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Dynamic structures and emerging trends in the management of major trauma: A bibliometric analysis of publications between 2012 and 2021

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Objective: Major trauma is currently a global public health issue with a massive impact on health at both the individual and population levels. However, there are limited bibliometric analyses on the management of major trauma. Thus, in this study we aimed to identify global research trends, dynamic structures, and scientific frontiers in the management of major trauma between 2012 and 2021.

Methods: We searched the Web of Science Core Collection to access articles and reviews concerning the management of major traumas and conducted a bibliometric analysis using CiteSpace.

Results: Overall, 2,585 studies were screened and published by 403 institutions from 110 countries/regions. The most productive country and institution in this field of research were the USA and Monash University, respectively. Rolf Lefering was the most prolific researcher and Holcomb JB had the most co-citations. *Injury* published the highest number of articles, and the *Journal of Trauma* was the most co-cited journal. A dual-map overlay of the literature showed that the articles of most publications were confined to the areas of medicine/medical/clinical and neurology/sports/ophthalmology. Document clustering indicated severe traumatic brain injury, traumatic coagulopathy, and resuscitative endovascular balloon occlusion as the recent hot topics. The most recent burst keywords were "trauma management," "neurocritical care," "injury severity," and "emergency medical services."

Conclusion: The dynamic structures and emerging trends in the management of major trauma were extensively analyzed using CiteSpace, a visualization software. Based on the analysis, the following research hotspots emerged: management of severe traumatic brain injury and massive hemorrhage, neurocritical care, injury severity, and emergency medical service. Our findings provide pertinent information for future research and contribute toward policy making in this field.

KEYWORDS

major trauma, management, bibliometric analysis, visualization, CiteSpace

Introduction

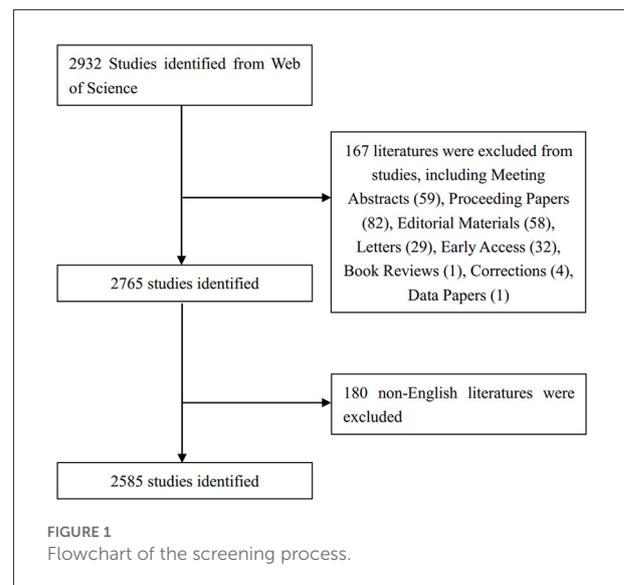
Major trauma is a life- or limb-threatening injury caused by a blunt force, penetrating injury, or burn injury. The Injury Severity Score (ISS) is a crucial element of the trauma system evaluation, with ISS scores ≥ 16 indicating major or severe trauma (1, 2). In the United States, the mortality rate of people with major trauma is 20%, and many survivors remain permanently disabled (3). Major trauma is currently a global public health issue (4), the main cause of death in the first four decades of life, and a major cause of potential loss of years of life (5). Efficient management of major trauma is of paramount importance in improving care quality and decreasing mortality (6). Many laboratory studies and clinical trials on the management of major trauma have been conducted over the last decades (7–10). However, there is a lack of summary and evaluation of publishing output trends; influential countries, regions, institutions, and authors; the current state of knowledge; and frontier trends in research related to the management of major trauma.

A bibliometric analysis is a quantitative analysis tool to examine the characteristics of literature, recent developments, and research hotspots (11). The bibliometric methodology has become popular and is increasingly being used in medical research (12). Contrary to systematic reviews and meta-analyses, bibliometric analyses aim to construct a citation network by summarizing publications using performance analysis and science mapping. Consequently, bibliometric analyses contribute toward bridging gaps in current knowledge and facilitating the creation of new directions (13). CiteSpace is an extensively used scientific software that identifies and visualizes the current knowledge domain, detects trending topics in the literature, and indicates future research directions (14). Though other popular tools such as Vosviewer and Biblioshiny exist, CiteSpace was one of the main tools used in several bibliometric analyses (15–17). Therefore, the aim of this study was to conduct a bibliometric analysis using CiteSpace to analyze the current state of knowledge, explore the evolutionary path of severe trauma management, and identify emerging trends in the management of major trauma.

Materials and methods

Data acquisition

Data were retrieved from the Web of Science Core Collection (WoSCC), and the search strategy was as follows: (TI = “management”) and (TI = “major trauma*” OR “severe trauma*” OR “severe injur*”). The symbol “*” was used as a wildcard, representing one or more letters. First, two researchers (ZZW and FZG) independently searched the original data on a single day (July 15, 2022) and then discussed the possible differences. Next, the search string was finally determined and



confirmed by the two researchers. The final agreement level reached 0.95, showing substantial consistency. The period of interest was 2012–2021. The publication types were confined to original articles and reviews, and only studies published in English were included (18). The screening process is illustrated in Figure 1.

Data analysis and visualization

The CiteSpace software (5.8. R3), developed by Chen Chaomei from Drexel University (18), was used to visualize collaboration networks (countries/regions, institutions, and authors), analyze co-citations (authors, journals, and references), create dual-map overlays, and determine reference citation bursts and keyword co-occurrences. The specific parameters were as follows: time slicing (from January 2012 to December 2021; years per slice = 1), text processing (title, abstract, author keywords, and keywords plus), node type (one option chosen at a time from a country, institution, author, co-cited journal, co-cited author, keywords, and co-cited reference), link strength (cosine), link scope (within slices), selection criteria (g-index, $k = 25$), and pruning (none).

The journal citation reports (JCR), 2021 impact factor (IF), and JCR division of analyzed journals were obtained from the Web of Science.

Results

Analysis of publications and citations

In total, 2,585 papers related to the management of major trauma were screened for subsequent visualization and analysis.

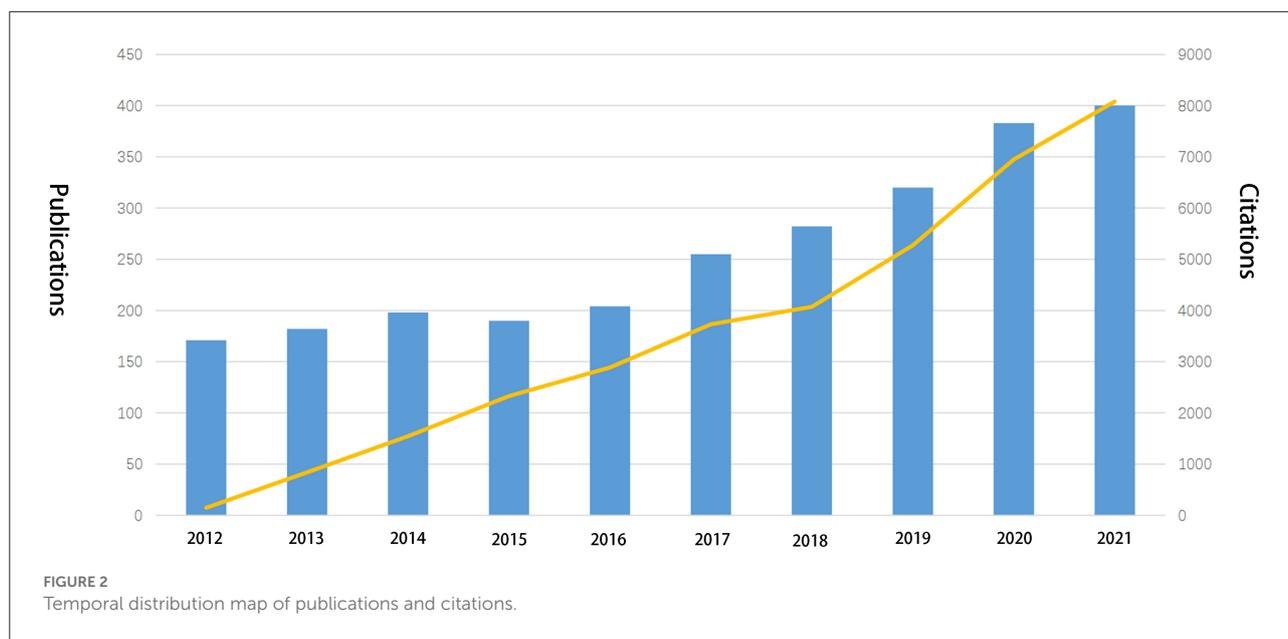


TABLE 1 The top 10 productive countries/regions and institutions.

Rank	Countries/regions	Count	Centrality	Year	Rank	Institutions	City	Count	Centrality	Year
1	USA	753	0.3	2012	1	Monash Univ	Melbourne	90	0.1	2012
2	England	446	0.11	2012	2	Univ Washington	Seattle	77	0.14	2012
3	Australia	225	0.09	2012	3	Alfred Hosp	Melbourne	52	0.04	2012
4	Germany	183	0.05	2012	4	Univ Pittsburgh	Pittsburgh	48	0.15	2012
5	Peoples R China	155	0.08	2012	5	Univ Sydney	Sydney	43	0.06	2012
6	Canada	150	0.09	2012	6	Univ Toronto	Toronto	42	0.06	2012
7	Italy	135	0.06	2012	7	Univ Cambridge	Cambridge	40	0.06	2016
8	France	135	0.06	2012	8	Univ Maryland	Washington	37	0.05	2012
9	Japan	75	0.04	2013	9	Univ Witten Herdecke	Cologne	32	0.06	2012
10	Netherlands	73	0.03	2012	10	Uniformed Serv Univ Hlth Sci	Bethesda	31	0.04	2013

There was generally a growing trend in the numbers and citations of publications from 2012 to 2021, with the lowest in 2012 ($n = 171$, citations = 148) and the highest in 2021 ($n = 400$, citations = 8,079) (Figure 2). Consequently, it is indicated that major trauma is gaining continuous attention and more research is being conducted in this field.

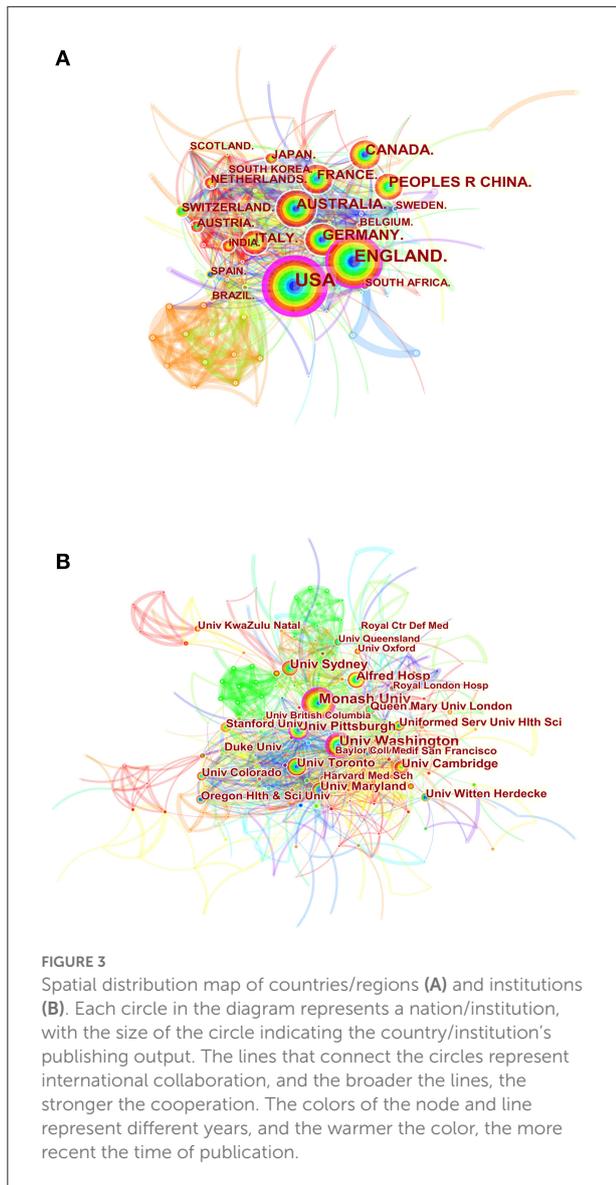
Distribution map of countries/regions and institutions

A total of 403 institutions from 110 countries/regions contributed to the research on the management of major trauma. As shown in Table 1, the most productive countries were the USA (753), followed by England (446) and Australia (225). The top three institutions were Monash University (90), the

University of Washington (77), and Alfred Hospital (52). In Figure 3, the purple ring indicates the centrality of literature (19). Some countries and institutions had high centralities, such as the USA (0.3), England (0.11), the University of Pittsburgh (0.15), the University of Washington (0.14), and Monash University (0.1). Links between nodes signify relationships of collaboration (19), and dense connections indicate active cooperation among countries and affiliations.

Visual analysis of authors and co-cited authors

Each node is labeled by the corresponding author, and the linkage between the two nodes indicates that the two authors cooperated to conduct the research, the details of which were



documented in the same paper (20). As shown in Figure 4A and Table 2, 474 authors contributed to the research on the management of major trauma. The most productive author was Rolf Lefering (26), followed by Kenji Inaba (19), Marc Maegele (17), and Mark Fitzgerald (17). The density of the network was 0.0104, indicating that the authors had not formed strong collaborative relations. There are only two authors, for whom the betweenness centrality was more than 0.1: Kenji Inaba (0.15) and Randall M. Chesnut (0.13).

When two scholars are cited in the same publication, an author co-citation relationship occurs. The closer the linkage between the two nodes, the more frequently the two authors are cited in the same paper (20). As shown in Figure 4B and Table 2, the top three most highly cited authors were Holcomb

JB (201 citations), Maas Air (194 citations), and Baker SP (178 citations). However, betweenness centralities were relatively low among them (<0.1).

Visual analysis of journals and co-cited journals

In this study, 2,585 papers concerning the management of major trauma were published in 200 journals, the top 10 of which are listed in Table 3. The most productive journal was *Injury* that published 134 related papers, followed by the *Journal of Trauma and Acute Care Surgery* (92), and the *European Journal of Trauma and Emergency* (61). The journals with the most citations included the *Journal of Trauma* (1,546 citations), *Injury* (1,028 citations), the *Journal of Trauma and Acute Care Surgery* (1,546 citations), *The Lancet* (1,546 citations), and the *New England Journal of Medicine* (1,546 citations). All journals were categorized as Q1 or Q2 in the JCR 2021, except for *Injury*.

The dual-map overlay of the literature is shown in Figure 5. In the visual representation, the left clusters represent where the retrieved records are published, whereas the right clusters indicate where they are cited (21). As shown in the figure, our dataset contained four main citation paths. The domains most frequently covering the records were: (1) 2. medicine, medical, clinical and (2) 8. neurology, sports, ophthalmology. The literature was mostly influenced by the following domains: (1) 8. molecular, biology, agents; (2) 5. health, nursing, medicine; and (3) 7. psychology, education, social. Publications from multiple domains contribute to the citation landscapes, indicating a multidisciplinary aspect of opinion mining (21).

Analysis of co-citation and clustering network

The generation of reference co-citation map resulted in 761 nodes and 3,382 links (Figure 6A). The first article was published in 2017 by Nancy Carney in terms of citation frequency (22). This article synthesized the available evidence and provided recommendations for the management of severe traumatic brain injury. Another guideline published by Donat R. Spahn in 2013 ranked second (23). The retrospective analysis published by Herbert Schöchl in 2010 (24) ranked third; it pointed out that ROTEM[®]-guided hemostatic therapy, with fibrinogen concentrate as first-line hemostatic therapy and additional prothrombin complex concentrate, was goal-directed and fast. More details pertaining to the top 10 cited references are presented in Table 4.

The network has a modularity value of 0.727 and an average silhouette score of 0.9026 that is considered very high, suggesting that the clustering is highly reliable (Figure 6B).

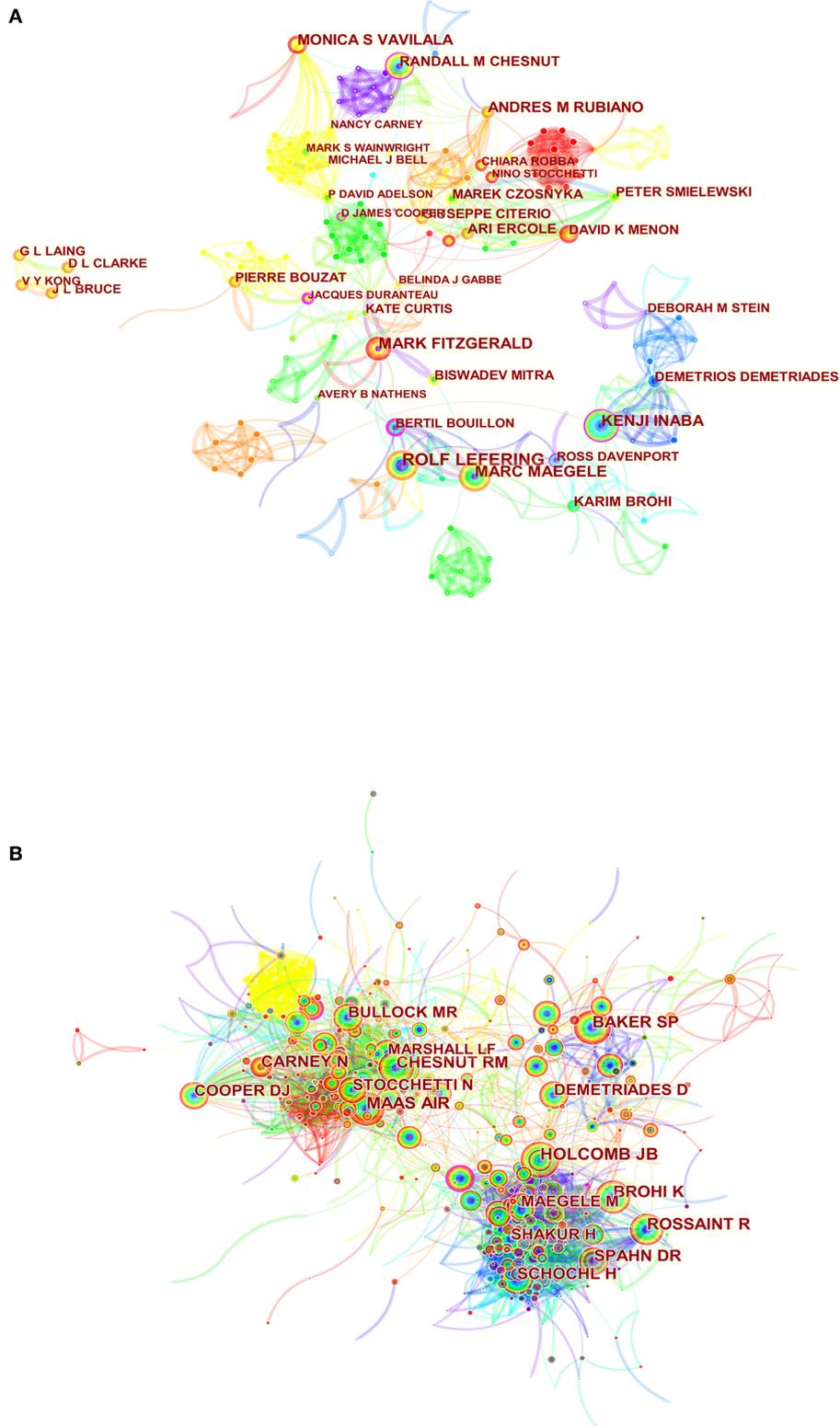


FIGURE 4
 Visual analysis of authors (A) and co-cited authors (B). The node size represents the number of studies published by the author, with larger nodes representing a higher number of publications. The closer the collaboration between two writers, the shorter the distance between two nodes. The purple nodes represent early published articles, while the red nodes represent recently published articles.

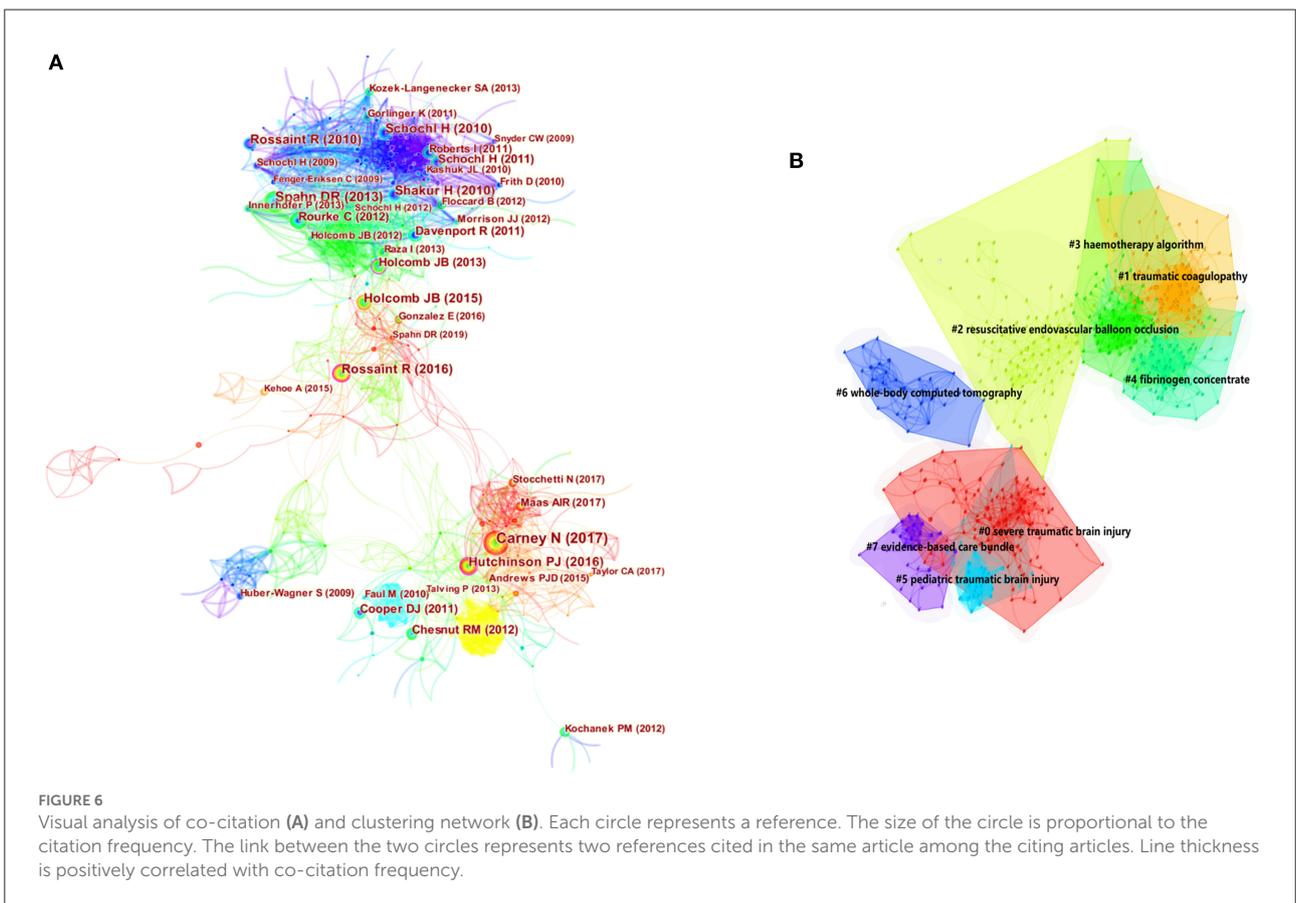
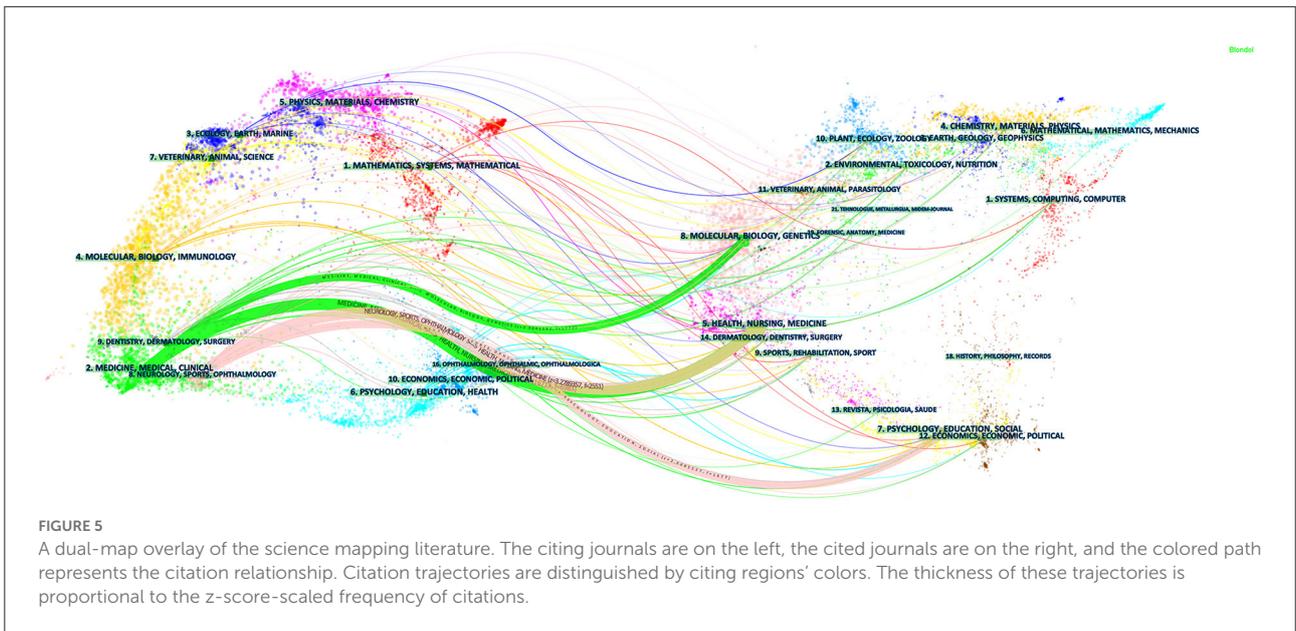
TABLE 2 The top 10 authors and co-citation authors.

Rank	Authors	Institutions	Count	Centrality	Year	Rank	Authors	Institutions	Citations	Centrality	Year
1	Rolf Lefering	University of Witten/Herdecke	26	0.03	2012	1	Holcomb JB	University of Alabama at Birmingham	201	0.02	2012
2	Kenji Inaba	University of Southern California Medical Center	19	0.15	2013	2	Maas Air	Antwerp University Hospital and University of Antwerp	194	0.03	2012
3	Marc Maegele	University of Witten/Herdecke	17	0.03	2012	3	Baker SP	Johns Hopkins University Bloomberg School of Public Health	178	0.01	2012
4	Mark Fitzgerald	The Alfred Hospital	17	0.03	2012	4	Chesnut RM	University of Washington	176	0.03	2012
5	Andres M Rubiano	El Bosque University	16	0.04	2013	5	Schochl H	AUVA Trauma Center Salzburg	170	0.02	2012
6	Monica S Vavilala	University of Washington	15	0.05	2014	6	Spahn DR	University Hospital of Zurich	165	0.01	2012
7	Randall M Chesnut	University of Washington	14	0.13	2012	7	Brohi K	Queen Mary University of London	158	0.01	2012
8	Ari Ercole	Addenbrooke's Hospital	13	0	2016	8	Carney N	Oregon Health and Science University	158	0.01	2017
9	Karim Brohi	The Alfred Hospital	13	0.03	2012	9	Rossaint R	Rhineland-Westfalen Technical University Hospital	153	0.07	2012
10	Demetrios Demetriades	University of Southern California Medical Center	12	0.02	2013	10	Cooper DJ	Monash University	127	0.05	2012

TABLE 3 The top 10 journals and co-cited journals.

Rank	Journals	Count	JCR	IF	Co-cited journals	Co-citations	JCR	IF
1	Injury	134	Q3	2.687	The Journal of trauma*	1,546	-	-
2	Journal of trauma and acute care surgery	92	Q2	3.697	Injury	1,028	Q3	2.687
3	European journal of trauma and emergency	61	Q3	2.374	Journal of trauma and acute care surgery	800	Q2	3.697
4	Scandinavian journal of trauma resuscitation	52	Q2	3.803	Lancet	734	Q1	202.731
5	Journal of neurotrauma	45	Q2	4.869	The New England journal of medicine	723	Q1	176.079
6	World neurosurgery	42	Q4	2.21	Critical care medicine	713	Q1	9.296
7	Emergency medicine journal	35	Q3	3.814	Critical care	685	Q1	19.334
8	Critical care	31	Q1	19.334	Journal of neurotrauma	630	Q2	4.869
9	PLOS one	30	Q3	3.752	Annals of surgery	602	Q1	13.787
10	BMJ open	28	Q4	3.006	Journal of neurosurgery	555	Q1	5.408

*This journal was continued by Journal of trauma and acute care surgery since 2011.



The areas of different colors represent the time when the co-citation links appeared for the first time. The brighter the color, the closer the average year of one cluster was to

the present (20, 25). Clusters were labeled with title terms extracted from the citing articles, using the log-likelihood ratio (LLR) algorithm. Figure 6B shows eight clusters, including #0

TABLE 4 Top 10 co-cited references.

Rank	Year	Title	Journal	Co-citations
1	2017	Guidelines for the Management of Severe Traumatic Brain Injury, Fourth Edition	Neurosurgery	146
2	2013	Management of bleeding and coagulopathy following major trauma: an updated European guideline	Critical care	104
3	2010	Goal-directed coagulation management of major trauma patients using thromboelastometry (ROTEM)-guided administration of fibrinogen concentrate and prothrombin complex concentrate	Critical care	72
4	2015	Transfusion of plasma, platelets, and red blood cells in a 1:1:1 vs. a 1:1:2 ratio and mortality in patients with severe trauma: the PROPPR randomized clinical trial	JAMA	65
5	2010	Management of bleeding following major trauma: an updated European guideline	Critical care	65
6	2016	The European guideline on management of major bleeding and coagulopathy following trauma: fourth edition	Critical care	61
7	2016	Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension	The New England journal of medicine	61
8	2010	Effects of tranexamic acid on death, vascular occlusive events, and blood transfusion in trauma patients with significant hemorrhage (CRASH-2): a randomized, placebo-controlled trial	Lancet	61
9	2012	A trial of intracranial-pressure monitoring in traumatic brain injury	The New England journal of medicine	55
10	2012	Fibrinogen levels during trauma hemorrhage, response to replacement therapy, and association with patient outcomes	Journal of thrombosis and hemostasis	50

severe traumatic brain injury, #1 traumatic coagulopathy, #2 resuscitative endovascular balloon occlusion, #3 hemotherapy algorithm, #4 fibrinogen concentrate, #5 pediatric traumatic brain injury, #6 whole-body computed tomography, and #7 evidence-based care bundles. The color of the convex hull of each cluster indicates recent research topics, including cluster #0 severe traumatic brain injury, #1 traumatic coagulopathy, and #2 resuscitative endovascular balloon occlusion.

The top 30 references with the strongest citation bursts between 2012 and 2021 were identified (Figure 7). References with strong values in the strength column tend to be significant milestones in science mapping research. For instance, in this study, the first milestone paper was a guideline for the management of bleeding and coagulopathy following a major traumatic injury (23), and the next milestone was a guideline for the management of severe traumatic brain injuries (22).

Visual analysis of keywords

We generated a network map of keywords consisting of 514 nodes and 4,223 links (Figure 8A). In the top 20 keywords listed in Table 5, the popular keywords were “management,” “traumatic brain injury,” “mortality,” “major trauma,” and “injury,” all of which had high citations.

The keyword “timezone view” displays the evolution of high-frequency keywords. Figure 8B shows the research hotspots in the management of major trauma. From 2012 to 2016, research keywords focused on “management,” “trauma,” “risk factor,” “trial,” and “emergency department.” These keywords indicate the research mainly involved in clinical practice or trials. From 2017 to 2021, the primary terms were “model,” “trauma management,” “neurocritical care,” “emergency medicine,” and “biomarker.” These results indicate that researchers may pay more attention to advanced technology, newer methods, strict administration, and fundamental research.

The top 30 keywords with the strongest citation bursts are shown in Figure 9. The keyword “fresh frozen plasma,” emerging in 2012, showed the strongest citation burst of 11.72. The most recent burst keywords were “trauma management,” “neurocritical care,” “injury severity,” and “emergency medical service,” revealing research trending over time and reflecting future hotspots (26).

Discussion

General information

Major trauma considerably affects health at both the individual and population levels (27). Previous literature

Top 30 References with the Strongest Citation Bursts

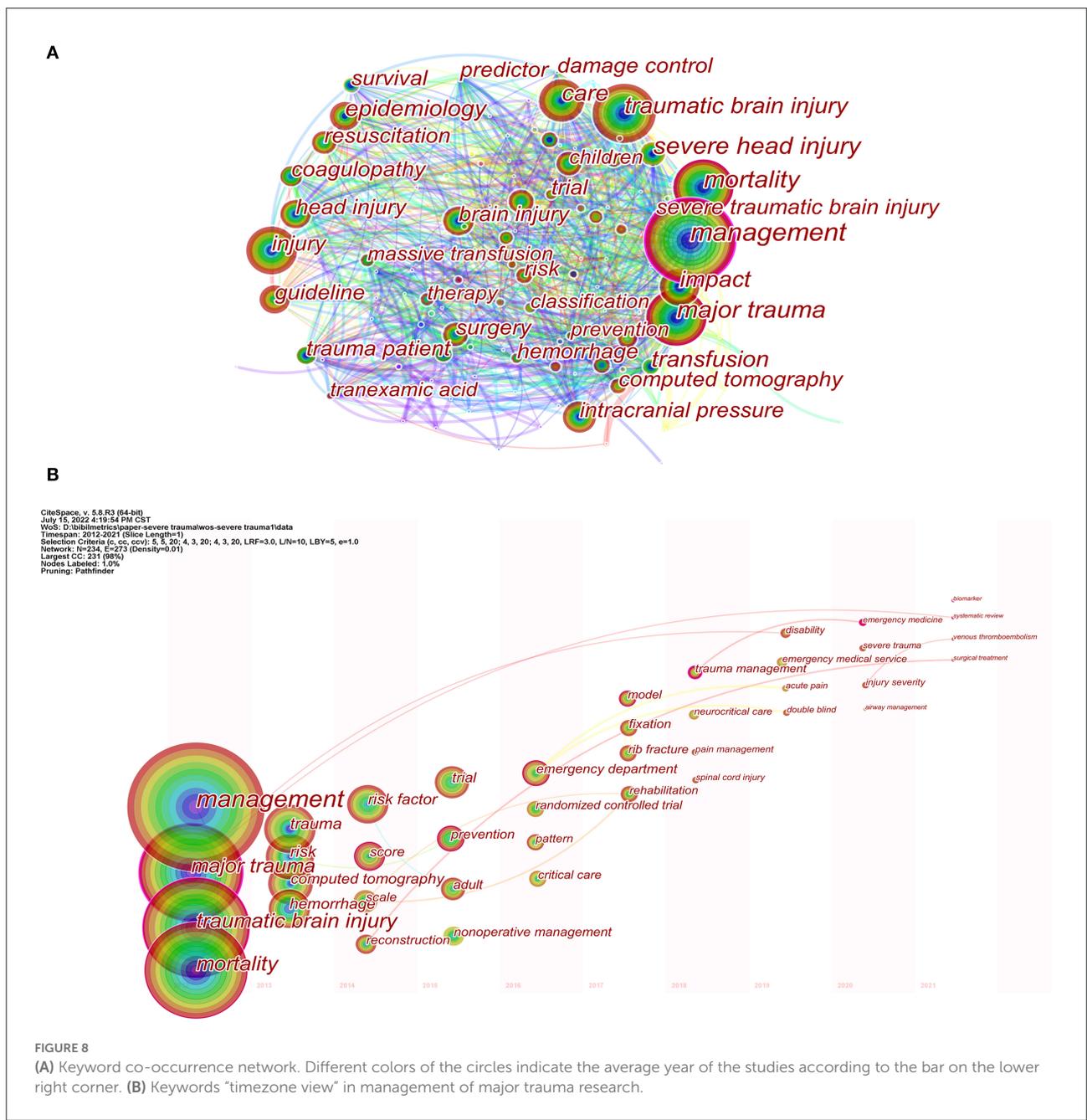
References	Year	Strength	Begin	End	2012 - 2021
Rossaint R, 2010, CRIT CARE, V14, P0, DOI 10.1186/cc8943, DOI	2010	17.21	2012	2013	
Schochl H, 2010, CRIT CARE, V14, P0, DOI 10.1186/cc8948, DOI	2010	15.8	2012	2015	
Shakur H, 2010, LANCET, V376, P23, DOI 10.1016/S0140-6736(10)60835-5, DOI	2010	13.35	2012	2015	
Stinger HK, 2008, J TRAUMA, V64, P0, DOI 10.1097/TA.0b013e318160a57b, DOI	2008	8.03	2012	2013	
Huber-Wagner S, 2009, LANCET, V373, P1455, DOI 10.1016/S0140-6736(09)60232-4, DOI	2009	7.62	2012	2014	
Holcomb JB, 2008, ANN SURG, V248, P447, DOI 10.1097/SLA.0b013e318185a9ad, DOI	2008	7.6	2012	2013	
Schochl H, 2009, J TRAUMA, V67, P125, DOI 10.1097/TA.0b013e31818b2483, DOI	2009	7.01	2012	2014	
Faul M, 2010, TRAUMATIC BRAIN INJU, V0, P0	2010	8.85	2013	2015	
Schochl H, 2011, CRIT CARE, V15, P0, DOI 10.1186/cc10539, DOI	2011	7.93	2013	2016	
Davenport R, 2011, CRIT CARE MED, V39, P2652, DOI 10.1097/CCM.0b013e3182281af5, DOI	2011	7.29	2013	2016	
Spahn DR, 2013, CRIT CARE, V17, P0, DOI 10.1186/cc12685, DOI	2013	24.92	2014	2016	
Rourke C, 2012, J THROMB HAEMOST, V10, P1342, DOI 10.1111/j.1538-7836.2012.04752.x, DOI	2012	8.54	2014	2017	
Rahe-Meyer N, 2013, ANESTHESIOLOGY, V118, P40, DOI 10.1097/ALN.0b013e3182715d4d, DOI	2013	7.91	2014	2016	
Kozek-Langenecker SA, 2013, EUR J ANAESTH, V30, P270, DOI 10.1097/EJA.0b013e32835f4d5b, DOI	2013	7.5	2014	2016	
Chesnut RM, 2012, NEW ENGL J MED, V367, P2471, DOI 10.1056/NEJMoa1207363, DOI	2012	14.42	2015	2017	
Cooper DJ, 2011, NEW ENGL J MED, V364, P1493, DOI 10.1056/NEJMoa1102077, DOI	2011	9.04	2015	2016	
Holcomb JB, 2015, JAMA-J AM MED ASSOC, V313, P471, DOI 10.1001/jama.2015.12, DOI	2015	14.05	2016	2021	
Andrews PJD, 2015, NEW ENGL J MED, V373, P2403, DOI 10.1056/NEJMoa1507581, DOI	2015	7.61	2016	2018	
Rossaint R, 2016, CRIT CARE, V20, P0, DOI 10.1186/s13054-016-1265-x, DOI	2016	16.78	2017	2021	
Talving P, 2013, J NEUROSURG, V119, P1248, DOI 10.3171/2013.7.JNS122255, DOI	2013	7.65	2017	2018	
Carney N, 2017, NEUROSURGERY, V80, P6, DOI 10.1227/NEU.0000000000001432, DOI	2017	51.05	2018	2021	
Hutchinson PJ, 2016, NEW ENGL J MED, V375, P1119, DOI 10.1056/NEJMoa1605215, DOI	2016	17.17	2018	2021	
Stocchetti N, 2017, LANCET NEUROL, V16, P452, DOI 10.1016/S1474-4422(17)30118-7, DOI	2017	10.7	2018	2021	
Kehoe A, 2015, EMERG MED J, V32, P911, DOI 10.1136/emered-2015-205265, DOI	2015	9.8	2018	2021	
Taylor CA, 2017, MMWR SURVEILL SUMM, V66, P1, DOI 10.15585/mmwr.ss6609a1, DOI	2017	8.01	2018	2021	
Maas AIR, 2017, LANCET NEUROL, V16, P987, DOI 10.1016/S1474-4422(17)30371-X, DOI	2017	16.56	2019	2021	
Spahn DR, 2019, CRIT CARE, V23, P0, DOI 10.1186/s13054-019-2347-3, DOI	2019	9.62	2019	2021	
Dewan MC, 2019, J NEUROSURG, V130, P1080, DOI 10.3171/2017.10.JNS17352, DOI	2019	9.16	2019	2021	
Moran CG, 2018, ECLINICALMEDICINE, V2-3, P13, DOI 10.1016/j.eclinm.2018.07.001, DOI	2018	8.7	2019	2021	
Okonkwo DO, 2017, CRIT CARE MED, V45, P1907, DOI 10.1097/CCM.0000000000002619, DOI	2017	7.78	2019	2021	

FIGURE 7
Visual analysis of references bursts. The intensity value reflects the cited frequency. The red bar indicates citation frequency; green bars indicate fewer citations.

reported bibliometric analysis of severe traumatic brain injury (28), spinal cord injury (29), traumatology (30), etc. As bibliometric studies concerning major trauma are scarce, this study, to the best of our knowledge, is the first bibliometric analysis of the dynamic structures and emerging trends in the management of major trauma between 2012 and 2021. After the screening process, we found that over the last decade, a total of 474 authors from 403 institutions in 110 countries published 2,585 papers related to the management of major trauma in 200 academic journals. We used CiteSpace to evaluate the networks

of co-authors' countries/institutions, co-authorship, author co-citations, journal co-citations, document co-citations, and co-occurring keywords, to identify the knowledge domain and frontier trends in the management of major trauma.

The analysis of the network of co-authors' countries/regions and institutions (Table 1; Figure 3) showed that the USA, England, and Australia were the top three nations in terms of the number of publications related to the management of major trauma. The USA has the highest betweenness centrality (0.3), indicating that it plays



a key role in bridging national cooperation networks worldwide. Meanwhile, only two Asian countries—China and Japan—were ranked among the top 10 productive countries, indicating that Asian countries need further investment in the field of research on severe trauma. Monash University published the highest number of papers. We also found extensive connections between institutions, indicating significant collaborative contributions to this research field.

In the analysis of authors and co-cited authors, Rolf Lefering, a researcher from the University of Witten/Herdecke, made the most contributions with 26 published studies, followed by Kenji Inaba from the University of Southern California Medical Center, with 19 articles. These two authors have been extensively involved in the clinical research of severe trauma, such as whole-body CT in polytrauma (31), the administration of tranexamic acid and fibrinogen concentrate in patients with trauma (32, 33), intracranial pressure monitoring in severe head

TABLE 5 The top 20 keywords.

Rank	Keywords	Citations	Centrality	Year
1	Management	983	0.22	2012
2	Traumatic brain injury	372	0.07	2012
3	Mortality	370	0.12	2012
4	Major trauma	320	0.2	2012
5	Injury	249	0.06	2012
6	Outcome	242	0.11	2012
7	Care	216	0.07	2012
8	Impact	173	0.06	2012
9	Guideline	150	0.05	2012
10	Epidemiology	144	0.06	2012
11	Intracranial pressure	142	0.02	2012
12	Head injury	141	0.05	2012
13	Severe head injury	126	0.08	2012
14	Brain injury	119	0.04	2012
15	Children	119	0.02	2012
16	Surgery	103	0.03	2012
17	Resuscitation	100	0.05	2012
18	Decompressive craniectomy	96	0.01	2012
19	Trauma	87	0.01	2012
20	Risk	86	0.04	2012

injury (34), massive transfusion protocol (35), and emergency operation (36). Holcomb JB from the University of Alabama at Birmingham received the most co-citations (201 citations) and is active in the field of severe trauma research (37–39).

As shown in Table 3, *Injury* published the highest number of papers, followed by the *Journal of Trauma and Acute Care Surgery* and the *European Journal of Trauma and Emergency*. Papers published in high-IF journals, such as *The Lancet*, the *New England Journal of Medicine*, and *Critical Care*, had more co-citations and the findings of this study provide a theoretical basis for future research (26). As shown in Figure 5, there are four main citation paths in our dataset, indicating a multidisciplinary aspect of this field, as publications in multiple domains have contributed to the citation landscape.

As shown in Table 4, the top 10 co-cited references mainly focused on the management of traumatic brain injury (22, 40) and trauma hemorrhage (4, 23, 24, 41). To automatically label the clusters of cited references, we extracted candidate terms from the titles and abstracts of the citing articles. The labels extracted by the LLR tended to reflect a unique aspect of the cluster. The purple and blue nodes represent early clustering labels that included pediatric traumatic brain injury (#5), whole-body computed tomography (#6), and evidence-based care bundle (#7), whereas the red and yellow nodes represent recent clustering labels, such as severe traumatic brain injury (#0),

traumatic coagulopathy (#1), and resuscitative endovascular balloon occlusion (#2).

Research hotspots and emerging topics

Reference clusters and citation bursts can characterize the emerging topics in the discipline. The two main themes indicate the current hot topics in major trauma research.

In cluster #0, the literature largely reported on the management of severe traumatic brain injury (42–47). The management of traumatic brain injury (TBI) has changed over the past decade; a multimodal approach is now being applied in detecting and treating the pathophysiological derangements. The theoretical highlights include initial pre- and in-hospital resuscitation, secondary injury management (management of elevated intracranial pressure, management of cerebral perfusion pressure, and multimodality monitoring), and extracranial complications (respiratory management, fluid management, nutrition management, mobilization and rehabilitation, etc.) (48, 49). The increasing availability of big data and computational science pave the way toward more accurate neuroprognostication (50). Experimental efforts to promote repair in TBI have been made including cell-based or gene therapies (51), acellular scaffolds (52), endogenous growth-related factors (48), etc.

In clusters #1 and #2, the literature focused on management of massive hemorrhage, specifically traumatic coagulopathy and resuscitative endovascular balloon occlusion. Management of massive hemorrhage over the past decade has evolved to now deliver a package of hemostatic resuscitation including surgical or radiological control of bleeding; regular monitoring of hemostasis; advanced critical care support; and avoidance of the lethal triad of hypothermia, acidemia, and coagulopathy (53). Resuscitative endovascular balloon occlusion of the aorta (REBOA) is growingly utilized in trauma resuscitation for patients with life-threatening hemorrhage below the diaphragm (54), and is also available in a few pre-hospital critical care teams (55). Traumatic coagulopathy describes abnormal coagulation processes that are attributable to trauma. In the early hours of traumatic coagulopathy development, hypocoagulability is typically present, resulting in bleeding, whereas later traumatic coagulopathy is characterized by a hypercoagulable state associated with venous thromboembolism and multiple organ failure (56).

Keyword analysis helps identify research hotspots and predicts developing trends in the field (57). As indicated in Figures 8B, 9, the following keywords may indicate the recent focus and research hotspots: “trauma management,” “neurocritical care,” “injury severity,” and “emergency medical service.”

Neurocritical care forms an essential component of trauma management and an emerging field within critical

Keywords	Year	Strength	Begin	End	2012 - 2021
fresh frozen plasma	2012	11.72	2012	2014	
fibrinogen concentrate	2012	4.88	2012	2015	
receiving massive transfusion	2012	4.79	2012	2013	
endotracheal intubation	2012	4.65	2012	2014	
concentrate	2012	4.39	2012	2016	
transfusion	2012	4.22	2012	2014	
red blood cell	2012	4.2	2012	2013	
advanced life support	2012	3.99	2012	2014	
hypothermia	2012	3.72	2012	2013	
death	2012	3.54	2012	2013	
protocol	2012	3.46	2012	2013	
survival	2012	5.96	2013	2015	
blunt abdominal trauma	2012	3.55	2013	2014	
hypotension	2012	3.44	2013	2014	
replacement	2012	4.74	2014	2015	
level	2012	3.69	2014	2015	
1st line therapy	2012	3.48	2014	2016	
prothrombin complex concentrate	2012	5.02	2015	2016	
disseminated intravascular coagulation	2012	4.97	2015	2017	
cardiac surgery	2012	4.15	2015	2016	
health	2012	5.32	2017	2018	
infection	2012	4.9	2017	2018	
trauma management	2012	4.6	2018	2021	
intubation	2012	4.14	2018	2021	
safety	2012	3.79	2018	2021	
neurocritical care	2012	3.78	2018	2021	
prevalence	2012	5.51	2019	2021	
injury severity	2012	5.03	2019	2021	
acute pain	2012	4.61	2019	2021	
emergency medical service	2012	3.66	2019	2021	

FIGURE 9
Top 30 keywords with citation burst (sorted by the beginning year of the burst).

care medicine. Intracranial pressure monitoring is now frequently discussed in the clinical care of many life-threatening brain insults; however, related technologies and management remain a high priority in neurosurgery and neurocritical care (58). Electroencephalography (EEG) is an extremely sophisticated brain monitoring tool that is extensively employed in neurocritical care; the emerging applications of EEG include seizure detection, ischemia monitoring, detection of cortical spreading depolarizations, assessment of consciousness and prognostication (59). Brain injury in children is a major public health problem; pediatric neurocritical care involves assessment, monitoring, and protection of the brain (60). More practice guidelines and establishment of multidisciplinary services are needed for improving healthcare for brain injuries (61).

The severity of injury is assessed by ISS that is associated with methods and description of studies concerning major trauma. In recent years, it is universally employed in scientific research related to major trauma. For instance, Versluijs et al. (62) reviewed the association between trauma severity and post-injury symptoms of depression; Santos et al. (63) predicted the severity of crash injury by investigating machine learning algorithms.

Emergency medical service (EMS) and pre-hospital rescue management are now globally confronted with challenges, including rising number of calls, overcrowding in emergency departments, difficulty in human resource management, etc. (64, 65). However, new EMS resources such as community paramedics and telemedical support systems offer opportunities to strengthen competencies in patient care (66). Consequently, increasing academization and research in this field are welcomed.

Limitations

This study had the following limitations. According to a study, it is acknowledged that WoSCC is the recommended database for bibliometric analysis (18). Consequently, data were collected from the WoSCC database, whereas data from other sources such as PubMed, Google Scholar, and Embase were not included. As several newly published and potentially high-impact studies may not have been included in our study, the emerging hotspots and trends in major trauma research may vary with bibliometric data updates.

Conclusion

In conclusion, this bibliometric study provides a comprehensive analysis of dynamic structures and emerging trends in major trauma research using the visualization software,

CiteSpace. Based on our findings, the leading countries are the United States, England, and Australia, while Asian countries need more investment in the research field. Management of severe traumatic brain injury and massive hemorrhage, neurocritical care, injury severity, and emergency medical service are emerging and promising research hotspots. Though current information is crucial for future research and policy making in this area, more evidence-based guidelines are needed for clinical practice in the management of major trauma.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

ZD and TW: design of this study and supervision. ZW: literature search and data analysis. FG, ZD, and TW: manuscript writing and editing. All authors approved the final version of the article.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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