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Epidural hematoma
Bibliometric analysis of scientific trends and developments from 1980 to 2023

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Abstract

The aim of this study is to identify research directions focused on epidural hematoma (EDHs) from past to present using bibliometric approaches, uncover current research trends through keyword analyses, delineate global productivity, and identify impactful studies through citation analyses. The study obtained 1785 articles related to EDH published between January 1, 1980, and December 31, 2023, from the Web of Science database, and comprehensive analyses were conducted using various bibliometric and statistical approaches. These analyses include citation and co-citation analyses, trend keyword analysis, multiple correspondence analysis, thematic evolution analysis, and various other bibliometric analyses. The bibliometric analyses were performed using Biblioshiny and VOSviewer. The top 3 journals contributing the most to the literature were Acta Neurochirurgica (n = 56, 3.1%), British Journal of Neurosurgery (48, 2.6%), and Neurosurgery (47, 2.6%). According to the h-index, the most influential top 3 journals were Neurosurgery (h = 27), Acta Neurochirurgica (h = 23), and Surgical Neurology (h = 21). Based on the m-index, the most influential top 3 journals were World Neurosurgery (m = 0.9), Medicine (m = 0.63), and Neurosurgery (m = 0.6). The most active country was the United States of America (n = 593), the most active author was Mahapatra AK (n = 10), and the most active institution was Harvard University (n = 25). Research interest in EDH has evolved over time, with notable increases in publication trends in 1968, 1982, and 1988, peaking in 1996 and 2004. Bibliometric analyses indicate that key topics such as spinal EDH, head injuries, magnetic resonance imaging, spontaneous spinal EDH, computed tomography, spine, complications, epidural, anticoagulants, pediatric cases, and trauma have stood out in EDH research. Trend analysis findings have shown an increasing focus on specific areas such as clinical management approaches, treatment methods, postoperative complications, risk factors, pediatric cases, as well as specific conditions like paralysis and cauda equina syndrome. Multiple correspondence analysis identified 6 core research dimensions, focusing on acute trauma management, surgical interventions, complications management, risk assessment, surgical outcomes, and incidence analysis.

Abbreviations: AC = average citation, CT = computed tomography, EDH = epidural hematoma, MCA = multiple correspondence analysis, MRI = magnetic resonance imaging, RPYS = reference publication year spectroscopy, SPSS = Statistical Package for the Social Sciences, TC = total citations, WoS = Web of Science.

Keywords: bibliometric analysis, epidural hematoma, extradural hematoma, research trends, scientometric analysis

1. Introduction

Epidural hematoma (EDH) is a serious and potentially life-threatening condition that arises as a result of traumatic brain injury.[1] This pathology is characterized by the accumulation of blood within the epidural space between the dura mater and the skull.[1] Cases of EDH are typically associated with post-traumatic events such as skull fractures or traumatic brain injuries.[1,2] Patients may present with clinical signs and symptoms such as headache, loss of consciousness, and neurological deficits. Without timely diagnosis and appropriate treatment, this type of bleeding can pose a vital threat.[1,3] The diagnosis of EDH is established through clinical evaluation, neurological examination, and imaging studies.[4,5] The management of EDH requires urgent surgical intervention. The goal is to control the source of bleeding, reduce intracranial pressure, and preserve neurological function.[6,7] Surgically, removal of the hematoma and repair of the bleeding source are typically performed through craniotomy or craniectomy.[6]

Bibliometric analysis is a quantitative method used to measure the impact of scientific publications within a specific field or subject.[8] This method systematically examines citation

patterns, publication trends, and collaboration networks to provide valuable insights into the productivity, impact, and development of research.[9] Unlike meta-analyses or systematic reviews, bibliometric analysis does not directly evaluate content quality or synthesize data. Instead, it sheds light on the dissemination and absorption of academic knowledge, contributing to the advancement of research and supporting evidence-based decision-making processes.[10] Additionally, it assists researchers in identifying effective studies, evaluating the impact of individual works, and gaining a broader understanding of a specific topic.[11]

Despite the advancements in imaging techniques and significant developments in minimal invasive surgical methods for EDHs, the lack of a comprehensive bibliometric study in this field is notable in the literature. Previous studies have been limited, often focusing on only a subset of highly cited articles or utilizing incomplete search strategies. This study addresses these gaps by incorporating a corrected search strategy, trend keyword analysis, multiple correspondence analysis (MCA), and thematic evolution analysis. The aim of this study is to identify research directions focused on EDHs from past to present through bibliometric approaches, including citation analysis, keyword trend analysis, co-citation analysis, and thematic evolution analysis. Specifically, this study seeks to answer the following research questions: (1) What are the primary research trends and thematic shifts in EDH studies over time? (2) Which countries, institutions, and authors have contributed most significantly to the field? (3) What are the most influential studies and emerging topics in EDH research? By addressing these questions, this study aims to uncover current research trends, delineate global productivity, and highlight impactful studies in the field.

2. Methods

2.1. Search strategy

For access to scientific research on EDH, we utilized the Web of Science (WoS) database by Clarivate Analytics (Philadelphia, PA). We defined the search process in WoS for the time period spanning from 1980 to 2023 (see Table S1, Supplemental Digital Content, http://links.lww.com/MD/O513, which details the search methodology). Access to the analyzed articles in our study was conducted on March 1, 2024. Researchers will be able to access the analyzed dataset using the code we provide, although the article counts may vary negligibly for searches conducted on different dates. Following our search strategy, we obtained 2672 publications; however, a total of 16 studies published in the Veterinary Sciences/Zoology research fields were excluded, resulting in a total of 2656 publications. From these publications, a total of 871 studies, excluding publication types such as letter, editorial material, review article, meeting abstract, proceeding paper, etc, were excluded, and bibliometric analyses were conducted with a total of 1785 articles published in the article publication type (see Table S2, Supplemental Digital Content, http://links.lww.com/MD/O514, which illustrates the article search process using a flowchart).

2.2. Statistical and bibliometric analysis

Basic statistical analyses were performed using Statistical Package for the Social Sciences (SPSS) software (Version: 22.0, SPSS Inc., Chicago, IL). To illustrate past publication trends related to EDH and forecast the 7-year publication trend (until 2030), we utilized the Smoothing Forecaster available in Microsoft Office Excel. The forecasting model includes seasonal adjustments to predict future publication trends.

For conducting bibliometric analyses and visualizing bibliometric networks, we utilized the biblioshiny interface in the bibliometrix library within the R Studio tool (http://www.

bibliometrix.org/) and VOSviewer, an open-access bibliometric software (Version 1.6.19, Leiden University).[12,13] Both Bibliometrix and VOSviewer software are widely used in scientific literature for performing comprehensive bibliometric analyses such as trend keyword analyses, citation analyses, MCA, etc, and these software tools offer users relatively different options. For the main bibliometric analyses, we used Biblioshiny as it provides comprehensive features such as thematic evolution analysis, MCA, and detailed keyword trend analysis over time. Additionally, VOSviewer was utilized for its strong performance in keyword burst analysis.

2.3. Bibliometric terminology

Co-word (or co-occurrence) analysis is used to identify related subjects or terms by examining the tendency of words to occur together in a text collection. Relationships between subject areas are revealed by analyzing the frequency of 2 or more terms occurring together. Trend keyword analysis aims to identify trends and changing research focuses in a specific subject or field by examining the changes in keywords used in articles published on that subject over time.[8–13] MCA is a statistical technique used to determine the underlying structure among variables in a dataset. It is used to uncover the fundamental structure underlying a subject and to explain this structure with fewer fundamental factors, thus making complex datasets more understandable.[12] Thematic evolution analysis is used to track thematic changes and developments in a research field over time. It is often conducted by tracking the usage of keywords in articles related to a specific subject over time.[12–14] The purpose of WordCloud analysis is to visualize the frequency and importance of words in a text document. In this analysis, the size of a word is determined based on the frequency of its occurrence in the text, with more frequently used words displayed larger, thus enabling a quick understanding of the content of a text. It particularly aids in identifying important words or main themes in large datasets or complex texts.[14]

Citation analysis is a method that examines how frequently a paper is cited by other studies. Co-citation analysis, on the other hand, determines the relationships between papers by examining how frequently 2 or more papers are co-cited by the same papers.[8–13] The h-index is a metric that represents the highest number of n papers that have received at least h citations for a researcher or a journal. This index is used to measure the effectiveness or impact of a researcher or a journal.[12] However, the m-index adjusts for the effect of the publication start time on the h-index, thus providing a fairer comparison.[14] The significance of the average citations (ACs) per year is to balance the advantage of older papers having more time compared to newer papers.[12–14] Reference publication year spectroscopy (RPYS) analysis is used to determine the development of a subject over time using citation analyses. By examining the citation year distributions of publications in a research field, it provides information about the historical progression of a subject. This analysis is used to understand when a particular subject emerged, when it became popular, and how it changed over time.[14]

3. Results

Of the 1785 articles published on EDH, 90% (n = 1601) were in English, with a small number published in other languages. Almost all of the articles were indexed in SCI-Expanded (83%, n = 1481) and ESCI (16.5%, n = 295).

3.1. Past, present, and future publication trends

A bar graph showing the distribution of articles published on EDH over the years is presented in Figure 1A. The findings revealed an increase in article productivity in 1996 and 2007.

Additionally, future predictions of the number of articles that could be published over the next 7 years, obtained through Exponential Smoothing forecasting with seasonal adjustment, are also shown in Figure 1A.

3.2. Global productivity: active research areas, countries, journals, and authors

The research areas most tagged in articles on EDH were Clinical Neurology (n = 800, 44.8%), Surgery (718, 40.2%), Medicine General Internal (203, 11.4%), Neurosciences (195, 10.9%), Pediatrics (173, 9.7%), Orthopedics (142, 7.9%), Emergency Medicine (121, 6.7%), Radiology Nuclear Medicine Medical Imaging (117, 6.5%), Anesthesiology (101, 5.6%), Critical Care Medicine (53, 2.9%), and Neuroimaging (50, 2.8%).

The journals that contributed the most to the literature were Acta Neurochirurgica (56, 3.1%), British Journal of Neurosurgery (48, 2.6%), Neurosurgery (47, 2.6%), Childs Nervous System (44, 2.4%), Surgical Neurology (44, 2.4%), World Neurosurgery (44, 2.4%), Indian Journal of Neurotrauma (39, 2.1%), Journal of Neurosurgery (35, 1.9%), Pediatric

Neurosurgery (32, 1.7%), Journal of Clinical Neuroscience (25, 1.4%), and Journal of Trauma Injury Infection and Critical Care (25, 1.4%).

Among the 421 journals publishing articles on EDH, the top 21 journals with an h-index of 8 or higher, along with citation analysis results, are presented in Table 1. According to the h-index, the top 10 influential journals were Neurosurgery, Acta Neurochirurgica, Surgical Neurology, Journal of Neurosurgery, Childs Nervous System, Journal of Trauma-Injury Infection and Critical Care, British Journal of Neurosurgery, Pediatric Neurosurgery, Spine, and American Journal of Neuroradiology. According to the m-index, the top 10 influential journals were World Neurosurgery, Medicine, Neurosurgery, Acta Neurochirurgica, Journal of Korean Neurosurgical Society, Surgical Neurology, Journal of Neurosurgery, Spine, Journal of Neurosurgery-Spine, and Pediatric Neurosurgery.

Based on the average number of citations per document for articles published solely on EDH, the top 10 influential journals were Journal of Bone and Joint Surgery-British Volume (AC per document: 152), Radiology (98), Journal of the Neurological Sciences (88.7), Journal of Neurology Neurosurgery and
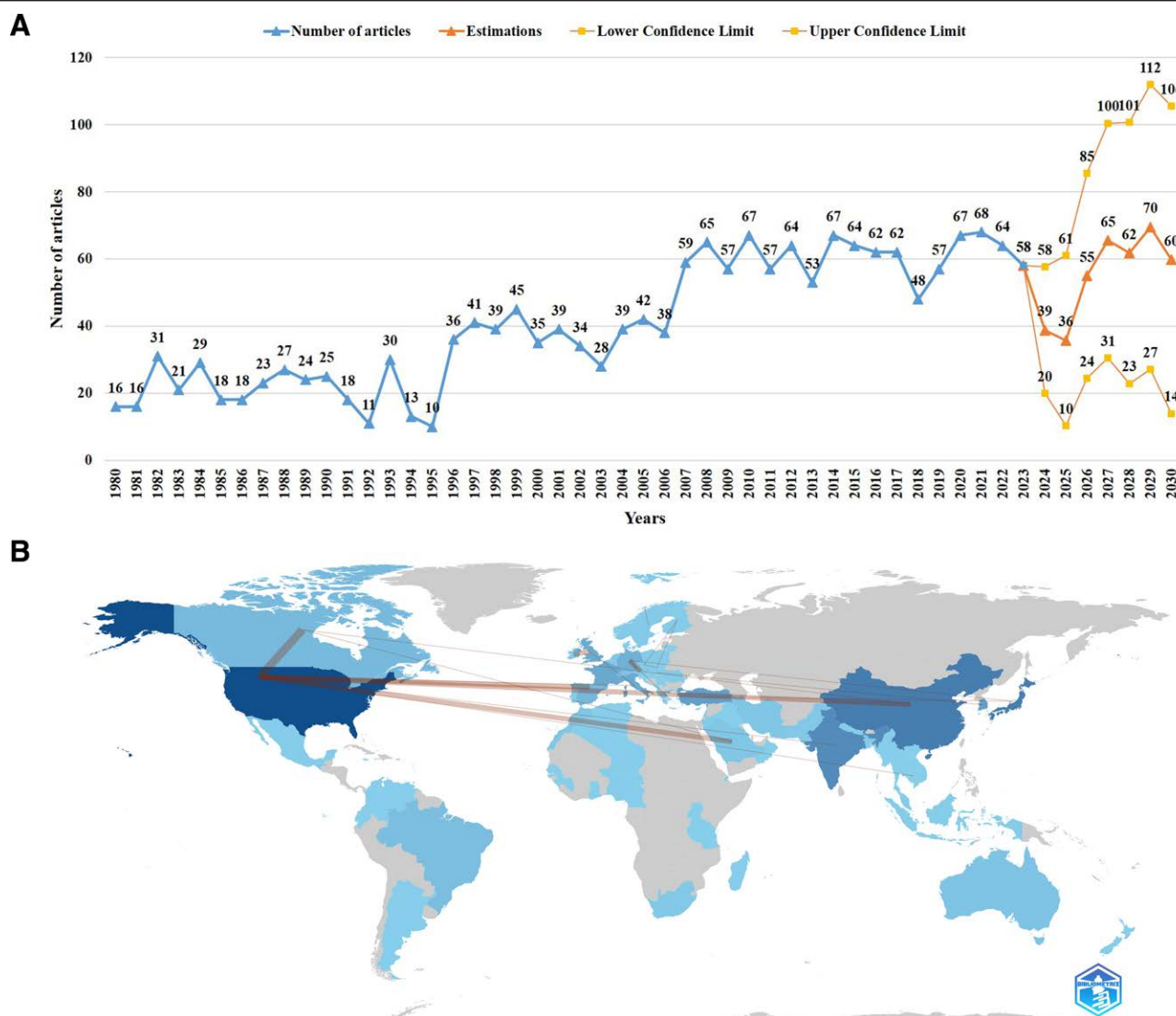
Figure 1. (A) Line graph showing the distribution of the number of articles published on epidural hematoma by years and forecast values until 2030. (Footnote: The orange lines represent the predicted number of articles that may be published in the coming years along with their confidence intervals.) (B) Colour intensity map and international collaboration map showing the distribution of article numbers by country. (Footnote: This map takes into account the nationality of all authors contributing to an article. The higher the number of articles a country contributes, the higher the color intensity.)

Table 1

The 21 most influential scientific journals according to the h-index (having an h-index of at least 8) on epidural hematoma.

Journal	h-index	m-index	TC	NA	AC	PY start
Neurosurgery	27	0.6	2099	47	44.7	1980
Acta Neurochirurgica	23	0.51	1384	56	24.7	1980
Surgical Neurology	21	0.47	1168	44	26.5	1980
Journal of Neurosurgery	20	0.46	1967	35	56.2	1981
Childs Nervous System	16	0.4	478	44	10.9	1985
Journal of Trauma-Injury Infection and Critical Care	15	0.33	651	25	26.0	1980
British Journal of Neurosurgery	14	0.39	479	48	10.0	1989
Pediatric Neurosurgery	13	0.41	415	32	13.0	1993
Spine	13	0.43	788	24	32.8	1995
American Journal of Neuroradiology	12	0.28	494	15	32.9	1982
Clinical Neurology and Neurosurgery	11	0.27	288	24	12.0	1984
Neuroradiology	10	0.22	314	18	17.4	1980
Anesthesia and Analgesia	9	0.31	391	14	27.9	1996
European Spine Journal	9	0.35	325	13	25.0	1999
Journal of Clinical Neuroscience	9	0.32	289	25	11.6	1997
Journal of Korean Neurosurgical Society	9	0.5	213	18	11.8	2007
World Neurosurgery	9	0.9	242	44	5.5	2015
American Journal of Emergency Medicine	8	0.28	211	22	9.6	1996
Journal of Neurosurgery-Spine	8	0.42	358	14	25.6	2006
Neurologia Medico-Chirurgica	8	0.3	161	18	8.9	1998
Neurosurgical Review	8	0.26	190	10	19.0	1994

AC = average citation per document, NA = number of articles, PY = publication year, TC = total citations.

Psychiatry (72), Journal of Neurosurgery (56.2), Yonsei Medical Journal (56), Neurology (52), Anesthesiology (47.8), Swiss Medical Weekly (47), and American Journal of Pediatric Hematology Oncology (46).

Taking into account the nationalities of all authors in the articles, the most productive countries with 100 or more published articles are the United States of America (n = 593), China (370), Japan (334), Turkey (223), India (219), South Korea (198), France (143), Italy (135), United Kingdom (116), Germany (110), Canada (77), Brazil (75), and Spain (72). A network visualization map in Figure 1B illustrates the density of articles by country and international collaboration among countries.

The most productive institutions in EDH research were Harvard University (n = 25), University of California System (24), All India Institute of Medical Sciences New Delhi (20), Chang Gung Memorial Hospital (19), Universidade De Sao Paulo (19), and Assistance Publique Hopitaux Paris (16).

The top 10 most productive authors in EDH research were Mahapatra AK (n = 10), Teixeira MJ (9), De Andrade AF (8), Kim SH (8), Lee SH (8), Kim JH (7), Li J (7), Paiva WS (7), Pozzati E (7), and Servadei F (7). According to the h-index, the top 5 influential authors were Kim SH (h = 7), Pozzati E (7), Kim JH (6), Simpson DA (6), and Ahn DK (5). According to the m-index, the top 5 influential authors were Gnus J (m = 0.67), Ahn DK (0.5), Choi DJ (0.5), Kim JE (0.5), and Park EJ (0.5).

3.3. Citation analysis

The most cited study based on total citations (TC) was the article by Lawton et al (1995) titled "Surgical-management of spinal epidural hematoma – relationship between surgical timing and neurological outcome" published in the Journal of Neurosurgery.[7] The second most influential study was Groen and van Alphen's (1996) article "Operative treatment of spontaneous spinal epidural hematomas: a study of the factors determining postoperative outcome" published in Neurosurgery.[15] The third most influential study was Groen and Ponssen's (1990) article "The spontaneous spinal epidural hematoma – a study of the etiology" published in the Journal of the Neurological Sciences.[16] The fourth and fifth most influential studies were by

Holtas et al (1996) and Foo and Rossier (1981).[17,18] Based on the ACs per document received by the articles, the top 5 most influential studies were by Lawton et al (1995), Lee et al (2017), Kou et al (2002), Amiri et al (2013), and Groen and van Alphen (1996).[7,15,19–21] Other notable articles with lower TC due to being published in the last decade but receiving attention based on their ACs per document include Bateman et al (2013), Kao et al (2015), and Kim et al (2019).[22–24] Among the 1785 articles analyzed on EDH, the top 15 most cited articles, based on ACs per year and total number of citations, are presented in Table 2.

3.4. Co-citation analysis

Among the 1785 articles analyzed on EDH, a total of 12,308 references were found in the references section. The most co-cited studies with over 100 co-citations were Lawton et al (1995, Co-Citation: 204), Groen and van Alphen (1996, CC: 166), Holtas et al (1996, CC: 146), Groen and Ponssen (1990, CC: 143), Foo and Rossier (1981, CC: 138), Beatty and Winston (1984, CC: 134), Kreppel et al (2003, CC: 124), and Jamieson and Yelland (1968, CC: 114).[7,15–18,25–27]

The co-citation network analysis (Fig. 2) revealed 4 distinct clusters, each representing a different thematic focus within the EDH literature. The red cluster includes foundational studies that established early definitions and surgical approaches for EDH, representing the historical and classical literature. The blue cluster comprises studies focused on the neurosurgical management of EDH, including surgical techniques and clinical outcomes. The green cluster is characterized by research on imaging and diagnostic approaches, particularly the use of computed tomography (CT) and magnetic resonance imaging (MRI) in EDH evaluation. Lastly, the yellow cluster consists of studies investigating long-term prognosis, complications, and clinical outcomes in EDH patients.

3.5. Historical roots of EDH with RPYS analysis

The RPYS graph for EDH is presented in Figure 3. RPYS graph, using the references from the analyzed articles' bibliography, displays the TC count for EDH each year, showing early peaks where historical roots may be found and years when academic interest peaked. According to the RPYS findings, academic

Table 2

The first 15 high-impact articles based on the total number of citations on Epidural hematoma.

No	Article	Author	Journal	PY	TC	AC
1	Surgical-management of spinal epidural hematoma – relationship between surgical timing and neurological outcome	Lawton MT. et al	Journal of Neurosurgery	1995	410	13.7
2	Risk of epidural hematoma after neuraxial techniques in thrombocytopenic parturients: a report from the multicenter perioperative outcomes group.	Lee LO. et al	Anesthesiology	2017	102	12.8
3	Risk factors for spinal epidural hematoma after spinal surgery	Kou J. et al	Spine	2002	220	9.6
4	Postoperative spinal epidural hematoma (SEH): incidence, risk factors, onset, and management	Amiri AR. et al	Spine Journal	2013	106	8.8
5	Operative treatment of spontaneous spinal epidural hematomas: A study of the factors determining postoperative outcome	Groen RJM; vanAlphen HAM	Neurosurgery	1996	255	8.8
6	Spontaneous spinal epidural hematoma: Findings at MR imaging and clinical correlation	Holtas S. et al	Radiology	1996	236	8.1
7	Incidence of postoperative symptomatic epidural hematoma in spinal decompression surgery Clinical article	Aono H. et al	Journal of Neurosurgery-Spine	2011	113	8.1
8	The risk and outcomes of epidural hematomas after perioperative and obstetric epidural catheterization: a report from the multicenter perioperative outcomes group research consortium	Bateman BT. et al	Anesthesia and Analgesia	2013	96	8.0
9	Symptomatic epidural hematoma after lumbar decompression surgery	Kao FC. et al	European Spine Journal	2015	77	7.7
10	Analysis of the risk factors for the development of postoperative spinal epidural hematoma	Awad JN. et al	Journal of Bone and Joint Surgery-British Volume	2005	152	7.6
11	Nonoperative treatment of spontaneous spinal epidural hematomas: a review of the literature and a comparison with operative cases	Groen RJM	Acta Neurochirurgica	2004	156	7.4
12	Prospective study of postoperative lumbar epidural hematoma – Incidence and risk factors	Sokolowski MJ. et al	Spine	2008	120	7.1
13	The spontaneous spinal epidural hematoma – a study of the etiology	Groen RJM; Ponssen H	Journal of the Neurological Sciences	1990	237	6.8
14	Risk factors of postoperative spinal epidural hematoma after biportal endoscopic spinal surgery	Kim JE. et al	World Neurosurgery	2019	36	6.0
15	Spontaneous spinal epidural hematoma: analysis of 23 cases	Liu Z. et al	Surgical Neurology	2008	91	5.4

AC = average citations per year, PY = publication year, TC = total citations.

trends that started in 1869, 1935, 1938, and 1941 significantly increased in 1968, 1982, and 1988, reaching their highest peak in 1996 and 2004. Other notable peak years can be seen on Figure 3.

3.6. Trend topics, word-cloud, MCA, and thematic evolution

In the 1785 articles published on the topic of EDH, a total of 2157 different keywords were used. To ensure consistency and avoid duplication, synonymous keywords were systematically merged before analysis. Specifically, variations referring to EDH, such as "epidural hematoma," "epidural hemorrhage," "extradural hematoma," "extradural hemorrhage," "epidural bleeding," and their spelling variations (e.g., hematoma vs hematoma, hemorrhage vs hemorrhage), were unified under a single term. Additionally, other synonymous terms, including "complication/complications," "hemophilia/hemophilia," and "sickle cell disease/sickle cell," were standardized to enhance data accuracy.

The most frequently used 50 different author keywords in the articles over time are shown in Figure 4A. The top 50 keywords used alongside EDH in the articles are spinal EDH, head injuries, MRI, spontaneous spinal EDH, CT, spine, complications, epidural, anticoagulants, pediatric, trauma, spontaneous EDH, surgery, acute EDH, cervical spine, spinal cord compression, traumatic brain injury, conservative treatment, clinical outcome, laminectomy, posterior fossa, paraplegia, Glasgow Coma Scale, head trauma, craniotomy, hemophilia, subdural hematoma, risk factors, spinal cord, spinal surgery, skull fracture, infant, postoperative complications, surgical decompression, lumbar spine, cerebral infarction, sickle cell disease, back pain, spinal cord injury, prognosis, cervical EDH, chronic EDH, epidural anesthesia, hemiparesis, pregnancy, thrombolysis, neurosurgery, postoperative EDH, and ventriculoperitoneal shunt.

The Word Cloud visualization based on the 50 most frequently used keywords by authors is presented in Figure 4B. According to the word cloud analysis visualization, it can be observed that the concept of EDH is primarily centered around spinal EDH, head injuries, MRI, spontaneous spinal EDH, CT, spine, complications, epidural, anticoagulants, pediatric, trauma, and spontaneous EDH terms.

The keyword co-occurrence network visualization and burst analysis, based on keywords appearing in at least 5 different articles, are presented in Figure 5. Keywords with stronger burst strength (indicating a sudden increase in research interest over time) or higher total link strength (reflecting their importance and degree of connectivity within the network) are highlighted in more intense colors. These keywords include EDH, spinal EDH, hematoma, head injury, epidural, extradural hematoma, spontaneous spinal EDH, MRI, trauma, spine, CT, spinal, surgery, cervical spine, traumatic brain injury, laminectomy, outcome, paraplegia, spinal cord compression, posterior fossa, and complications.

Trend keyword analysis was conducted using author keywords in 2 different time periods. The analysis was based on articles published between 1980 and 2013 (pre-last decade) and articles published between 2014 and 2023 (last decade). The analysis in Figure 6 shows the trend keywords that appeared in at least 4 different articles each year (co-occurrences) for each year in the 1980 to 2013 period. Similarly, Figure 7 presents the trend keyword analysis findings for the 2014 to 2023 period. According to the findings of the trend keyword analysis, during the pre-last decade (1980–2013), trend topics included neurological outcome, CT, head injuries, brain swelling, MRI, coagulopathy, clivus, venous sinuses, delayed EDH, infant, skull fracture, spinal cord, hemophilia, eosinophilic granuloma, Brown-Sequard syndrome, thrombolysis, posterior fossa, conservative treatment, acute EDH, spontaneous EDH, spine, ossification,
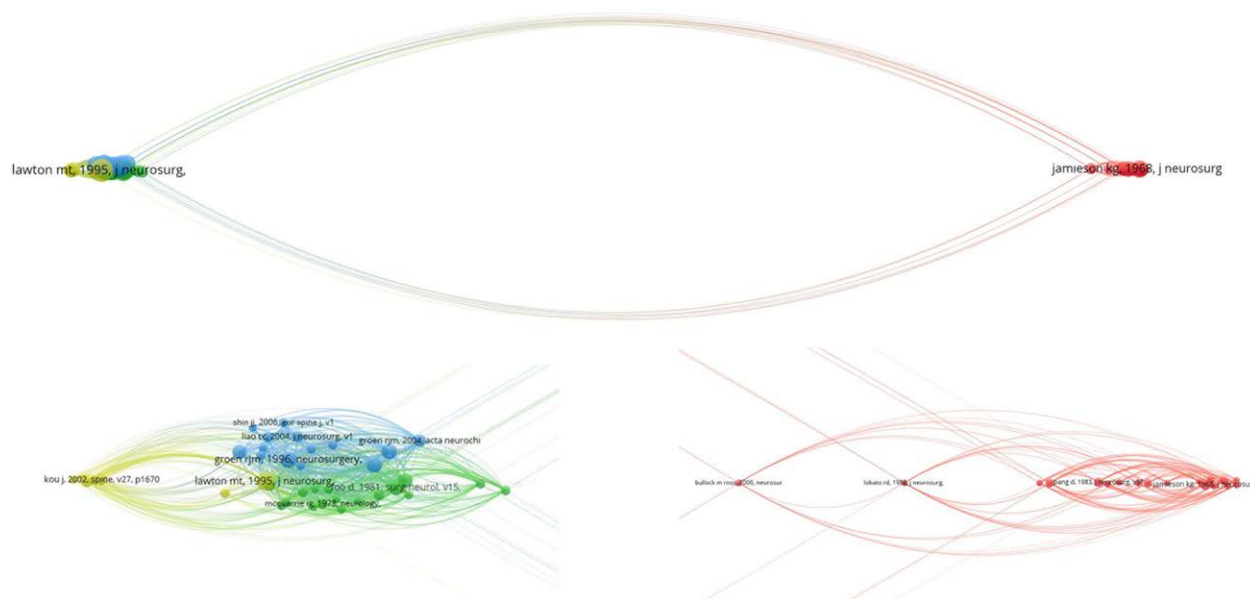
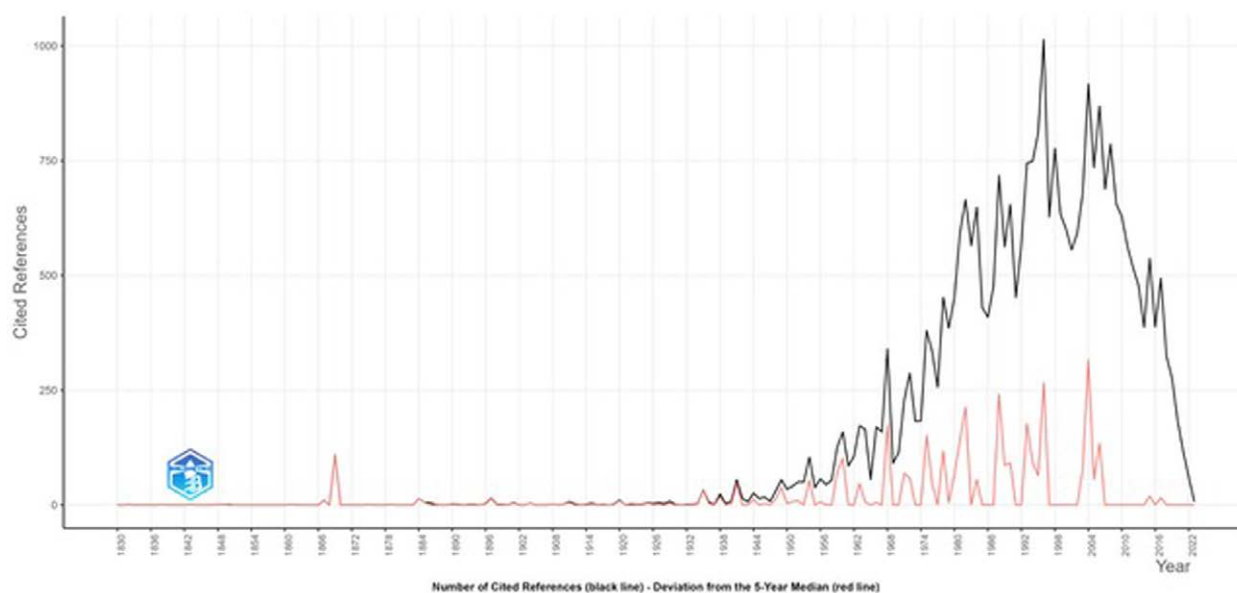**Figure 2.** Co-citation network of studies on epidural hematoma (EDH).

Figure 3. Line graph showing the findings of the Reference Publication Year Spectroscopy (RPYS) analysis. (Footnote: The RPYS method, conducted using the Biblioshiny package, identifies key historical publications by analyzing citation frequency across publication years. The black line represents the total number of cited references per year, while the red line illustrates the deviation from the median citation frequency, highlighting peak years with influential publications. Peaks in the red line indicate years with significant contributions to the development of the research field.)

postoperative, pregnancy, paraplegia, surgery, trauma, complications, epidural, cervical EDH, spinal cord injury, surgical decompression, and spinal EDH. In the last decade (2014–2023), trend topics included treatment, hemiparesis, anticoagulants, spontaneous spinal EDH, spinal anesthesia, postoperative complications, craniotomy, pediatric, decompressive craniectomy, sickle cell disease, cerebral infarction, spinal surgery, spontaneous cervical EDH, pain, neurosurgery, Glasgow Coma Scale, lumbar puncture, endovascular treatment, drainage, postoperative EDH, cauda equina syndrome, back pain, risk factors, traumatic brain injury, stroke mimics, neurological deficit, paralysis, postoperative spinal EDH, neck pain, and hypertension. Readers can examine in more detail which topics were trending in which years by using Figures 6 and 7.

MCA was conducted using author keywords to determine the subdimensions of EDH. The visualization of the MCA conducted using MCA and the topics in its subdimensions are shown in Figure 8. The findings of the MCA revealed that EDH articles consisted of 6 sub-research dimensions. These dimensions include Acute Head Trauma and Epidural Hematoma (head injuries, CT, spine, epidural, pediatric, trauma, acute EDH, traumatic brain injury, clinical outcome, posterior fossa, glasgow coma scale, head trauma, craniotomy, subdural hematoma, skull fracture, sickle cell disease, prognosis, chronic EDH, neurosurgery, ventriculoperitoneal shunt, delayed EDH, vertex EDH, acute subdural hematoma, clivus, decompressive craniectomy, calcification), Spinal Epidural Hematoma and Related Conditions (spinal EDH, MRI, spontaneous spinal EDH, anticoagulants, spontaneous EDH, surgery, cervical spine, spinal
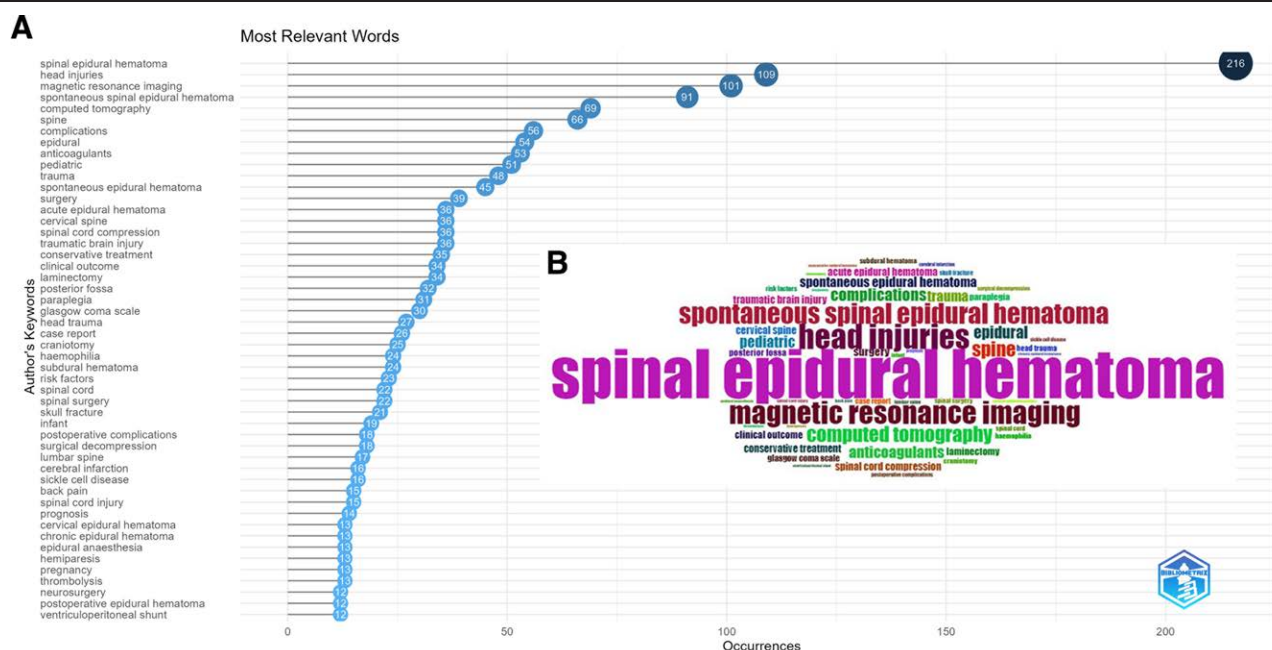
Figure 4. (A) Graph showing the 50 most frequently used keywords by authors in articles published in epidural hematoma literature. (Footnote: Obtained with Biblioshiny tools in R studio. Options; Field: Author's keywords, Minimum number of words: 50.) (B) Word cloud analysis visualization. (Footnote: Obtained with Biblioshiny tools in R studio. Options; Field: Author's keywords, number of words: 50, other visualization parameters were set to default. The font size of each keyword represents its relative frequency in the dataset, with more frequently used keywords appearing larger.)

cord compression, conservative treatment, laminectomy, paraplegia, hemophilia, spinal cord, infant, surgical decompression, cerebral infarction, back pain, spinal cord injury, cervical EDH, epidural anesthesia, hemiparesis, pregnancy, thrombolysis, aspirin, elderly, spontaneous resolution), Complications and Management of Epidural Hematoma (complications, postoperative complications, cauda equina syndrome, drainage, spinal stenosis, paralysis), Risk Factors and Postoperative Spinal Epidural Hematoma (risk factors, postoperative spinal EDH), Surgical and Postoperative Management of Epidural Hematoma (spinal surgery, lumbar spine, postoperative EDH, treatment, diagnosis), and Incidence of Epidural Hematoma.

Thematic evolution analysis was conducted using author keywords to determine the thematic evolution and topics of EDH between 2 different periods: 1980 to 2013 and 2014 to 2023 (the last decade). The thematic evolution from 1980 to 2013 to the last decade is shown in Figure 9A. EDH evolved as acute EDH and vertex EDH, while Spinal EDH evolved as spinal EDH and cervical EDH in the last decade. The thematic maps obtained for the period from 1980 to 2013 are shown in Figure 9B, and those obtained for the last decade are shown in Figure 9C. According to the thematic maps, in the period from the past to 2013, the basic themes were identified as EDH, head injuries, and CT, while the emerging or declining themes were acute EDH and acute subdural hematoma. The motor themes were spinal EDH, MRI, and spontaneous spinal EDH, and the niche theme was eosinophilic granuloma. In the last decade, the basic themes were EDH, pediatric, traumatic brain injury, spinal EDH, spontaneous spinal EDH, anticoagulants, acute EDH, CT, delayed EDH, intracranial pressure, and traumatic EDH. The emerging or declining theme was cervical EDH, the motor theme was cranial EDH, and the niche themes were endovascular treatment, embolization, middle meningeal artery, vertex EDH, superior sagittal sinus, intracranial hypotension, and cerebrospinal fluid.

4. Discussion

When evaluating the past publication trend and expected future predictions regarding EDH, it can be said that article productivity will follow a negligible increasing trend. However, the confidence intervals for the future predictions are relatively wide. This variability arises from fluctuations in historical publication trends, differences in research interest over time, and potential external factors influencing scientific output. The use of Exponential Smoothing forecasting with seasonal adjustment accounts for these fluctuations, yet inherent uncertainties in long-term projections contribute to the broader confidence intervals.

This study addresses the contributions of different countries to the literature on EDH. Our findings highlight significant contributions not only from developed countries but also from developing ones. Various bibliometric studies in the literature show a positive correlation between the economic size of countries and their academic article productivity.[8–11] This aligns with our findings, confirming that the economic size of countries positively impacts the scientific productivity of universities, academics, and research laboratories by influencing their numbers and research budgets. This underscores the importance of strengthening research infrastructure in contributing to scientific development. Additionally, our analysis of international collaborations revealed that United States of America-China collaborations play a dominant role in shaping global EDH research. These 2 countries not only contribute significantly in terms of publication volume but also form strong research networks, enhancing knowledge exchange and innovation. This trend underscores the impact of cross-border cooperation in fostering high-impact research and technological advancements. Beyond this, our findings indicate an increasing trend of international cooperation across multiple regions, fostering a more interconnected and globally inclusive research environment in the EDH field. However, while emphasizing these findings, it's crucial to highlight the significance of contributions from developing countries. This underscores that research and innovation in the EDH field are not limited to developed countries but require a global effort. In conclusion, examining contributions to the literature in the EDH field is important not only for scientific advancement but also for understanding their impact on global health services and technological innovations.
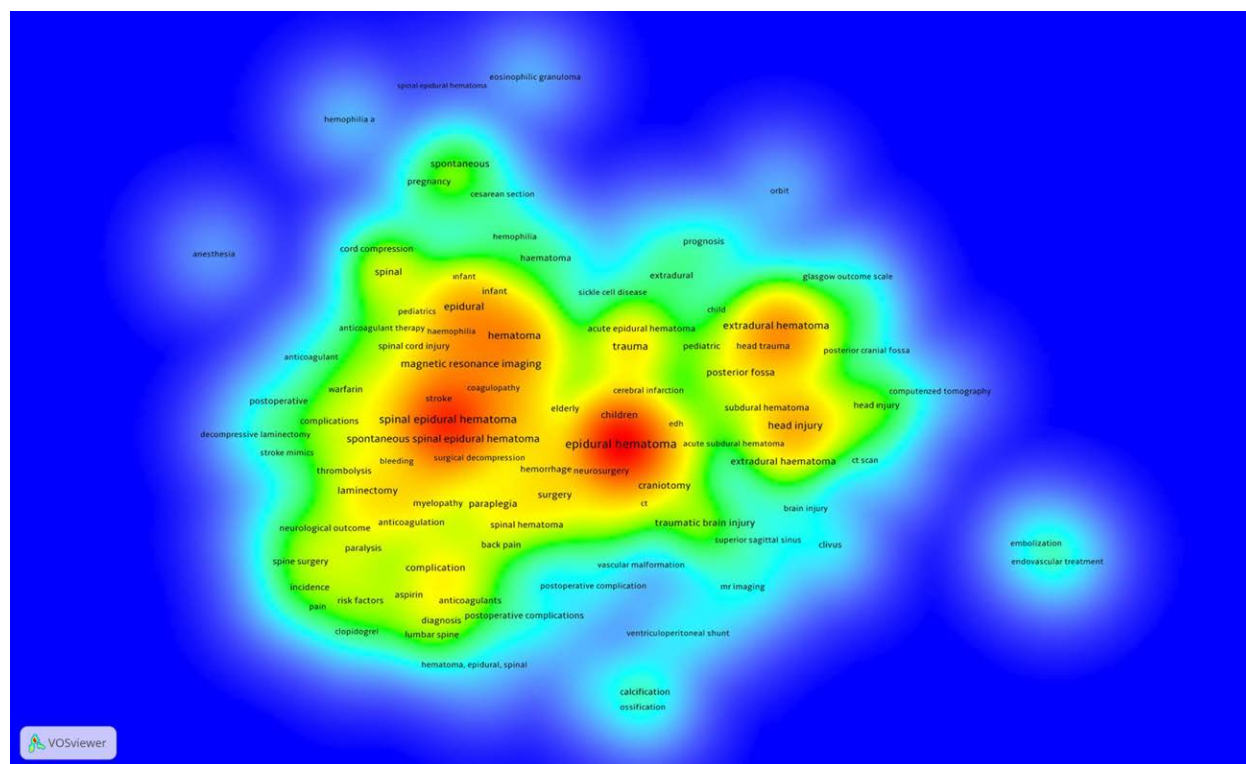
Figure 5. Visualisation of keyword burst analysis. (Footnote: Obtained with VOSviewer. Type of analysis: co-authorship, unit of analysis: author keywords, minimum number of occurrences of a keyword: 5, weights: total link strength. Total link strength reflects the total strength of relationships between a key word and other key words. Therefore, the higher the number and strength of connections between a key word and other key words, the higher the total link strength.)
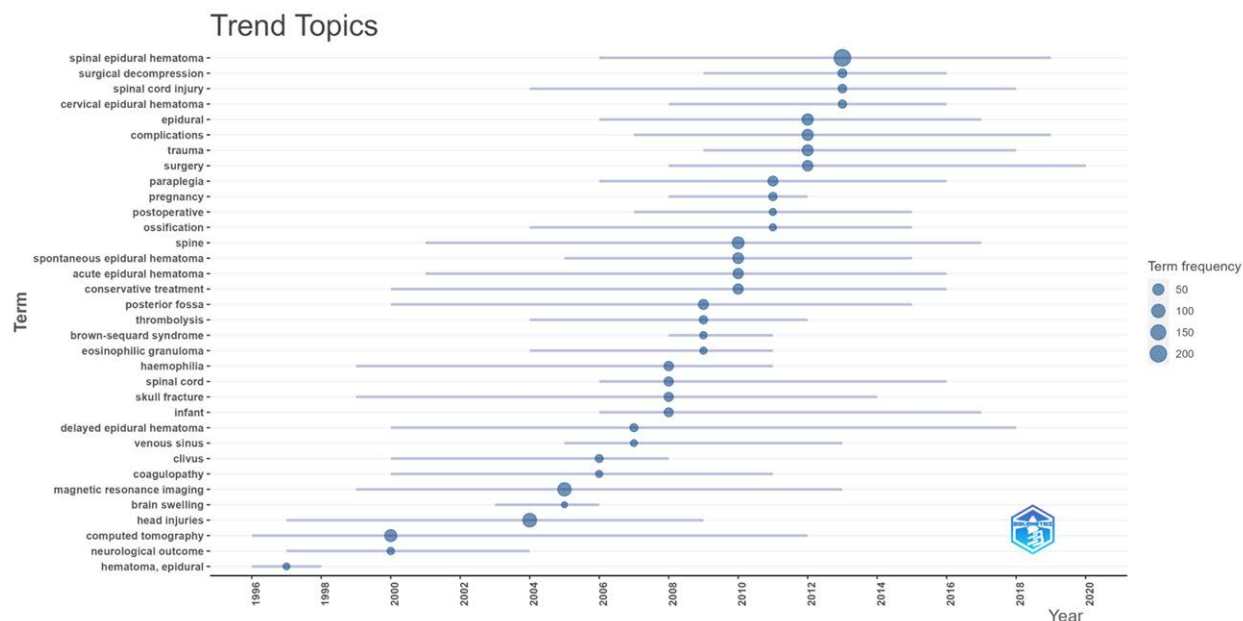

Figure 6. A graph showing the most frequently used trending keywords in the period 1980 to 2013. (Footnote: Horizontal lines represent the years in which keywords are commonly used, while circle sizes represent the frequency of use of keywords. Obtained with Biblioshiny tools in R studio. Options; keyword minimum frequency (co-occurrence) = 4, Number of trend keywords per year = 4.)

Collaboration and knowledge sharing between developed and developing countries can accelerate progress in the EDH field and improve healthcare services in this area. Therefore, it's important for future research to further examine such collaborations and global contributions.

Several influential journals stand out based on their productivity, h-index, and m-index rankings, providing significant scientific contributions to the field of EDH. The high h-index and m-index values of these journals indicate their prestigious position in the scientific community, characterized by broad academic impact and frequent citations. The m-index, specifically, is designed to assess the productivity and citation impact of an author or journal relative to their age. Unlike the h-index, which simply measures the number
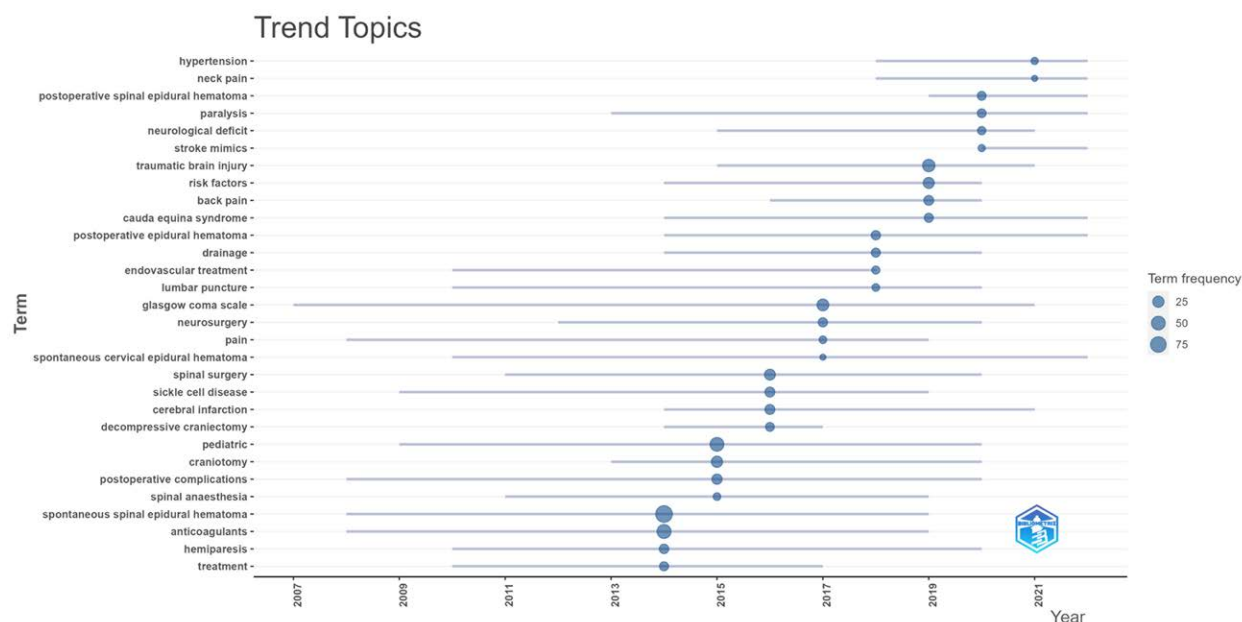
Figure 7. A graph showing the most frequently used trending keywords in the period 2014 to 2023. (Footnote: Horizontal lines represent the years in which keywords are commonly used, while circle sizes represent the frequency of use of keywords. Obtained with Biblioshiny tools in R studio. Options; keyword minimum frequency (co-occurrence) = 4, Number of trend keywords per year = 4.)
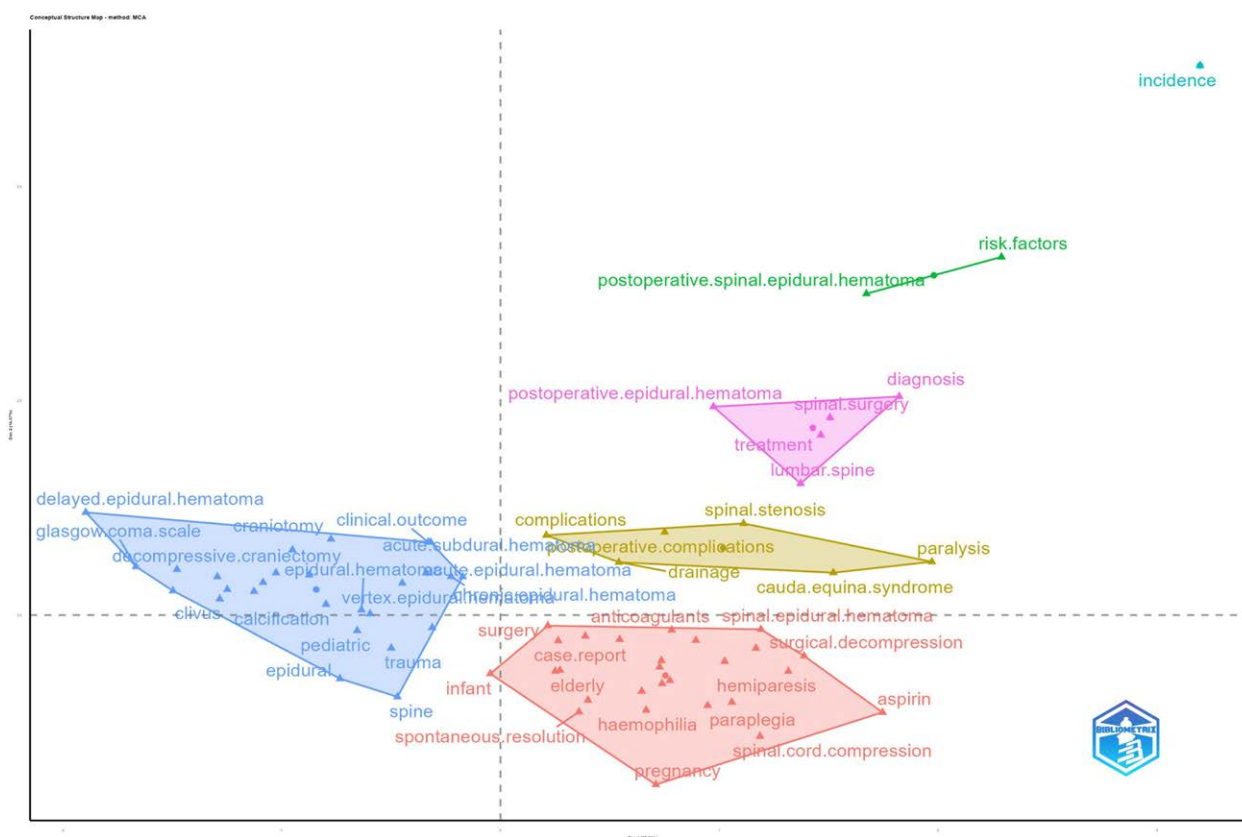

Figure 8. Map showing the findings of the MCA (Multiple Correspondence Analysis) using multiple correspondence analysis. (Footnote: The center of the map represents the center of the research topic and shows the main topics. Each color represents a different sub-factor. Obtained with Biblioshiny tools in R studio. Options; method: multiple correspondence analysis, field: author's keywords, number of words: 75, other options: default.)

of highly-cited papers, the m-index accounts for the temporal aspect of productivity, offering a more nuanced view of long-term academic contribution.[11,12] On the other hand, journals known for their high AC per article host articles that prominently contribute to EDH research and foster extensive scientific interaction.

Our study aimed to examine high-impact articles using citation analyses to identify important research topics in the field of
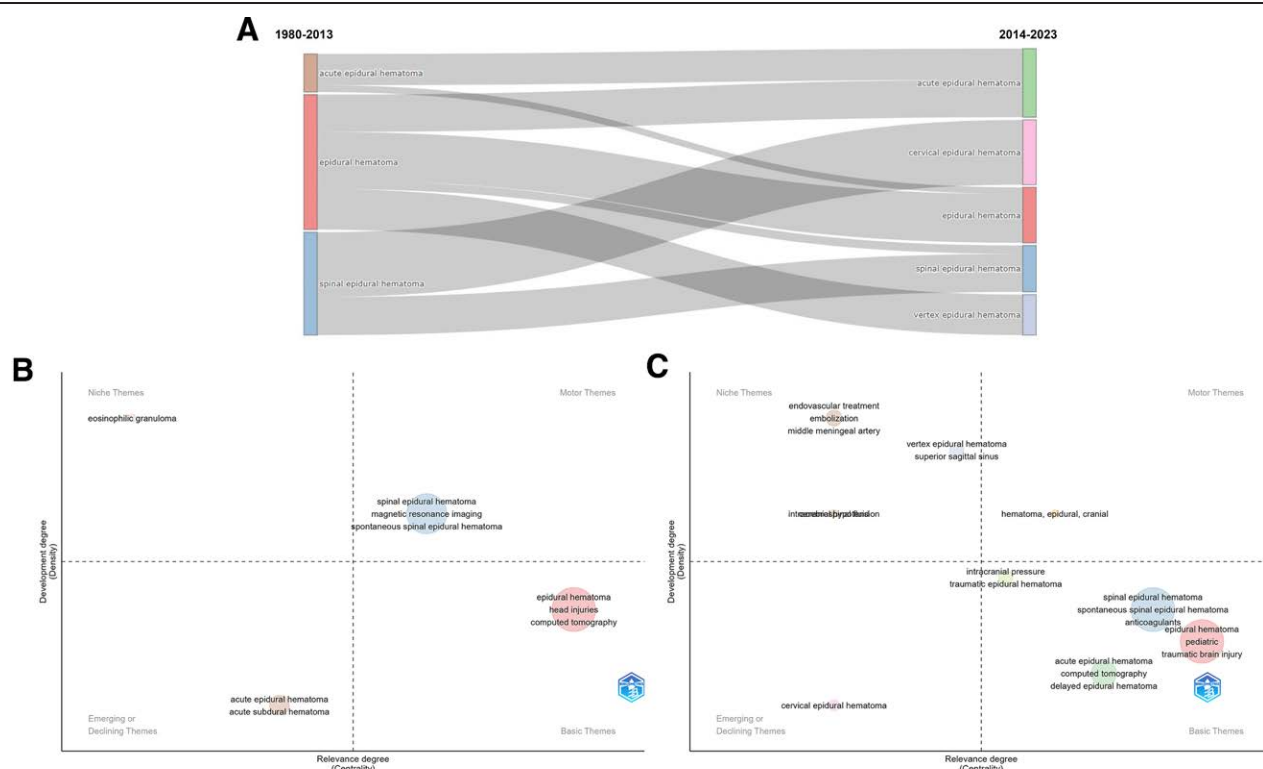
Figure 9. (A) Thematic Maps for the Period 1980 to 2013. (B) Thematic Maps for the Period 2014 to 2023. (Footnote: Thematic maps: (1) upper right quadrant: motor themes; (2) lower right quadrant: basic themes; (3) lower left quadrant: emerging or declining themes; and (4) upper left quadrant: niche themes. Obtained with Biblioshiny tools in R studio. Options; Field: Author's keywords, number of words: 350, Number of Cutting Points: 1, Cutting Year 1: 2013, other options: default.)

EDH. Our findings reveal that highly influential studies in the literature often focus on EDH etiology, diagnosis and imaging, preoperative assessment and prognostic factors, risk factors, treatment, surgical management, and recovery. In particular, the most-cited articles highlight key aspects of EDH management. Lawton et al (1995) investigated the relationship between surgical timing and neurological outcomes, emphasizing the critical role of early intervention.[7] Similarly, Kou et al (2002) and Amiri et al (2013) identified significant risk factors associated with postoperative spinal epidural hematomas, aiding in the prediction and prevention of complications.[20,21] Studies by Lee et al (2017) and Bateman et al (2013) explored the risks of neuraxial techniques and epidural catheterization, providing valuable insights for anesthesiologists and obstetricians.[19,22] Radiological assessments remain crucial for early diagnosis, as demonstrated by Holtas et al (1996), who correlated MRI findings with clinical presentation in spontaneous cases.[17] Groen and van Alphen (1996) further analyzed surgical outcomes, identifying factors influencing postoperative prognosis.[15] Additionally, Kao et al (2015) and Awad et al (2005) examined the incidence and management of symptomatic epidural hematomas following lumbar decompression surgery.[23–28] Aono et al (2011) focused on the frequency of postoperative symptomatic EDH in spinal decompression procedures, underscoring the need for vigilant perioperative monitoring.[29] These findings suggest that researchers interested in EDH should prioritize these studies identified through citation and co-citation analyses, as they provide a comprehensive understanding of EDH pathophysiology, risk factors, and management strategies.

RPYS analysis provides insights into the historical progression of a topic by using the TC counts received by all referenced publications within articles for each year.[14] According to the RPYS analysis findings regarding the historical development of the EDH topic, the first peak in 1869 was attributed to Jackson's

(1869) article titled "Case of spinal apoplexy."[30] The second and third significant peaks in 1935 and 1938 were due to the works of Priest (1935) and McKenzie (1938).[31,32] Subsequently, in 1941, there was a renewed interest with the studies by Munro and Maltby (1941) and Coleman (1941).[33,34] Academic interest continued to rise with numerous studies, culminating in a notable peak in the 1968s led by Jamieson and Yelland (1968) and Gallagher and Browder (1968).[27,35] The trend of interest in the topic rapidly increased in the following years. It was determined that the highest academic interest in EDH occurred in 1996 and 2004. The peak in 1996 was driven by the studies of Groen and van Alphen (1996) and Holtas et al (1996).[15,17] The formation of these peaks during these periods can be attributed to significant scientific discoveries shared in research on spontaneous spinal EDHs.[15,17] The second highest peak in 2004 was influenced by the studies of Groen (2004) and Liao et al (2004) in the field of spontaneous spinal EDHs.[36,37] These peaks likely correspond to periods when key advancements in imaging techniques and surgical interventions for EDH were introduced, leading to increased academic interest and citations.

The most commonly used keywords from past to present reflect different aspects of EDH. Among these are various types of EDH, as well as imaging studies for EDH diagnosis such as MRI and CT, research on surgical treatments, pediatric and pregnancy studies, posttreatment complications, and prognosis. Additionally, topics related to head trauma and brain injuries, spinal cord and spine issues, hematological conditions, anticoagulants, trauma, clinical outcomes, and risk factors have also been extensively researched. This diversity indicates a wide range of investigations into the medical, surgical, and neurological aspects of EDH, as well as treatment options, prognosis, and the epidemiology of the disease. These studies can help us better understand EDH and may even contribute to the development of more effective treatment methods in the future.

Trend keyword analysis in EDH reveals significant changes between the decade before and the past decade. Initially, research on EDH focused primarily on different types of EDH, diagnostic methods, hematological conditions, spinal cord and spine-related conditions, and head and brain injuries. Understanding EDH diagnosis and disease progression was prominent during that period. However, trend analysis from the past decade indicates a notable shift in the research focus. In recent years, there has been a greater emphasis on EDH treatment, surgical interventions, posttreatment complications, risk factors, associated conditions, neurological conditions and diseases, spontaneous spinal and cervical EDH, traumatic brain injury, and the Glasgow Coma Scale. Particularly, the increase in research on treatment methods, post-disease outcomes, and complication management reflects the evolution of approaches to EDH clinical management and patient outcomes. Additionally, another prominent area in the past decade has been pediatric cases of EDH. The increase in EDH cases in children and the evaluation of treatment strategies in these patients have been the focus of recent research. These analyses highlight the evolution of research in the EDH field over time and the changing focus areas, emphasizing developments in EDH clinical management and treatment strategies.

The results of MCA are an important step in identifying the underlying fundamental research dimensions in EDH literature. Analysis of articles related to EDH has revealed the existence of 6 main research dimensions. The first factor focuses on topics that include acute head trauma and emergency medical conditions such as EDH. The second factor encompasses topics related to spinal EDH and its treatment. The third factor focuses on potential complications of EDH and the management of these complications. The fourth factor includes risk factors influencing the development of spinal EDH and postoperative complications. The fifth factor covers topics related to the surgical treatment of EDH and its management during the postoperative period. The sixth factor emphasizes research topics related to the incidence of EDH. Considering these subdimensions can support better understanding of EDH and the development of effective treatment strategies.

Thematic evolution analysis results provide a valuable insight into the development and focus areas of EDH over time. Comparative analyses between 2 different periods, 1980 to 2013 and 2014 to 2023, show a significant thematic evolution in the EDH field. Firstly, it was found that the focal points of EDH during the 1980 to 2013 period were dominated by fundamental themes such as EDH, head injuries, and CT. When evaluated in conjunction with trend keyword analyses, there was an observed rise in topics like acute EDH and acute subdural hematoma during this period. Additionally, among motor themes, topics like spinal EDH, MRI, and spontaneous spinal EDH stood out. Eosinophilic granuloma emerged as a notable niche theme. In the past decade, it was determined that pediatric patients, traumatic brain injury and EDH, spinal EDH, spontaneous spinal EDH, anticoagulant use, acute EDH, CT, delayed EDH, intracranial pressure, and other fundamental topics took precedence. However, cervical EDH was observed to be a decreasing theme. Cranial EDH showed a significant increase among motor themes. Among niche themes, topics like endovascular treatment, embolization, middle meningeal artery, vertex EDH, superior sagittal sinus, intracranial hypotension, and cerebrospinal fluid were prominent. These findings indicate an increase in research focusing on more specific and advanced treatment methods for EDH in the past decade.

The identified trends and research gaps provide valuable guidance for future EDH research. The increasing focus on pediatric cases highlights the need for comprehensive studies on age-specific diagnostic and treatment strategies, particularly considering differences in clinical presentation and outcomes. Similarly, the emphasis on risk factors suggests that further research is needed to refine predictive models for EDH occurrence, especially in patients with coexisting conditions such as anticoagulant use. Moreover, the rise of niche themes like endovascular treatment and embolization underscores the importance of exploring minimally invasive therapeutic approaches to improve patient outcomes.

We came across only 1 bibliometric study on the EDH topic in the literature.[38] Abdulqader et al's (2022) basic-level bibliometric research focused solely on the top 100 most cited articles. Additionally, the search strategy conducted with missing keywords in Abdulqader et al's (2022) study has been revised and corrected in our study. Our study can be considered the first comprehensive bibliometric research in this regard due to its inclusion of extensive bibliometric analyses such as citation and co-citation analyses, trend keyword analyses, MCA, and thematic evolution analysis. Unlike Abdulqader et al (2022), our study provides deeper insights into research dynamics by identifying thematic shifts over time, mapping intellectual structures, and offering a broader perspective on the evolution of EDH-related literature.

One limitation of our study can be identified as our preference for WoS over other major databases like Scopus or PubMed. While databases like WoS and Scopus are generally preferred for bibliometric studies, we opted for WoS due to PubMed's inability to perform citation and co-citation analyses.[39–43] However, it is important to note that excluding databases like Scopus or PubMed may impact the completeness of our analysis, as each database has its own strengths and coverage. The inclusion of high-impact journals in WoS and its wide usage in bibliometric research[8–11] are among the reasons behind our preference; furthermore, in recent years, WoS has been widely preferred in many bibliometric studies.[44,45]

5. Conclusion

In conclusion, the comprehensive analysis and research conducted on EDH in this study have provided significant insights into the trends, thematic evolution, and fundamental research dimensions of this important medical condition. Academic interest, starting in 1869, 1935, 1938, and 1941, notably increased in 1968, 1982, and 1988, reaching its highest peaks in 1996 and 2004. The examination of 1785 articles and analyses spanning several decades indicates that key topics such as spinal EDH, head injuries, MRI, spontaneous spinal EDH, CT, spine, complications, epidural, anticoagulants, pediatric cases, trauma, and spontaneous EDH have stood out in EDH research. The findings have shown a dynamic change in research focuses over time, highlighting increased emphasis on specific areas such as clinical management approaches, treatment modalities, postoperative complications, risk factors, pediatric cases, as well as specific issues like paralysis and cauda equina syndrome.

The 6 fundamental research dimensions identified through MCA have shed light on primary focus areas such as acute trauma management, surgical interventions, complications management, risk assessment, surgical outcomes, and incidence analysis. These dimensions underscore the necessity for multidisciplinary approaches and comprehensive strategies to effectively address EDH, providing guidance for future research endeavors. Thematic evolution analysis reveals the changing trends in EDH literature over time.

Furthermore, the international perspective has highlighted contributions from both developed and developing countries, showcasing the collaborative nature of scientific progress in addressing the comprehensive challenges of EDH. High-impact journals and influential authors have made significant contributions to knowledge dissemination and advancements in EDH management, paving the way for future research directions and innovative approaches.

Overall, this study not only delves into the history and current state of EDH research but also lays the foundation for

evidence-based practice, scientific progress, and advancements in the field. Its ongoing evolution and dynamic nature emphasize the importance of continuous exploration, innovation, and global collaboration in tackling the multifaceted challenges posed by this complex medical condition.

Author contributions

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Formal analysis: Hakan Kına, Murat Kiraz.
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Project administration: Hakan Kına, Murat Kiraz.
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Software: Hakan Kına, Murat Kiraz.
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Validation: Hakan Kına, Murat Kiraz.
Visualization: Hakan Kına, Murat Kiraz.
Writing – original draft: Hakan Kına, Murat Kiraz.
Writing – review & editing: Hakan Kına, Murat Kiraz.

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