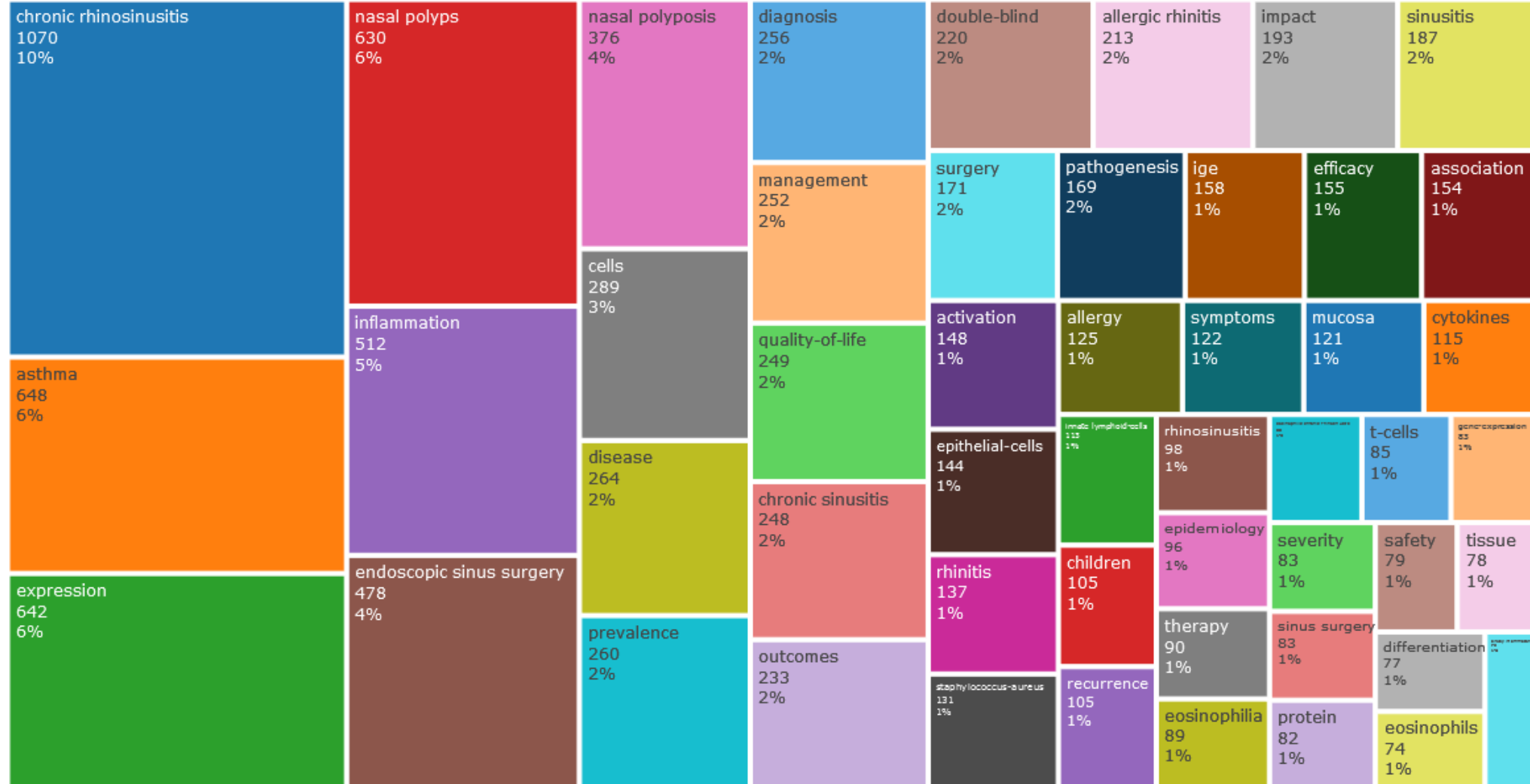
Supplementary figure 4

Trend Topics

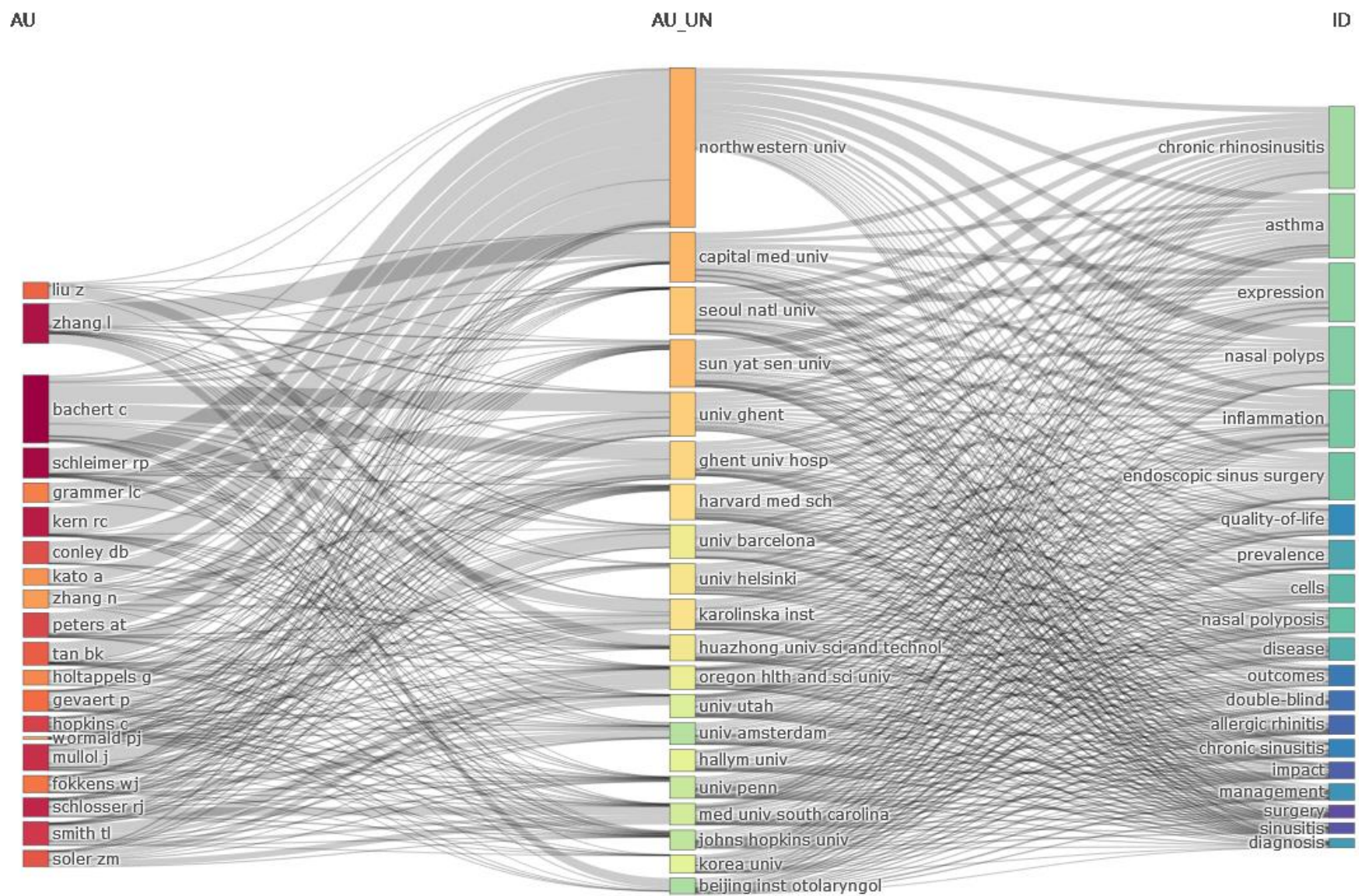


Supplementary figure 6

Tree



Supplementary figure 7



Supplementary figure 8