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ORIGINAL ARTICLE

The top 100 most cited articles in anaphylaxis: a bibliometric analysis

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Abstract

Bibliometric analysis is helpful to determine the most influential studies in a specific field. A large number of publications in anaphylaxis have been published. However, no bibliometric analysis of anaphylaxis was conducted based on our known. The aim of this study is to identify the top 100 most cited articles in anaphylaxis and analyze their bibliometric characteristics. We searched in the Web of Science core database on November 20, 2021. Articles were listed in descending order by their total citations. Hence the top 100 most cited articles in anaphylaxis were identified and analyzed. Bibliometric indicators included: year of publication, total number of citations and average citations per year (ACY), journal of publication and impact factor (IF), countries, institutes, and authors, which were analyzed by Biblioshiny. Co-occurrence was used to visualize the classification and hotspots. The top 100 most cited articles were published between 1991 and 2017. The largest number of articles was published in a single interval in 2006–2008. Total citations of the 100 articles were between 155 and 1241 and were positively correlated with the number of articles published in each 3-year interval. The top100 articles were published in 34 different journals. ***The Journal of Allergy and Clinical Immunology*** published the most ($n = 41$). The corresponding authors of the top100 articles were from 13 different countries, mostly in North America and Europe. Statistical analysis revealed a positive correlation between total number of citations and ACY ($r = 0.670$, $p < 0.01$) and between total number of citations and IF ($r = 0.219$, $p < 0.05$), whereas a negative correlation between ACY and length of time since publication ($r = -0.697$, $p < 0.01$). The research focuses were classified into three clusters: (1) the epidemiology and management. (2) the risk factor and treatment. (3) the assessment and diagnosis. COVID-19 vaccines, drug allergy and management were the recent major topics. This bibliometric analysis reveals the progress and hotspots of research in anaphylaxis, which may lay a foundation for further research.

Keywords Anaphylaxis · Bibliometric analysis · Biblioshiny

Abbreviations

ACY: Average citations per year
IF: Impact factor

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Introduction

Anaphylaxis is a serious systemic hypersensitivity reaction that is usually rapid in onset and may cause death. Severe anaphylaxis is characterized by potentially life-threatening compromise in breathing and/or the circulation and may occur without typical skin features or circulatory shock being present [1]. Recent studies have confirmed that the incidence of anaphylaxis has increased and poses a significant burden on population health and healthcare settings [2], [3]. With a better understanding of anaphylaxis, more and more articles have been published. However, the information in the database will also be more complex, making it difficult for clinicians to find most needed and valuable research.

Bibliometric analysis is the process of extracting measurable data through statistical analysis of published research studies, which can provide researchers with important messages in a specific field [4]. Citation analysis

is one of bibliometric analysis methods that has been used to quantify the relative significance of a scientific article by examining the citations attributed to that paper. A thorough bibliometric analysis of the top 100 most cited articles can help the understanding of disciplinary development and future directions of a research field [5].

According to document index, some allergic diseases have been explored by bibliometric analysis, such as asthma [6], allergic rhinitis [7], and food allergy [8]. However, no bibliometric analysis of anaphylaxis was conducted based on our knowledge. Thus, this study aimed to identify the top 100 most cited articles in anaphylaxis and analyze their bibliometric characteristics.

Methods

Data sources and search strategies

Web of Science Core Database was chosen as the database to perform the literature source and bibliometric analysis for this study. The top100 most cited articles in anaphylaxis were retrieved from the database Web of Science Core Collection on November 20, 2021, with the following strategy: topic = anaphylaxis, from 1991 to 2021, no language limitation. Only article and review were included in analysis. Abstracts, editorials, proceeding papers, and book chapters articles were excluded. A total of 14,096 publications were retrieved from the Web of Science Core Database. Articles were ranked based on the total number of citations. If articles with the same total citation, recent articles were ranked higher.

Data extraction and bibliometric parameters

Research focusing on anaphylaxis or regarding anaphylaxis as a main part were included in this study. The two researchers examined the articles independently for qualify and finally reached an agreement on the list of the top 100 most cited articles. Then the top 100 list was imported into Biblioshiny and VOSviewer for bibliometric analysis.

Biblioshiny is a new advanced tool of bibliometric analyses [9, 10]. In this study, it was used it to perform a basic bibliometric analysis. To obtain more comprehensive information of the result based on co-occurrence which can visualize the research hotspots and classification, the study also constructed bibliometric maps by VOSviewer. Bibliometric indicators included year of publication, total number of citations and average citations per year (ACY), journal of publication and impact factor (IF), countries, institutes, and authors and co-occurrence network.

Statistical analysis

SPSS 19.0 was used for the statistical analysis. The Kolmogorov–Smirnov test was used to analyze the normal distribution of data. Spearman's correlation was used to evaluate the association between total number of citations, ACY, IF, and length of time since publication. A p-value < 0.05 was accepted as statistically significant.

Ethical statement

This research did not involve intervention or data collection in animal experiments or clinical trials. Thus, approval from an ethical committee was not needed.

Results

The top 100 most cited articles are listed in Table 1, sorted in descending order according to the number of citations. In the top 100 list, 82 were articles and 18 were reviews.

Year of publication

The top 100 most cited articles were published between 1991 and 2017. The number of articles published in each 3-year interval followed normal distribution ($p = 0.682$). The largest number of articles published in a single interval was 25, which occurred in 2006–2008.

Figure 1 shows the number of articles published in each 3-year interval.

Citations

The total citations of articles in each 3-year interval are shown in Fig. 2. The total number of citations in each 3-year interval followed normal distribution ($p = 0.962$). The largest total number of citations in each 3-year interval was also 2006–2008. We identified a positive correlation between total citations and the number of articles published in each 3-year interval ($r = 0.921$, $p < 0.01$). Total citations of the 100 articles were between 156 and 1243, with a mean of 278.02. Top 10 most cited articles accounted for 24.44% ($n = 6796$) of the total citations. Average citations per year (ACY) of the top 100 articles were from 5.61 to 68.13, with a mean of 18.54. Six of the top 10 most cited articles according to total citations still ranked in the top 10 list according to average citations per year. We observed that the most cited article among the

Table 1 List of the top 100 most cited articles in anaphylaxis(1991-2021)

Rank	Article	Total Number of Citations	Average Citations per Year	Length of Time since Publication	IF
1	Sampson H A, Mendelson L, Rosen J P. Fatal and near-fatal anaphylactic reactions to food in children and adolescents[J]. New England Journal of Medicine, 1992, 327(6): 380–384	1243	41.43	30	91.253
2	Bock S A, Muñoz-Furlong A, Sampson H A. Fatalities due to anaphylactic reactions to foods[J]. Journal of Allergy and Clinical Immunology, 2001, 107(1): 191–193	1173	55.86	21	10.793
3	Chung C H, Mirakhur B, Chan E, et al. Cetuximab-induced anaphylaxis and IgE specific for galactose-α-1, 3-galactose[J]. New England journal of medicine, 2008, 358(11): 1109–1117	921	65.79	14	91.253
4	Pumphrey R S H. Lessons for management of anaphylaxis from a study of fatal reactions[J]. Clinical and experimental allergy, 2000, 30(8): 1144–1150	693	31.50	22	5.018
5	Brown S G A. Clinical features and severity grading of anaphylaxis[J]. Journal of Allergy and Clinical Immunology, 2004, 114(2): 371–376	548	30.44	18	10.793
6	Muraro A, Roberts G, Worm M, et al. Anaphylaxis: guidelines from the European Academy of Allergy and Clinical Immunology[J]. Allergy, 2014, 69(8): 1026–1045	545	68.13	8	13.146
7	Simons F E R, Ardusso L R F, Bilò M B, et al. World allergy organization guidelines for the assessment and management of anaphylaxis[J]. World Allergy Organization Journal, 2011, 4(2): 13–37	453	41.18	11	4.084
8	Nelson H S, Lahr J, Rule R, et al. Treatment of anaphylactic sensitivity to peanuts by immunotherapy with injections of aqueous peanut extract[J]. Journal of Allergy and Clinical Immunology, 1997, 99(6): 744–751	431	17.24	25	10.793
9	Lieberman P, Nicklas R A, Oppenheimer J, et al. The diagnosis and management of anaphylaxis practice parameter: 2010 update[J]. Journal of Allergy and Clinical immunology, 2010, 126(3): 477–480	401	33.42	12	10.793
10	Commins S P, Satinover S M, Hosen J, et al. Delayed anaphylaxis, angioedema, or urticaria after consumption of red meat in patients with IgE antibodies specific for galactose-α-1, 3-galactose[J]. Journal of Allergy and Clinical Immunology, 2009, 123(2): 426–433	388	29.85	13	10.793
11	Sampson H A. Anaphylaxis and emergency treatment[J]. Pediatrics, 2003, 111(Supplement 3): 1601–1608	367	19.32	19	7.125
12*	Muraro A, Roberts G, Clark A, et al. The management of anaphylaxis in childhood: position paper of the European academy of allergology and clinical immunology[J]. Allergy, 2007, 62(8): 857–871	365	24.33	15	13.146
13	Mertes P M, Laxenaire M C, Alla F. Anaphylactic and anaphylactoid reactions occurring during anesthesia in France in 1999–2000.[J]. Anesthesiology, 2003, 99(3):536	365	19.21	19	7.892
14	Yocum M W, Butterfield J H, Klein J S, et al. Epidemiology of anaphylaxis in Olmsted County: a population-based study[J]. Journal of Allergy and Clinical Immunology, 1999, 104(2): 452–456	354	15.39	23	10.793
15	Vadas P, Gold M, Perelman B, et al. Platelet-activating factor, PAF acetylhydrolase, and severe anaphylaxis[J]. New England Journal of Medicine, 2008, 358(1): 28–35	346	24.71	14	91.253
16	Turner P J, Gowland M H, Sharma V, et al. Increase in anaphylaxis-related hospitalizations but no increase in fatalities: an analysis of United Kingdom national anaphylaxis data, 1992–2012[J]. Journal of Allergy and Clinical Immunology, 2015, 135(4): 956–963	337	48.14	7	10.793
17	Simons F E R, Ardusso L R F, Bilò M B, et al. World Allergy Organization anaphylaxis guidelines: summary[J]. Journal of Allergy and Clinical Immunology, 2011, 127(3): 587–593	336	30.55	11	10.793
18	Oettgen H C, Martin T R, Wynshaw-Boris A, et al. Active anaphylaxis in IgE-deficient mice[J]. Nature, 1994, 370(6488): 367–370	333	11.89	28	49.962
19	Bernstein D I, Wanner M, Borish L, et al. Twelve-year survey of fatal reactions to allergen injections and skin testing: 1990–2001[J]. Journal of Allergy and Clinical Immunology, 2004, 113(6): 1129–1136	332	18.44	18	10.793

Table 1 (continued)

Rank	Article	Total Number of Citations	Average Citations per Year	Length of Time since Publication	IF
20	Li X M, Serebrisky D, Lee S Y, et al. A murine model of peanut anaphylaxis: T-and B-cell responses to a major peanut allergen mimic human responses[J]. Journal of Allergy and Clinical Immunology, 2000, 106(1): 150–158	329	14.95	22	10.793
21*	Bochner B S, Lichtenstein L M. Anaphylaxis.[J]. New England Journal of Medicine, 1991, 324(25):1785–1790	329	10.61	31	91.253
22	Liew W K, Williamson E, Tang M L K. Anaphylaxis fatalities and admissions in Australia[J]. Journal of Allergy and Clinical Immunology, 2009, 123(2): 434–442	322	24.77	13	10.793
23	Brockow K, Jofer C, Behrendt H, et al. Anaphylaxis in patients with mastocytosis: a study on history, clinical features and risk factors in 120 patients[J]. Allergy, 2008, 63(2): 226–232	320	22.86	14	13.146
24	Schwartz, Lawrence B. Diagnostic value of tryptase in anaphylaxis and mastocytosis.[J]. Immunology and Allergy Clinics of North America, 2006, 26(3):451–463	315	19.69	16	3.479
25	Sampson H A, Muñoz-Furlong A, Campbell R L, et al. Second symposium on the definition and management of anaphylaxis: summary report—Second National Institute of Allergy and Infectious Disease/Food Allergy and Anaphylaxis Network symposium[J]. Journal of Allergy and Clinical Immunology, 2006, 117(2): 391–397	314	19.63	16	10.793
26	Dombrowicz D, Flamand V, Brigman K K, et al. Abolition of anaphylaxis by targeted disruption of the high affinity immunoglobulin E receptor α chain gene[J]. Cell, 1993, 75(5): 969–976	314	10.83	29	41.584
27	Simons F E R, Ebisawa M, Sanchez-Borges M, et al. 2015 update of the evidence base: World Allergy Organization anaphylaxis guidelines[J]. World Allergy Organization Journal, 2015, 8: 32	308	44.00	7	4.084
28*	Lieberman P, Camargo Jr C A, Bohlke K, et al. Epidemiology of anaphylaxis: findings of the American college of allergy, asthma and immunology epidemiology of anaphylaxis working group[J]. Annals of Allergy, Asthma and Immunology, 2006, 97(5): 596–602	306	19.13	16	6.347
29*	Kemp S F, Lockey R F. Anaphylaxis: a review of causes and mechanisms[J]. Journal of allergy and clinical immunology, 2002, 110(3): 341–348	301	15.05	20	10.793
30	Blumchen K, Ulbricht H, Staden U, et al. Oral peanut immunotherapy in children with peanut anaphylaxis[J]. Journal of Allergy and Clinical Immunology, 2010, 126(1): 83–91	300	25.00	12	10.793
31*	Finkelman F D. Anaphylaxis: lessons from mouse models[J]. Journal of Allergy and Clinical Immunology, 2007, 120(3): 506–515	300	20.00	15	10.793
32	Ruëff F, Przybilla B, Biló M B, et al. Predictors of severe systemic anaphylactic reactions in patients with Hymenoptera venom allergy: importance of baseline serum tryptase—a study of the European Academy of Allergology and Clinical Immunology Interest Group on Insect Venom Hypersensitivity[J]. Journal of Allergy and Clinical Immunology, 2009, 124(5): 1047–1054	296	22.77	13	10.793
33	Decker W W, Campbell R L, Manivannan V, et al. The etiology and incidence of anaphylaxis in Rochester, Minnesota: a report from the Rochester Epidemiology Project[J]. Journal of Allergy and Clinical Immunology, 2008, 122(6): 1161–1165	287	20.50	14	10.793
34	Miyajima I, Dombrowicz D, Martin T R, et al. Systemic anaphylaxis in the mouse can be mediated largely through IgG1 and Fc gammaRIII. Assessment of the cardiopulmonary changes, mast cell degranulation, and death associated with active or IgE-or IgG1-dependent passive anaphylaxis[J]. The Journal of clinical investigation, 1997, 99(5): 901–914	286	11.44	25	14.808
35	Simons F E R. Anaphylaxis.[J]. Journal of Allergy and Clinical Immunology, 2010, 125(2):S161-S181	285	23.75	12	10.793

Table 1 (continued)

Rank	Article	Total Number of Citations	Average Citations per Year	Length of Time since Publication	IF
36	Simons F E R, Roberts J R, Gu X, et al. Epinephrine absorption in children with a history of anaphylaxis[J]. Journal of Allergy and Clinical Immunology, 1998, 101(1): 33–37	273	11.38	24	10.793
37*	Neugut A I, Ghatak A T, Miller R L. Anaphylaxis in the United States: an investigation into its epidemiology[J]. Archives of internal medicine, 2001, 161(1): 15–21	272	12.95	21	17.333
38	Tsujimura Y, Obata K, Mukai K, et al. Basophils play a pivotal role in immunoglobulin-G-mediated but not immunoglobulin-E-mediated systemic anaphylaxis[J]. Immunity, 2008, 28(4): 581–589	268	19.14	14	31.745
39	Poulos L M, Waters A M, Correll P K, et al. Trends in hospitalizations for anaphylaxis, angioedema, and urticaria in Australia, 1993–1994 to 2004–2005[J]. Journal of Allergy and Clinical Immunology, 2007, 120(4): 878–884	261	17.40	15	10.793
40	Grabenhenrich L B, Dölle S, Moneret-Vautrin A, et al. Anaphylaxis in children and adolescents: the European Anaphylaxis Registry[J]. Journal of Allergy and Clinical Immunology, 2016, 137(4): 1128–1137	259	43.17	6	10.793
41	Brown A F T, McKinnon D, Chu K. Emergency department anaphylaxis: a review of 142 patients in a single year[J]. Journal of Allergy and Clinical Immunology, 2001, 108(5): 861–866	254	12.10	21	10.793
42	Lieberman P, Nicklas R A, Randolph C, et al. Anaphylaxis—a practice parameter update 2015[J]. Annals of Allergy, Asthma and Immunology, 2015, 115(5): 341–384	253	36.14	7	6.347
43	Bonadonna P, Perbellini O, Passalacqua G, et al. Clonal mast cell disorders in patients with systemic reactions to Hymenoptera stings and increased serum tryptase levels[J]. Journal of allergy and clinical immunology, 2009, 123(3): 680–686	251	19.31	13	10.793
44*	Moneret-Vautrin D A, Morisset M, Flabbee J, et al. Epidemiology of life-threatening and lethal anaphylaxis: a review[J]. Allergy, 2005, 60(4): 443–451	249	14.65	17	13.146
45	Rivas M N, Burton O T, Wise P, et al. A microbiota signature associated with experimental food allergy promotes allergic sensitization and anaphylaxis[J]. Journal of Allergy and Clinical Immunology, 2013, 131(1): 201–212	245	27.22	9	10.793
46	Laxenaire M C, Mertes P M, des Réactions Anaphylactoïdes G E. Anaphylaxis during anaesthesia. Results of a two-year survey in France[J]. British Journal of Anaesthesia, 2001, 87(4): 549–558	237	11.29	21	9.166
47	Laxenaire M C, Charpentier C, Feldman L. Anaphylactoid reactions to colloid plasma substitutes: incidence, risk factors, mechanisms. A French multicenter prospective study[C]Annales Francaises D'anesthesie et de Reanimation. 1994, 13(3): 301–310	230	8.21	28	1.131
48*	Hepner D L, Castells M C. Anaphylaxis during the perioperative period[J]. Anesthesia and Analgesia, 2003, 97(5): 1381–1395	229	12.05	19	5.178
49	Mertes P M, Alla F, Tréchot P, et al. Anaphylaxis during anesthesia in France: an 8-year national survey[J]. Journal of Allergy and Clinical Immunology, 2011, 128(2): 366–373	225	20.45	11	10.793
50	Bohlke K, Davis R L, DeStefano F, et al. Epidemiology of anaphylaxis among children and adolescents enrolled in a health maintenance organization[J]. Journal of Allergy and Clinical Immunology, 2004, 113(3): 536–542	223	12.39	18	10.793
51	Mertes PM, Malinovsky JM, Jouffroy L, et al. Reducing the risk of anaphylaxis during anesthesia: 2011 updated guidelines for clinical Practice[J]. Journal of Investigational Allergology and Clinical Immunology. 2011;21(6):442–453	220	20.00	11	7.033
52	Rüggeberg J U, Gold M S, Bayas J M, et al. Anaphylaxis: case definition and guidelines for data collection, analysis, and presentation of immunization safety data[J]. Vaccine, 2007, 25(31): 5675–5684	220	14.67	15	3.641
53	Schwartz L B, Bradford T R, Rouse C, et al. Development of a new, more sensitive immunoassay for human tryptase: use in systemic anaphylaxis[J]. Journal of clinical immunology, 1994, 14(3): 190–204	220	7.86	28	8.317

Table 1 (continued)

Rank	Article	Total Number of Citations	Average Citations per Year	Length of Time since Publication	IF
54	Strait R T, Morris S C, Yang M, et al. Pathways of anaphylaxis in the mouse[J]. Journal of Allergy and Clinical Immunology, 2002, 109(4): 658–668	219	10.95	20	10.793
55*	Pumphrey R. Anaphylaxis: can we tell who is at risk of a fatal reaction?[J]. Current opinion in allergy and clinical immunology, 2004, 4(4): 285–290	216	12.00	18	3.142
56	Strait R T, Morris S C, Finkelman F D. IgG-blocking antibodies inhibit IgE-mediated anaphylaxis in vivo through both antigen interception and FcγRIIb cross-linking[J]. The Journal of clinical investigation, 2006, 116(3): 833–841	213	13.31	16	14.808
57	Kemp S F, Lockey R F, Wolf B L, et al. Anaphylaxis: a review of 266 cases[J]. Archives of internal medicine, 1995, 155(16): 1749–1754	213	7.89	27	17.333
58*	Panesar S S, Javad S, De Silva D, et al. The epidemiology of anaphylaxis in Europe: a systematic review[J]. Allergy, 2013, 68(11): 1353–1361	212	23.56	9	13.146
59	Mangan N E, Fallon R E, Smith P, et al. Helminth infection protects mice from anaphylaxis via IL-10-producing B cells[J]. The Journal of Immunology, 2004, 173(10): 6346–6356	212	11.78	18	5.422
60	Laxenaire MC.Epidemiology of anesthetic anaphylactoid reactions. Fourth multicenter survey (July 1994-December 1996). Annales Francaises D'anesthesie et de Reanimation. 1999;18(7):796–809	212	9.22	23	1.131
61	Kemp S F, Lockey R F, Simons F E R, et al. Epinephrine: the drug of choice for anaphylaxis–a statement of the World Allergy Organization[J]. World Allergy Organization Journal, 2008, 1: S18-S26	211	15.07	14	4.084
62	Bohlke K, Davis R L, Marcy S M, et al. Risk of anaphylaxis after vaccination of children and adolescents[J]. Pediatrics, 2003, 112(4): 815–820	205	10.79	19	7.125
63	Zabel B A, Nakae S, Zúñiga L, et al. Mast cell–expressed orphan receptor CCRL2 binds chemerin and is required for optimal induction of IgE-mediated passive cutaneous anaphylaxis[J]. The Journal of experimental medicine, 2008, 205(10): 2207–2220	202	14.43	14	14.307
64	Wood R A, Camargo Jr C A, Lieberman P, et al. Anaphylaxis in America: the prevalence and characteristics of anaphylaxis in the United States[J]. Journal of Allergy and Clinical Immunology, 2014, 133(2): 461–467	201	25.13	8	10.793
65*	Simons F E R, Frew A J, Ansotegui I J, et al. Risk assessment in anaphylaxis: current and future approaches[J]. Journal of allergy and clinical immunology, 2007, 120(1): S2-S24	201	13.40	15	10.793
66	Jerschow E, Lin R Y, Scaperotti M M, et al. Fatal anaphylaxis in the United States, 1999–2010: temporal patterns and demographic associations[J]. Journal of allergy and clinical immunology, 2014, 134(6): 1318–1328	196	24.50	8	10.793
67	Vennekens R, Olausson J, Meissner M, et al. Increased IgE-dependent mast cell activation and anaphylactic responses in mice lacking the calcium-activated nonselective cation channel TRPM4[J]. Nature immunology, 2007, 8(3): 312–320	196	13.07	15	25.606
68	Yunginger J W, Nelson D R, Squillace D L, et al. Laboratory investigation of deaths due to anaphylaxis[J]. Journal of Forensic Science, 1991, 36(3): 857–865	191	6.16	31	1.832
69	Jönsson F, Mancardi D A, Kita Y, et al. Mouse and human neutrophils induce anaphylaxis[J]. The Journal of clinical investigation, 2011, 121(4): 1484–1496	190	17.27	11	14.808
70	Braganza S C, Acworth J P, McKinnon D R L, et al. Paediatric emergency department anaphylaxis: different patterns from adults[J]. Archives of disease in childhood, 2006, 91(2): 159–163	187	11.69	16	3.801
71	Webb L M, Lieberman P. Anaphylaxis: a review of 601 cases[J]. Annals of Allergy, Asthma and Immunology, 2006, 97(1): 39–43	186	11.63	16	6.347
72	Steinke J W, Platts-Mills T A E, Commins S P. The alpha-gal story: lessons learned from connecting the dots[J]. Journal of Allergy and Clinical Immunology, 2015, 135(3): 589–596	183	26.14	7	10.793

Table 1 (continued)

Rank	Article	Total Number of Citations	Average Citations per Year	Length of Time since Publication	IF
73	Metcalfe D D, Peavy R D, Gilfillan A M. Mechanisms of mast cell signaling in anaphylaxis[J]. Journal of Allergy and Clinical Immunology, 2009, 124(4): 639–646	183	14.08	13	10.793
74*	Simons F E R, Ardusso L R F, Bilo M B, et al. 2012 Update: World Allergy Organization Guidelines for the assessment and management of anaphylaxis[J]. Current opinion in allergy and clinical immunology, 2012, 12(4): 389–399	180	18.00	10	3.142
75	Cox L, Platts-Mills T A E, Finegold I, et al. American academy of allergy, asthma & immunology/American college of allergy, asthma and immunology joint task force report on omalizumab-associated anaphylaxis[J]. Journal of allergy and clinical immunology, 2007, 120(6): 1373–1377	179	11.93	15	10.793
76	Gold M S, Sainsbury R. First aid anaphylaxis management in children who were prescribed an epinephrine autoinjector device (EpiPen)[J]. Journal of Allergy and Clinical Immunology, 2000, 106(1): 171–176	179	8.14	22	10.793
77*	Simons F E R, Ardusso L R F, Dimov V, et al. World Allergy Organization Anaphylaxis Guidelines: 2013 update of the evidence base[J]. International archives of allergy and immunology, 2013, 162(3): 193–204	177	19.67	9	2.749
78	Dohi M, Suko M, Sugiyama H, et al. Food-dependent, exercise-induced anaphylaxis: a study on 11 Japanese cases[J]. Journal of allergy and clinical immunology, 1991, 87(1): 34–40	177	5.71	31	10.793
79	Palosuo K, Alenius H, Varjonen E, et al. A novel wheat gliadin as a cause of exercise-induced anaphylaxis[J]. Journal of Allergy and Clinical Immunology, 1999, 103(5): 912–917	176	7.65	23	10.793
80	Ownby D R, Tomlanovich M, Sammons N, et al. Anaphylaxis associated with latex allergy during barium enema examinations[J]. AJR. American journal of roentgenology, 1991, 156(5): 903–908	174	5.61	31	3.959
81	Yocum, M. W., & Khan, D. A. (1994). Assessment of patients who have experienced anaphylaxis: a 3-year survey. Mayo Clinic Proceedings *69*(1), 16–23	172	6.14	28	7.619
82	Vultaggio A, Matucci A, Nencini F, et al. Anti-infliximab IgE and non-IgE antibodies and induction of infusion-related severe anaphylactic reactions[J]. Allergy, 2010, 65(5): 657–661	170	14.17	12	13.146
83*	Lieberman P. Biphasic anaphylactic reactions[J]. Annals of allergy, asthma and immunology, 2005, 95(3): 217–226	170	10.00	17	6.347
84	Pumphrey R S H, Roberts I S D. Postmortem findings after fatal anaphylactic reactions[J]. Journal of clinical pathology, 2000, 53(4): 273–276	170	7.73	22	3.411
85	Srivastava K D, Kattan J D, Zou Z M, et al. The Chinese herbal medicine formula FAHF-2 completely blocks anaphylactic reactions in a murine model of peanut allergy[J]. Journal of Allergy and Clinical Immunology, 2005, 115(1): 171–178	168	9.88	17	10.793
86*	Turner P J, Jerschow E, Umasunthar T, et al. Fatal anaphylaxis: mortality rate and risk factors[J]. The Journal of Allergy and Clinical Immunology: In Practice, 2017, 5(5): 1169–1178	167	33.40	5	8.861
87	Mullins R J. Anaphylaxis: risk factors for recurrence[J]. Clinical and Experimental Allergy, 2003, 33(8): 1033–1040	167	8.79	19	5.018
88	Helbling A, Hurni T, Mueller U R, et al. Incidence of anaphylaxis with circulatory symptoms: a study over a 3-year period comprising 940 000 inhabitants of the Swiss Canton Bern[J]. Clinical and Experimental Allergy, 2004, 34(2): 285–290	166	9.22	18	5.018
89	Novembre E, Cianferoni A, Bernardini R, et al. Anaphylaxis in children: clinical and allergologic features[J]. Pediatrics, 1998, 101(4):	166	6.92	24	7.125
90	Ross M P, Ferguson M, Street D, et al. Analysis of food-allergic and anaphylactic events in the National Electronic Injury Surveillance System[J]. Journal of Allergy and Clinical Immunology, 2008, 121(1): 166–171	165	11.79	14	10.793

Table 1 (continued)

Rank	Article	Total Number of Citations	Average Citations per Year	Length of Time since Publication	IF
91*	Kroigaard M, Garvey L H, Gillberg L, et al. Scandinavian Clinical Practice Guidelines on the diagnosis, management and follow-up of anaphylaxis during anaesthesia[J]. Acta anaesthesiologica scandinavica, 2007, 51(6): 655–670	165	11.00	15	2.105
92	Kelso J M, Jones R T, Yunginger J W. Anaphylaxis to measles, mumps, and rubella vaccine mediated by IgE to gelatin[J]. Journal of allergy and clinical immunology, 1993, 91(4): 867–872	165	5.69	29	10.793
93	Olivera A, Mizugishi K, Tikhonova A, et al. The sphingosine kinase-sphingosine-1-phosphate axis is a determinant of mast cell function and anaphylaxis[J]. Immunity, 2007, 26(3): 287–297	164	10.93	15	31.745
94	Akin C, Scott L M, Kocabas C N, et al. Demonstration of an aberrant mast-cell population with clonal markers in a subset of patients with "idiopathic" anaphylaxis[J]. Blood, 2007, 110(7): 2331–2333	164	10.93	15	23.629
95	Haeberli G, Brönnimann M, Hunziker T, et al. Elevated basal serum tryptase and hymenoptera venom allergy: relation to severity of sting reactions and to safety and efficacy of venom immunotherapy[J]. Clinical and Experimental Allergy, 2003, 33(9): 1216–1220	164	8.63	19	5.018
96	Mehl A, Wahn U, Niggemann B. Anaphylactic reactions in children–a questionnaire-based survey in Germany[J]. Allergy, 2005, 60(11): 1440–1445	163	9.59	17	13.146
97	Shida K, Takahashi R, Iwadate E, et al. Lactobacillus casei strain Shirota suppresses serum immunoglobulin E and immunoglobulin G1 responses and systemic anaphylaxis in a food allergy model[J]. Clinical and Experimental Allergy, 2002, 32(4): 563–570	163	8.15	20	5.018
98*	De Silva I L, Mehr S S, Tey D, et al. Paediatric anaphylaxis: a 5 year retrospective review[J]. Allergy, 2008, 63(8): 1071–1076	158	11.29	14	13.146
99*	Simons F E R. Anaphylaxis: recent advances in assessment and treatment[J]. Journal of Allergy and Clinical Immunology, 2009, 124(4): 625–636	156	12.00	13	10.793
100	Shadick N A, Liang M H, Partridge A J, et al. The natural history of exercise-induced anaphylaxis: survey results from a 10-year follow-up study[J]. Journal of allergy and clinical immunology, 1999, 104(1): 123–127	156	6.78	23	10.793

*Review

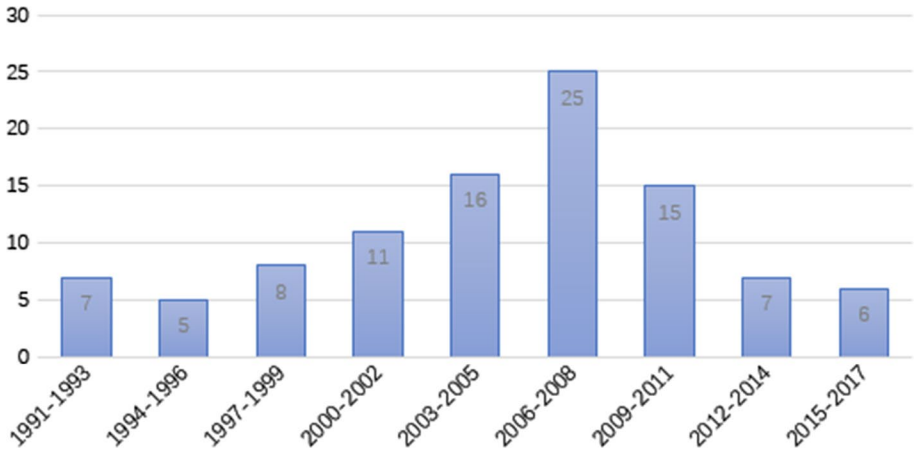


Fig. 1 The number of articles published in each 3 year interval

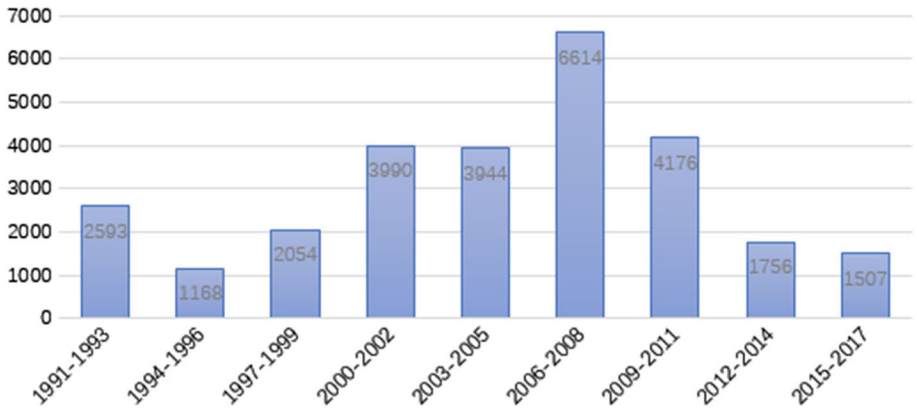


Fig. 2 The number of citations in each 3 year interval

Table 2 List of journals from the top 100 articles

Journal	Number of articles	Impact factor
Journal of Allergy and Clinical Immunology	41	10.793
Allergy	9	13.146
Clinical and Experimental Allergy	5	5.018
Annals of Allergy Asthma and Immunology	4	6.347
New England Journal of Medicine	4	91.253
Journal of Clinical Investigation	3	14.808
Pediatrics	3	7.125
Annales Francaises D Anesthesie et de Reanimation	2	1.131
Archives of Internal Medicine	2	17.333
Current Opinion in Allergy and Clinical Immunology	2	3.142
Immunity	2	31.745
Acta Anaesthesiologica Scandinavica	1	2.105
American Journal of Roentgenology	1	3.959
Anesthesia and Analgesia	1	5.178
Anesthesiology	1	7.892
Annals of Emergency Medicine	1	5.721
Archives of Disease in Childhood	1	3.801
Blood	1	23.629
British Journal of Anaesthesia	1	9.166
Cell	1	41.584
Immunology and Allergy Clinics of North America	1	3.479
International Archives of Allergy and Immunology	1	2.749
Journal of Allergy and Clinical Immunology-In Practice	1	8.861
Journal of Clinical Immunology	1	8.317
Journal of Clinical Pathology	1	3.411
Journal of Experimental Medicine	1	14.307
Journal of Forensic Sciences	1	1.832
Journal of Immunology	1	5.422
Journal of Investigational Allergology And Clinical Immunology	1	7.033
Mayo Clinic Proceedings	1	7.619
Nature	1	49.962
Nature Immunology	1	25.606
Vaccine	1	3.641
World Allergy Organization Journal	1	4.084

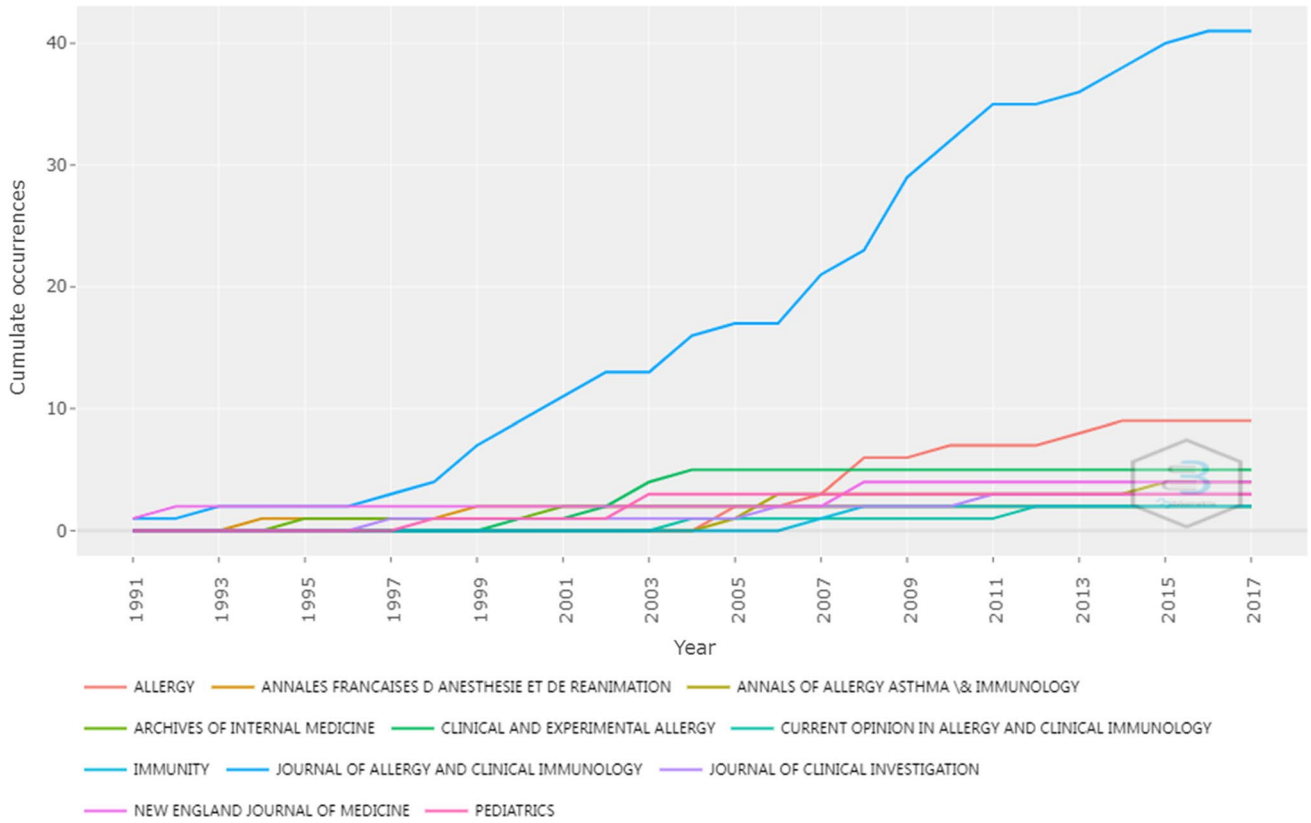


Fig. 3 Dynamic changes in the number of articles in major journals

top 100 list was a study by Sampson HA with the following title: "Fatal and Near-Fatal Anaphylactic Reactions to Food in Children and Adolescents" published in ***New England Journal of Medicine*** 1992.

Journal of publication

Journals and their impact factor are listed in Table 2.

The top 100 articles were published in 34 different journals. ***The Journal of Allergy and Clinical Immunology*** published the most ($n = 41$), followed by ***Allergy*** ($n = 9$) and ***Clinical and Experimental Allergy*** ($n = 5$). 77% articles of top 100 were published in 11 journals. We determined that the IF of these 34 journals was from 1.131 to 91.253 (according to Clarivate Analytics 2020). There was no correlation between IF and number of publications ($p > 0.05$).

Figure 3 shows the dynamic changes of articles published in major journals. Since the middle 1990s, the publications of ***The Journal of Allergy and Clinical Immunology*** began to increase rapidly compared with other journals.

Correlation analysis between citations, ACY, IF, and publication time

The correlation analysis for the total number of citations, ACY, IF, and length of time since publication in the top 100 list revealed a positive correlation between total number of citations and ACY ($r = 0.670$, $p < 0.01$), and between total number of citations and IF ($r = 0.219$, $p < 0.05$), whereas a negative correlation was observed between ACY and length of time since publication ($r = -0.697$, $p < 0.01$). There was no correlation between total number of citations and length of time since publication or between ACY and IF or between length of time since publication and IF (Fig. 4).

Countries collaboration, affiliations, and authors

The data extracted from web of science indicated that the corresponding authors of the top 100 articles were from 13 different countries (Fig. 5). Most of the top 100 cited articles were from the USA ($n = 46$), followed by Canada ($n = 10$), Australia ($n = 8$), and France ($n = 8$).

Figure 6 shows the country collaboration map worldwide generated by the Biblioshiny.

There were 219 pairs of collaborating countries worldwide, of which the top 3 were the USA and Canada with

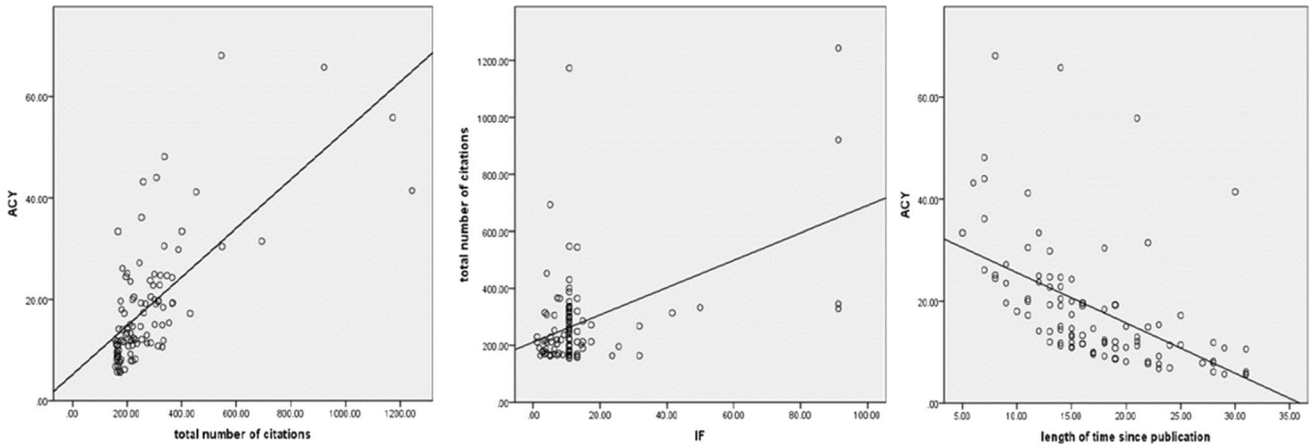


Fig. 4 Correlation analysis between citations, ACY, IF, and publication time

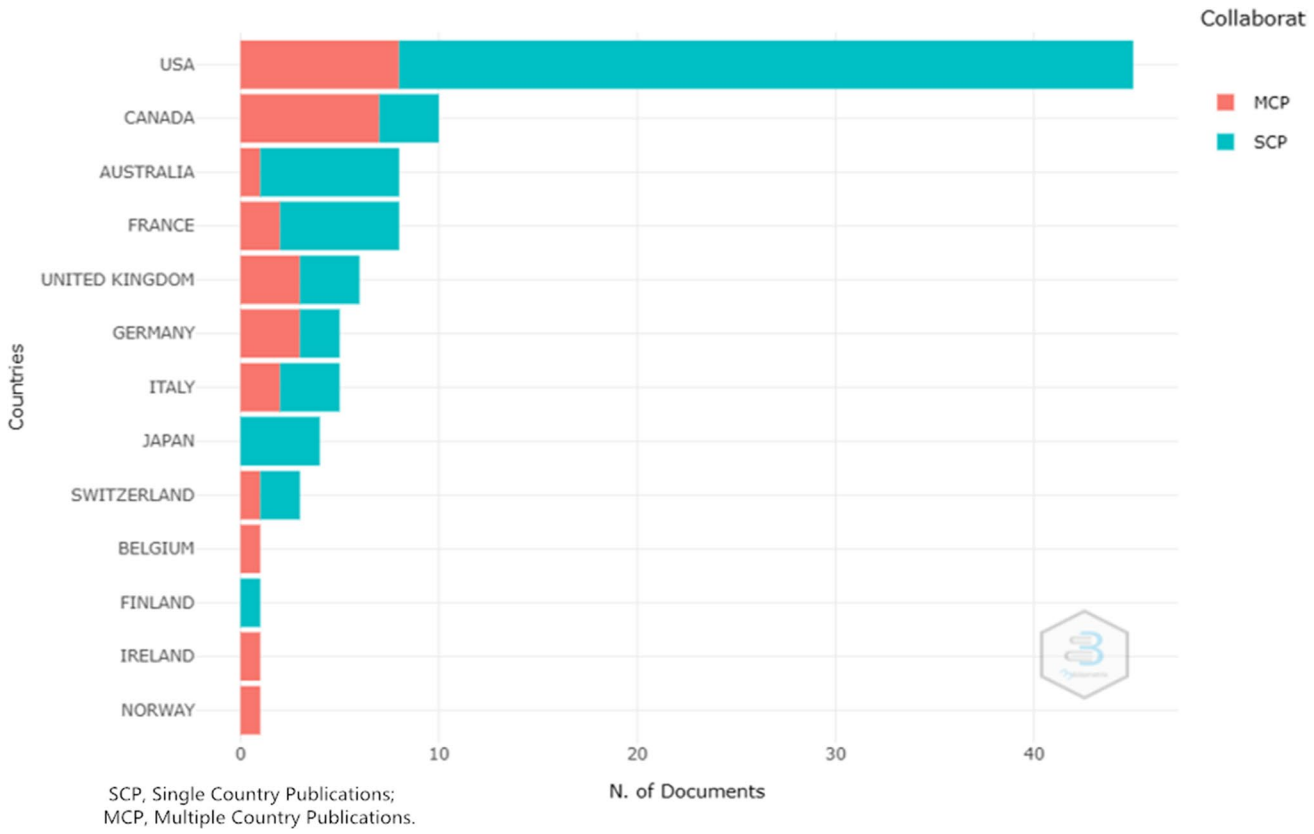
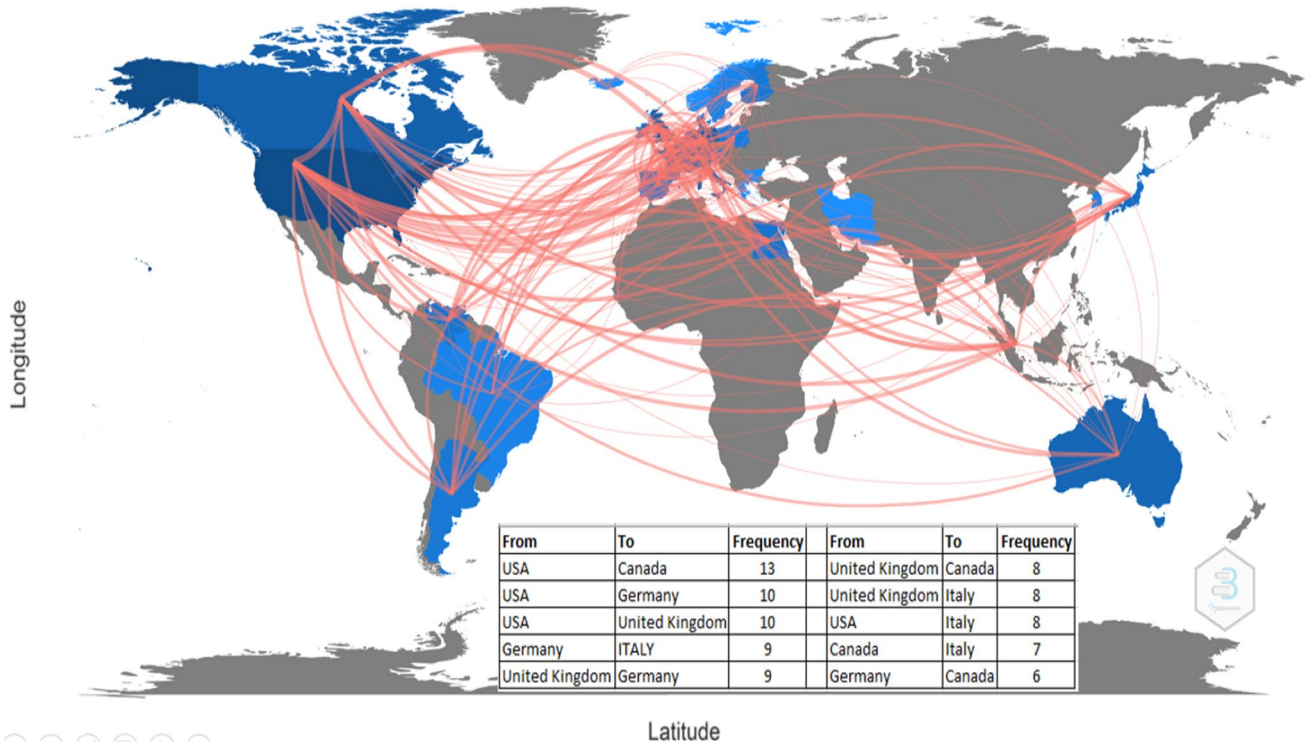


Fig. 5 Corresponding author's country

13 collaborations, followed by the USA and Germany with 10 collaborations, as well as the USA with UK with 10 collaborations. Collaboration Network according to the Biblioshiny is shown in Fig. 7. We observed that the collaboration network had two clusters, one was the continental European countries, and the other mainly included the USA, Canada, Australia, and UK.

As to the most relevant affiliations according to Biblioshiny, University of Manitoba published the most articles ($n = 21$), followed by Harvard University, University of Cincinnati ($n = 13$), and University of Florida ($n = 10$) (Table 3).

The top 10 most prolific authors demonstrated by Biblioshiny was that Simons FER from University of Manitoba produced the most top-cited articles in anaphylaxis($n = 14$),



From	To	Frequency	From	To	Frequency
USA	Canada	13	United Kingdom	Canada	8
USA	Germany	10	United Kingdom	Italy	8
USA	United Kingdom	10	USA	Italy	8
Germany	ITALY	9	Canada	Italy	7
United Kingdom	Germany	9	Germany	Canada	6

Fig. 6 Country collaboration map

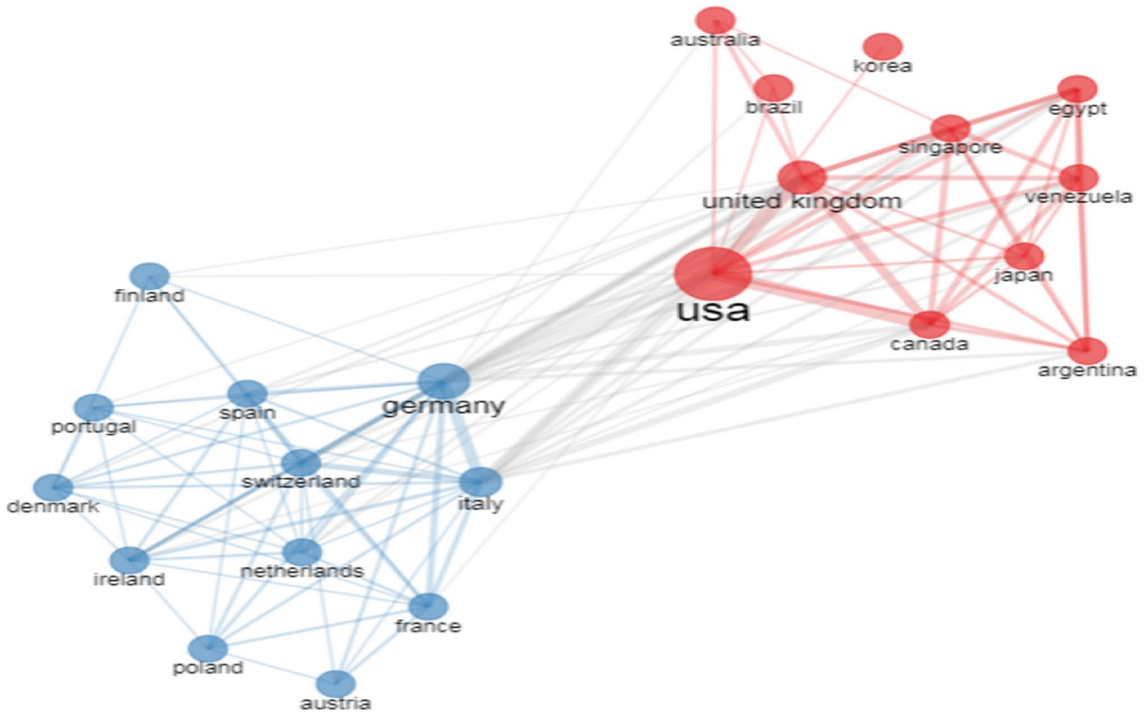


Fig. 7 .Collaboration network

Table 3 List of the top10 affiliations in the number of articles

Affiliations	Articles
UNIV MANITOBA	21
HARVARD UNIV	13
UNIV CINCINNATI	13
UNIV S FLORIDA	10
JOHNS HOPKINS UNIV	8
TECH UNIV MUNICH	8
UNIV EDINBURGH	8
UNIV HOSP	8
UNIV TENNESSEE	8
UNIV WASHINGTON	8

followed by Sampson HA($n = 8$), Sheikh A($n = 7$), Lieberman P($n = 6$), Worm M($n = 6$), Thong BY ($n = 5$), Ardusso LRF($n = 4$), Kemp SF($n = 4$), Laxenaire MC($n = 4$), Lockey RF($n = 4$).

Figure 8 shows the details of the top 10 authors and their productions over time. The larger the circle, the more articles published. The deeper the color, the more citations.

The analysis of co-occurrence network

Apart from searching term "anaphylaxis," authors keywords and keywords plus extracted from the top 100 articles were analyzed by VOSviewer (Fig. 9). According to Fig. 9A, different colors represent different clusters and the size of the ball reflects the frequency of keywords. It was observed that the research focus was classified into three clusters, marked with red, blue, and green, respectively. In addition, the color of keywords corresponds to the average publication year as shown in Fig. 9B. The recent keywords after 2005 mainly included "drug allergy," "adrenaline," "prevalence," "diagnosis," and "management."

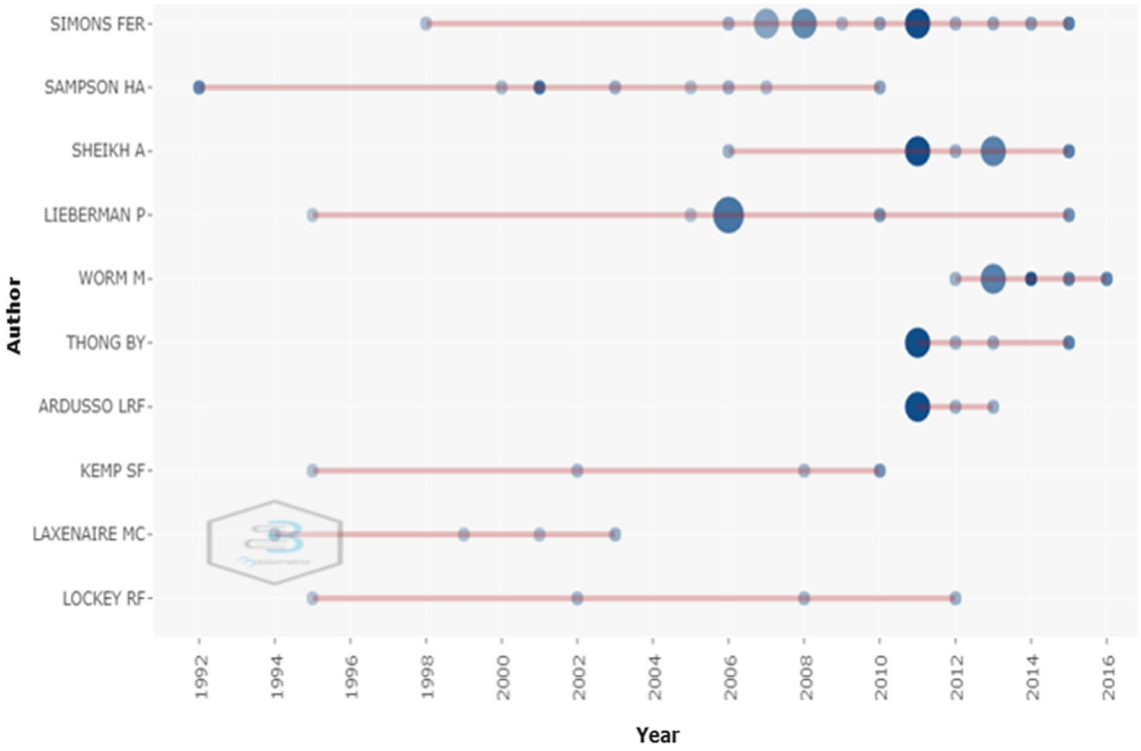


Fig. 8 Top-autors' production over the time

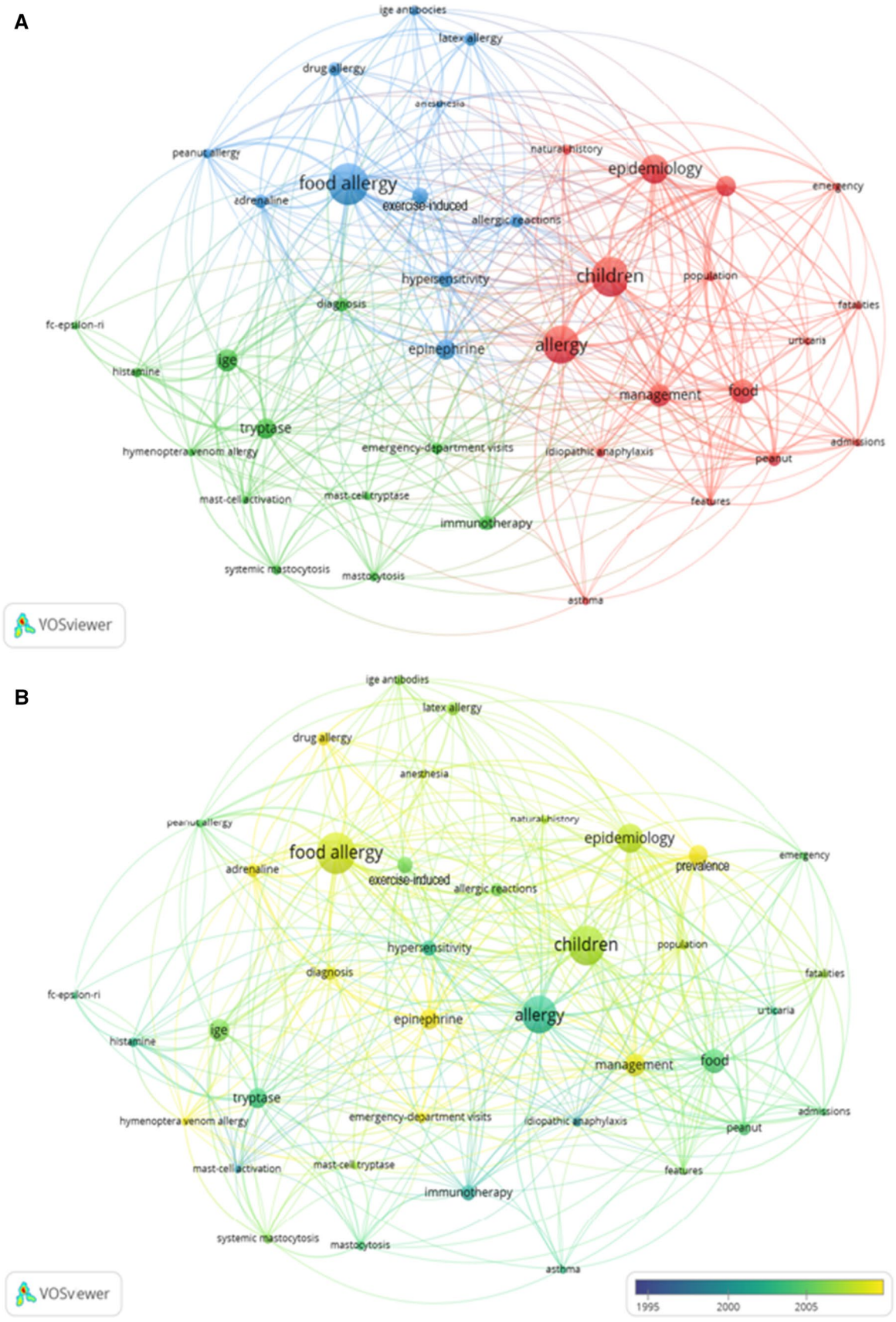


Fig. 9 .Co-occurrence network

Table 4 List of the top 10 most cited articles in anaphylaxis(2018-2021)

Rank	Article	Total Number of Citations	Average Citations per Year	Length of Time since Publication	IF
1	Harper N J N, Cook T M, Garcez T, et al. Anaesthesia, surgery, and life-threatening allergic reactions: epidemiology and clinical features of perioperative anaphylaxis in the 6th National Audit Project (NAP6)[J]. British Journal of Anaesthesia, 2018, 121(1):159	151	37.75	4	9.166
2*	Mss A, Dvw B, Dbkg C, et al. Anaphylaxis—a 2020 practice parameter update, systematic review, and Grading of Recommendations, Assessment, Development and Evaluation (GRADE) analysis[J]. Journal of Allergy and Clinical Immunology, 2020, 145(4):1082–1123	111	55.5	2	10.793
3	Gowthaman U, Chen J S, Zhang B, et al. Identification of a T follicular helper cell subset that drives anaphylactic IgE[J]. Science, 2019, 365(6456):eaaw6433	110	36.67	3	47.728
4	CDC COVID-19 Response Team; Food and Drug Administration. Allergic Reactions Including Anaphylaxis After Receipt of the First Dose of Pfizer-BioNTech COVID-19 Vaccine—United States, December 14–23, 2020. MMWR-MORBIDITY AND MORTALITY WEEKLY REPORT. 2021;70(2):46–51	102	102	1	17.586
5	Worm M, Francuzik W, Renaudin J M, et al. Factors increasing the risk for a severe reaction in anaphylaxis: An analysis of data from The European Anaphylaxis Registry[J]. Allergy, 2018	87	21.75	4	13.146
6	Aba B, Pgwb C, Saff A R, et al. mRNA Vaccines to Prevent COVID-19 Disease and Reported Allergic Reactions: Current Evidence and Suggested Approach[J]. The Journal of Allergy and Clinical Immunology: In Practice, 2020	84	42	2	8.861
7	CDC COVID-19 Response Team; Food and Drug Administration. Allergic Reactions Including Anaphylaxis After Receipt of the First Dose of Moderna COVID-19 Vaccine—United States, December 21, 2020-January 10, 2021.MMWR-MORBIDITY AND MORTALITY WEEKLY REPORT. 2021;70(4):125–129	67	67	1	17.586
8	Leyva-Castillo J M, Galand C, Kam C, et al. Mechanical Skin Injury Promotes Food Anaphylaxis by Driving Intestinal Mast Cell Expansion[J]. Immunity, 2019	59	19.67	3	31.745
9	Cardona V, Ansotegui I J, Ebisawa M, et al. World allergy organization anaphylaxis guidance 2020[J]. World Allergy Organization Journal, 2020, 13(10): 100,472	58	29	2	4.084
10	Bahri R, Custovic A, Korosec P, et al. Mast cell activation test in the diagnosis of allergic disease and anaphylaxis[J]. Journal of Allergy and Clinical Immunology, 2018, 142(2): 485–496. e16	58	14.5	4	10.793

*Review

Recent articles

No articles published after 2017 were observed in the top 100 list. In order to better show the recent research hotspots, we retrieved the top 10 most cited articles published from 2018 to 2021 (Table 4). The total citations of the top 10 articles were from 58 to 151, and ACY of them were between 14.5 and 102. Nine of the top 10 most cited articles were original articles, and one was review. The correlation analysis for the total number of citations, ACY, IF, and length of time since publication in the top 10 list revealed a negative correlation between ACY and length of time since publication ($r = -0.782$, $p < 0.01$). However, there was no correlation between the other parameters, which was different from the results of top 100. The research hotspots of the top 10 articles were COVID-19 vaccine ($n = 3$), pathogenesis ($n = 3$), perioperative anaphylaxis ($n = 1$), diagnosis ($n = 1$), and others ($n = 2$).

Discussion

Bibliometric analysis explores the characteristics of published articles based on specific and reliable parameters [11]. The top 100 most cited articles may be the highly recognized articles in a certain area, and analysis of these articles may quantitatively determine primary research concerns and provide information about dynamic research changes.

Among the top 100 list, the largest number of articles published in a single interval is between 2006 and 2008, which may be mainly attributed to the publication of the article in 2006 entitled "Second symposium on the definition and management of anaphylaxis: summary report–Second National Institute of Allergy and Infectious Disease/Food Allergy and Anaphylaxis Network symposium" with 314 citations. Even though anaphylaxis was first described around 100 years ago, there was no universal agreement on its definition or criteria for diagnosis, which greatly hampered research into the epidemiology, pathophysiology, and management of anaphylaxis. This article provided a definition of anaphylaxis and clinical criteria for diagnosis, which became a landmark in anaphylaxis research. Subsequently, several important biomarkers were confirmed, such as platelet-activating factor [12] and tryptase [13]. In addition, owe to the technological progress and clinical research, galactose-α-1,3-galactose [14] and extensive skin disease with mastocytosis [15] were also confirmed as the important risk factors of anaphylaxis.

The number of citations generated by a paper is an indicator of the impact on the research field, but not necessarily the quality and eminence of it [16]. It would accumulate over time, so the time strongly influenced the impact assessment through citation analysis. Garfield demonstrated that older papers had more chance to be cited [17], and even the most cited papers had no citation when they were just published. Therefore, we use ACY to try to reduce this bias; however, we illustrated a positive correlation between total citations and ACY among top 100 list. It indicates that there may be a positive correlation between ACY and total citations over time.

Our analysis showed that the majority of the top 100 articles were published in ***The Journal of Allergy and Clinical Immunology*** followed by ***Allergy*** and ***Clinical and Experimental Allergy***.

We found that there was no correlation between IF and number of articles, which indicated that IF may not represent the production of journals in top 100 list. Such findings were similar to bibliometric analyses of allergic rhinitis [7]. The correlation analysis also showed a positive correlation between total number of citations and IF, whereas a negative correlation was observed between ACY and length of time since publication. It may be explained by the inherent bias that researchers tended to choose high impact factor journals for citation and younger articles have higher ACY.

The publication of papers in different countries may reflect the influence of the country in the field of anaphylaxis to some extent. We identified the corresponding authors from 13 different countries of the top 100 most cited articles. Simons FER from University of Manitoba published the most articles, while most articles were from the USA. The European and the North America are two major research collaboration networks. Despite the relatively high prevalence in these areas, different degrees of economic growth might also explain this phenomenon.

Co-occurrence of keywords analysis, aiming to investigate the co-occurring relationships between keywords in a set of publications, can show the different research hotspots and topics [18]. According to the co-occurrence network by VOSviewer, we found that cluster 1 (red) was mainly about the epidemiology and management, cluster 2 (blue) mainly focused on the risk factor and treatment, cluster 3 (green) mainly reflected the assessment and diagnosis of anaphylaxis (Fig. 9A). According to Fig. 9B, we can see that the recent hotspots mainly on drug allergy, optimizing treatment as well as management, and improving clinical diagnosis.

Although co-occurrence analysis has shown the research hotspots in recent years, the latest research hotspots may not be shown as no articles published after 2017 in top 100 list, so we retrieved the top 10 most cited articles published from 2018 to 2021. We found that the number of articles related to COVID-19 vaccines has increased sharply (Table 4), as the COVID-19 vaccination is an essential way to control the current pandemic situation. Although anaphylaxis due to a vaccine is rare, it can lead to fear and undermine public confidence [19]; therefore, the importance of vaccine safety research is self-evident.

Although we spared no effort to eliminate potential defects in this bibliometric analysis, some limitations were inevitable. First, although Web of Science Core Database is a recommended database for clinical research and a relatively reliable source, the citations of articles may be insufficient and affect the results of bibliometric analysis. Second, the definition of anaphylaxis has been controversial for many years; therefore, when we regard the key word "anaphylaxis" as the search subject word, we may miss some relevant articles. Besides, citation ranking may not be intended to measure quality, but rather a degree of recognition. Low citation numbers may not represent low research value, and historical high citation numbers also cannot represent the longtime influence in the future. Despite these defects, the data presented here provide insight into the outline of anaphylaxis research over the past 30 years. In conclusion, this study identified the top 100 most cited articles in anaphylaxis and showed their bibliometric characteristics, which may pave the way for further study.

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

Declarations

Conflict of interest The authors declare that they have no competing interests.

Consent for publication Not applicable.

Ethical approval This research did not involve intervention or data collection in animal experiments or clinical trials. Thus, approval from an ethical committee was not needed.

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