



A Bibliometric Analysis of the Most-Cited Articles on Craniospinal Epidural Hematoma

Sarah BIN ABDULQADER¹, Othman T. ALMUTAIRI¹, Modhi A. ALHUSSINAN², Turki ELARJANI³, Abdullah ALBATHI⁴, Abdulrahman Y. ALTURKI^{1,5}, Mohammed BAFAQUH¹

¹National Neuroscience Institute King Fahad Medical City, Department of Neurosurgery, Riyadh, Kingdom of Saudi Arabia

²Alfaisal University, College of Medicine, Riyadh, Kingdom of Saudi Arabia.

³University of Miami, Department of Neurological Surgery, Miami, Florida, United States of America.

⁴College of Medicine, King Abdulaziz University Hospital, Jeddah, Kingdom of Saudi Arabia.

⁵Division of Neurocritical Care, Critical Care Administration, King Fahad Medical City, Riyadh, Saudi Arabia

Corresponding author: Sarah BIN ABDULQADER ✉ binabdulqader@gmail.com

ABSTRACT

AIM: To analyze the most-cited articles on cranial and spinal epidural hematomas (EDHs).

MATERIAL and METHODS: A title-specific search was performed on the Scopus database using the term “epidural hematoma” in June 2020, with no publication date restrictions. The top 100 most-cited articles were collected, reviewed, and analyzed.

RESULTS: A total of 2165 articles were published on EDH from 1949 to 2020, and the top 100 most-cited ones were published between 1966 and 2014, receiving an average citation of 84.7 per paper. Most papers were published in Neurosurgery and Journal of Neurosurgery (JNS). 48% of the most-cited articles on EDH originated from the United States of America (USA). Notably, studies on spinal EDH represented 75% of the most-cited articles in our review. The most-cited article on EDH was published by Lawton et al. in 1995, receiving a total of 412 citations at an annual citation rate of 16.4%.

CONCLUSION: This report identifies the most influential publications on EDH as well as the publications trends over the last 70 years. Recognition of the most impactful work is an important tool for clinicians and researchers as it can reflect the enormous changes in the clinical practice. This report can serve as a guide for developing evidence-based practices and identifying areas of research inadequacy.

KEYWORDS: Epidural hematoma, Spinal epidural hematoma, Bibliometric, Citation analysis

ABBREVIATIONS: **H-Index:** Hirsch index, **SNIP:** Journal’s Source Normalized Impact Per Paper, **SJR:** Journal’s SCImago Journal Rank, **IF:** Journal impact factor, **CC:** Citation count, **CY:** Citation per year, **EDH:** Epidural hematoma

INTRODUCTION

Epidural hematoma (EDH) is a commonly encountered neurosurgical condition. EDH can be classified as cranial or spinal based on its location and as traumatic or non-traumatic based on etiopathological factors (infection/abscess, coagulopathy, hemorrhagic tumors, and vascular malformation). Cranial EDH, which is mostly

attributed to traumatic brain injury, represents 2–10% of all types of head injuries and has a mortality rate of 1.2–33% (6,7,9,13,16,22,32). In most cases, the source of bleeding is an arterial branch of the middle meningeal artery, which underlies the pterion (18). Spinal EDH, on the other hand, has diverse causes and risk factors, including trauma, vascular malformation, coagulopathies, and the use of anticoagulant

medications. Focal neurological deficits resulting from spinal cord compression are the most common signs or symptoms of spinal EDH (19). Cranial EDH management primarily aims to decrease intracranial pressure (ICP) and improve mass effect-related symptoms (5). The management of spinal EDH involves decompressing the spinal cord, limiting further progression, and preserving function (19).

Citation analysis remains one of the most widely recognized methods of quantifying the impact of articles and the contribution of authors, journals, and institutions to a particular field (26). In addition, it studies the chronological trends of the articles, culminating at the most contemporary category. Bibliometric analyses have been applied to various subjects in many different medical specialties, including neurosurgery (1-3,27,21), neurology (15,23,29), psychiatry (25), radiology (17), urology (28), and orthopedics (20).

EDH has been a subject of extensive research for several years, with articles published in the late 19th century covering almost every aspect of the disease, including incidence and epidemiology, management, diagnosis, and treatment costs. The objective of the present study was to conduct a bibliometric analysis of the top 100 most-cited articles on EDH. Bibliometric trends analysis acts as an important source for highlighting impactful studies that have contributed to evidence-based clinical practice.

■ MATERIAL and METHODS

The execution of this bibliometric analysis involved a specific, keyword-based database search using Scopus as the search engine and without placing restrictions on the publication dates. To identify the most-cited articles, "Epidural Hematoma" was used as the keyword. The identified articles were stratified based on their respective citation counts, and the top 100 most-cited articles were obtained and categorized based on a thorough review. The identified categories were as follows: clinical, diagnosis, epidemiology, etiology, management, pathophysiology, and prognosis. Further clustering of data

stratified the most-cited articles, based on the location of the EDH, as spinal or cranial. The following important article-based parameters were collected for analytical correlation: the article's citation count, article's citation per year, article's year of publication, contributing authors, specialty of the top contributing authors, most contributing author's H-Index, affiliation of the corresponding authors, country of publication, journal of publication, journal's impact factor, journal's source normalized impact per paper (SNIP), and journal's SCImago journal rank (SJR).

■ RESULTS

This bibliometrics-based search identified a total of 2165 articles published on EDH from 1949 to June 2020. The top 100 most-cited articles were published between 1966 and 2014 and had an accumulative citation count of 8447, with 84.7 as the average number of citations per paper and 1.19% as the rate of self-citation for all the authors (Table I, Figure 1). Studies assessing spinal EDH comprised two-thirds of the most-cited articles (Figure 2), and clinical studies accounted for one-third of the list (Figure 3). The United States of America (USA) contributed to approximately half of the most-cited articles (Figure 4). The University of Ghang Gung Memorial Hospital, Taiwan, was the most active in studying EDH, having published eight of the 100 articles (Figure 5). *Neurosurgery* and the *Journal of Neurosurgery* were the top two highest contributing journals in the list, with 17 and 14 articles, respectively (Figure 6). An analysis of the contributing authors revealed similar contributions among those who contributed two or more articles (Figure 7). The list of the top 20 authors showed that neurosurgeons contributed the most to the list.

The most-cited article on EDH, entitled "Surgical management of spinal epidural hematoma: Relationship between surgical timing and neurological outcome," was written by Lawton M. T. et al. and published in the *Journal of Neurosurgery* in 1995. It collected 412 citations since its publication at a rate of 16.4% citations per year.

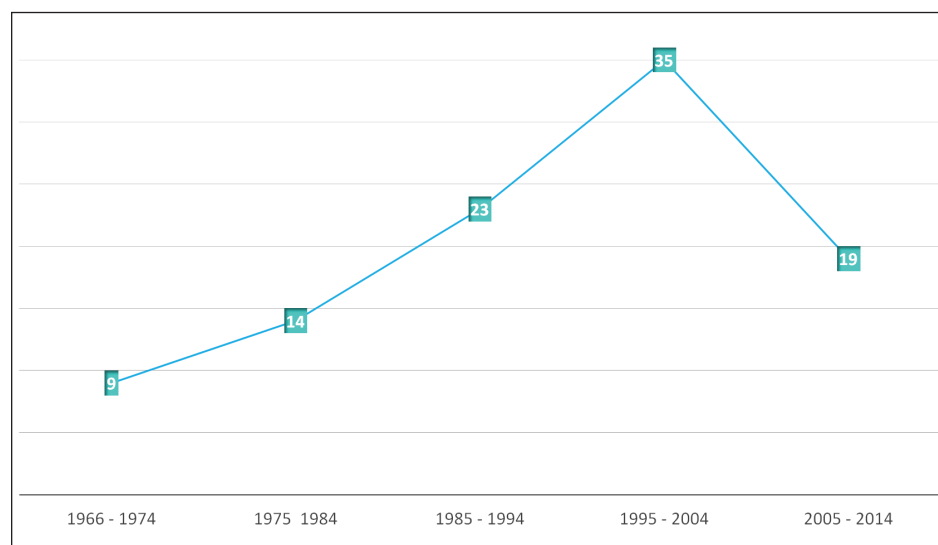


Figure 1: Publications trends related to epidural hematoma.

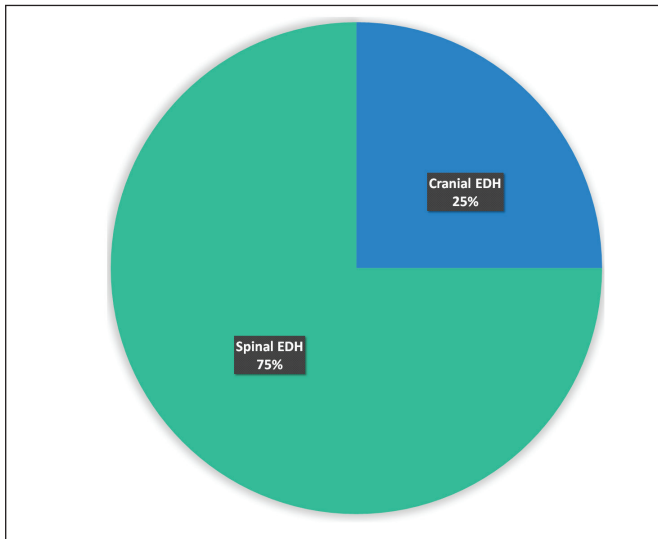


Figure 2: Studies on cranial versus spinal epidural hematoma.

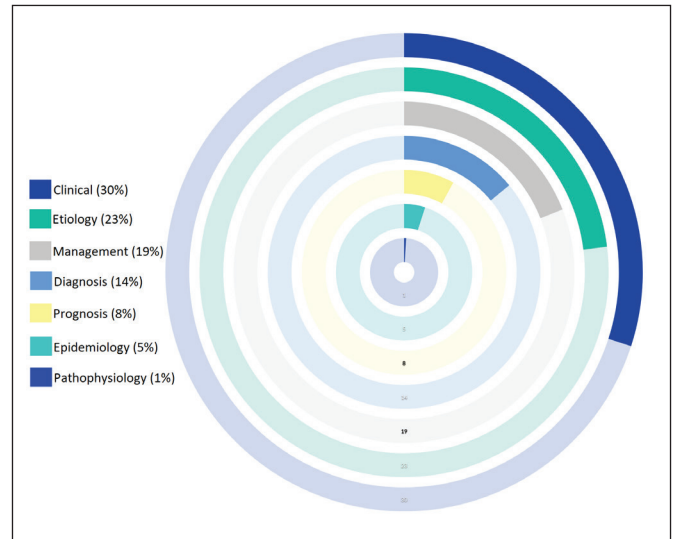


Figure 3: Study categories.

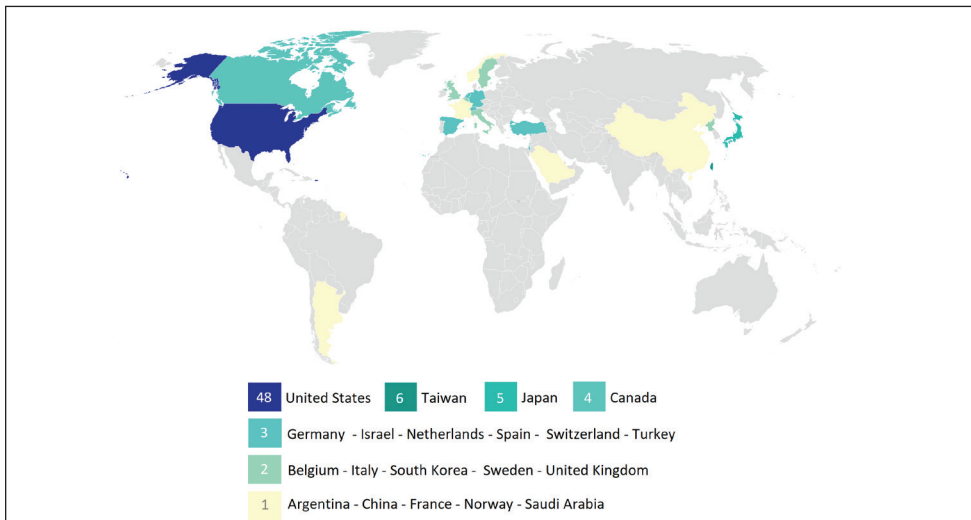


Figure 4: Countries contributing to epidural hematoma research.

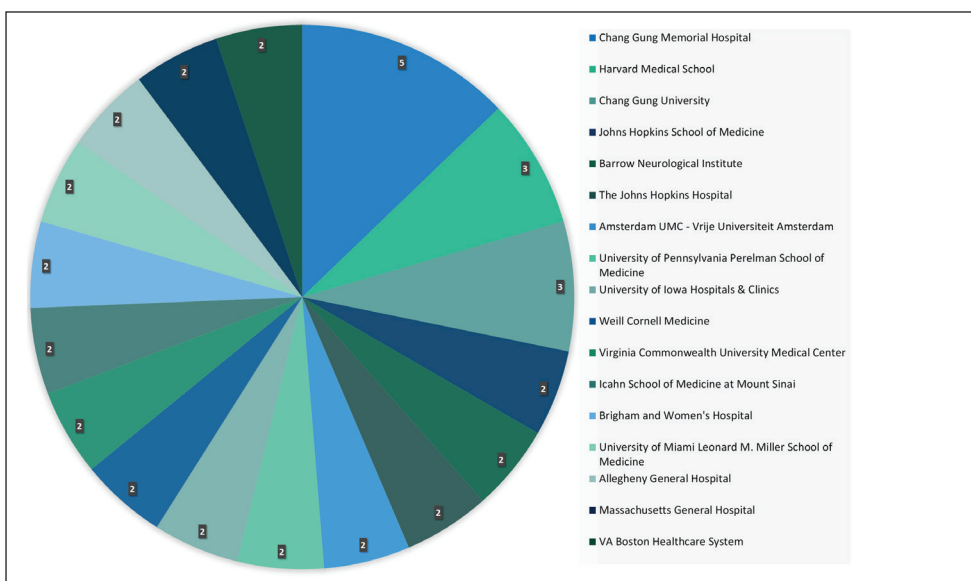


Figure 5: Institutions contributing to epidural hematoma research.

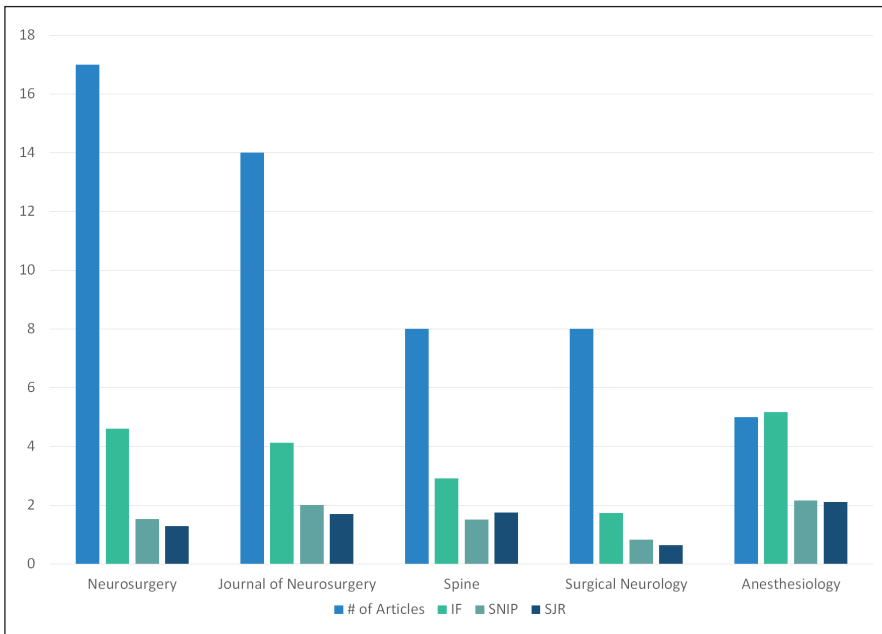


Figure 6: Journals contributing to epidural hematoma research.

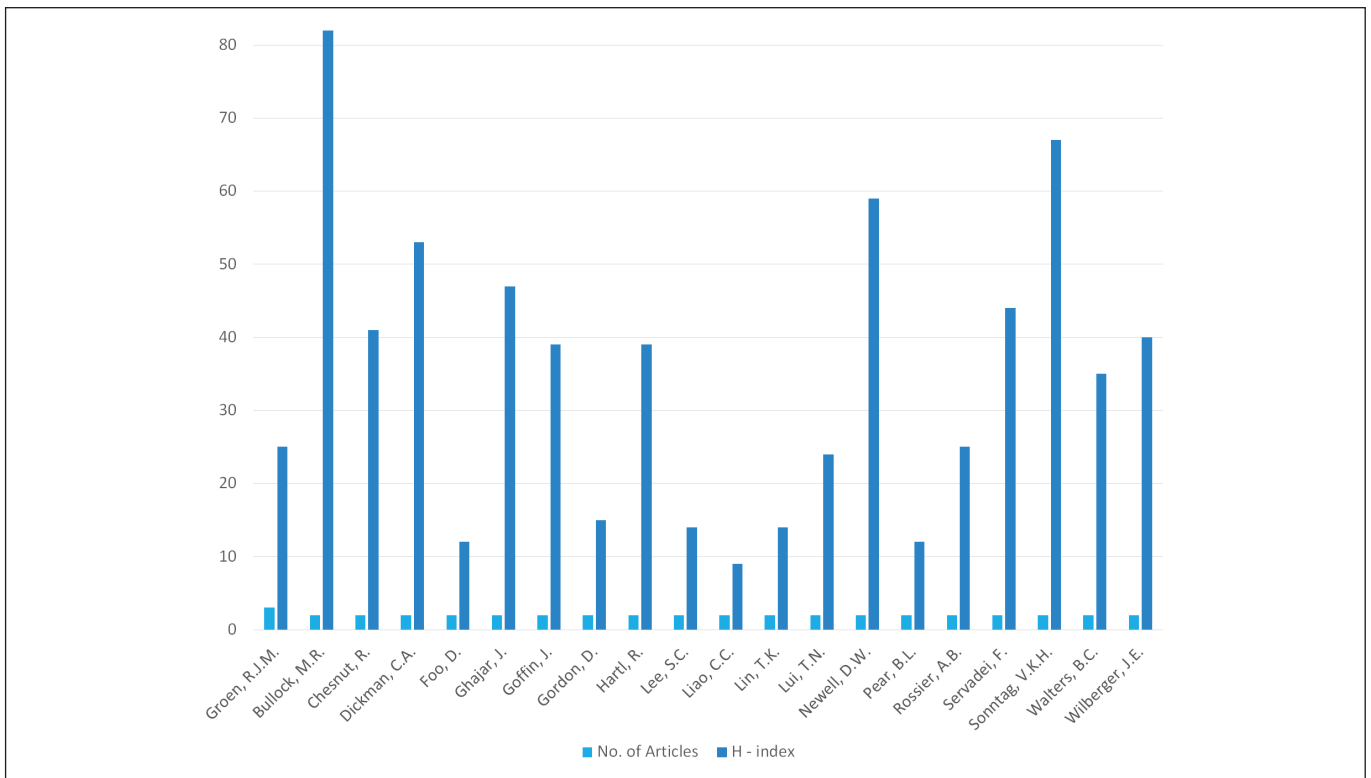


Figure 7: Authors contributing to epidural hematoma research.

Table I: Rate of Self-Citation for All the Authors

Rank	Authors	Title	Journal	CC	CY
1 st	Lawton et al., 1995	Surgical management of spinal epidural hematoma: Relationship between surgical timing and neurological outcome	<i>Journal of Neurosurgery</i>	412	16.48
2 nd	Groen & Ponsen, 1990	The spontaneous spinal epidural hematoma. A study of the etiology	<i>Journal of the Neurological Sciences</i>	267	8.9
3 rd	Groen & Alphen, 1996	Operative treatment of spontaneous spinal epidural hematomas: A study of the factors determining postoperative outcome	<i>Neurosurgery</i>	262	10.92
4 th	Holtás et al., 1996	Spontaneous spinal epidural hematoma: Findings at MR imaging and clinical correlation	<i>Radiology</i>	228	9.5
5 th	Foo & Rossier, 1981	Preoperative neurological status in predicting surgical outcome of spinal epidural hematomas	<i>Surgical Neurology</i>	220	5.64
6 th	Ruppen et al., 2006	Incidence of epidural hematoma, infection, and neurologic injury in obstetric patients with epidural analgesia/analgesia	<i>Anesthesiology</i>	213	15.21
7 th	Rose et al., 1990	Spontaneous spinal epidural hematoma with associated platelet dysfunction from excessive garlic ingestion: A case report	<i>Neurosurgery</i>	207	6.9
8 th	Beatty & Winston, 1984	Spontaneous cervical epidural hematoma. A consideration of etiology	<i>Journal of Neurosurgery</i>	207	5.75
9 th	Bullock et al., 2006	Surgical management of acute epidural hematomas	<i>Neurosurgery</i>	183	13.07
10 th	Kou et al., 2002	Risk factors for spinal epidural hematoma after spinal surgery	<i>Spine</i>	179	9.94
11 th	Bullock et al., 2006	Surgical management of acute epidural hematomas.	<i>Neurosurgery</i>	159	11.36
12 th	Groen & Goffin, 2004	Non-operative treatment of spontaneous spinal epidural hematomas: A review of the literature and a comparison with operative cases	<i>Acta Neurochirurgica</i>	145	9.06
13 th	Wyowski et al., 1998	Spinal and epidural hematoma and low-molecular-weight heparin [4] (multiple letters)	<i>New England Journal of Medicine</i>	125	5.68
14 th	Markham et al., 1967	The syndrome of spontaneous spinal epidural hematoma. Report of three cases.	<i>Journal of neurosurgery</i>	120	2.26
15 th	Fukui et al., 1999	Acute spontaneous spinal epidural hematomas	<i>American Journal of Neuroradiology</i>	113	5.38
16 th	Harik S I et al., 1971	Spontaneously Remitting Spinal Epidural Hematoma in a Patient on Anticoagulants	<i>New England Journal of Medicine</i>	112	2.29
17 th	Gundry & Heithoff, 1993	Epidural hematoma of the lumbar spine: 18 Surgically confirmed cases	<i>Radiology</i>	111	4.11
18 th	Liao et al., 2004	Experience in the surgical management of spontaneous spinal epidural hematoma	<i>Journal of Neurosurgery</i>	107	6.69
19 th	McQuarrie, 1978	Recovery from paraplegia caused by spontaneous spinal epidural hematoma	<i>Neurology</i>	105	2.5
20 th	Mattle et al., 1987	Nontraumatic spinal epidural and subdural hematomas	<i>Neurology</i>	101	3.06
21 st	Braun et al., 2007	MRI findings in spinal subdural and epidural hematomas	<i>European Journal of Radiology</i>	99	7.61
22 nd	Lonjon et al., 1997	Nontraumatic spinal epidural hematoma: Report of four cases and review of the literature	<i>Neurosurgery</i>	97	4.21
24 th	Knuckey N et al., 1989	The management of 'asymptomatic' epidural hematomas. A prospective study	<i>Journal of Neurosurgery</i>	96	3.09
23 rd	Sokolowski et al., 2008	Prospective study of postoperative lumbar epidural hematoma: Incidence and risk factors	<i>Spine</i>	96	8
27 th	Foo & Rossier, 1982	Post-traumatic spinal epidural hematoma	<i>Neurosurgery</i>	91	2.39
26 th	Pan et al., 1988	Traumatic epidural hematoma of the cervical spine: Diagnosis with magnetic resonance imaging. Case report	<i>Journal of Neurosurgery</i>	91	2.84
25 th	Rosen et al., 2004	An epidural hematoma in an adolescent patient after cardiac surgery	<i>Anesthesia and Analgesia</i>	91	5.67
28 th	Glottzbecker et al., 2010	Postoperative spinal epidural hematoma: A systematic review	<i>Spine</i>	87	8.7
30 th	Dickman et al., 1990	Spinal epidural hematoma associated with epidural anesthesia: Complications of systemic heparinization in patients receiving peripheral vascular thrombolytic therapy	<i>Anesthesiology</i>	84	2.8
29 th	Hentschel et al., 2001	Resolution of spontaneous spinal epidural hematoma without surgery: report of two cases.	<i>Spine</i>	84	4.42
31 st	Lobato et al., 1988	Acute epidural hematoma: An analysis of factors influencing the outcome of patients undergoing surgery in coma	<i>Journal of Neurosurgery</i>	83	2.6
32 nd	Metzger & Singbartl, 1991	Spinal epidural hematoma following epidural anesthesia versus spontaneous spinal subdural hematoma. Two case reports	<i>Acta Anaesthesiologica Scandinavica</i>	81	2.79

Tablo I: Cont.

Rank	Authors	Title	Journal	CC	CY
33 rd	Pear, 1972	Spinal epidural hematoma.	<i>The American Journal of Roentgenology, Radium Therapy, and Nuclear Medicine</i>	80	1.67
35 th	Clarke et al., 1992	Spontaneous spinal epidural hematoma causing paraplegia: Resolution and recovery without surgical decompression	<i>Neurosurgery</i>	77	2.75
34 th	Shin et al., 2006	Surgical management of spontaneous spinal epidural hematoma	<i>European Spine Journal</i>	77	5.5
36 th	Yi et al., 2006	Postoperative spinal epidural hematoma: Risk factor and clinical outcome	<i>Yonsei Medical Journal</i>	76	5.43
39 th	Cohen et al., 1996	Prognosis and clinical relevance of anisocoria-craniotomy latency for epidural hematoma in comatose patients	<i>Journal of Trauma - Injury, Infection and Critical Care</i>	75	3.12
38 th	Kebaish & Awad, 2004	Spinal epidural hematoma causing acute cauda equina syndrome.	<i>Neurosurgical Focus</i>	75	4.69
37 th	Bateman et al., 2013	The risk and outcomes of epidural hematomas after perioperative and obstetric epidural catheterization: A report from the multicenter perioperative outcomes group research consortium	<i>Anesthesia and Analgesia</i>	75	10.71
40 th	Patel et al., 1998	Spontaneous spinal epidural hematoma in children	<i>Pediatric Neurology</i>	74	3.36
41 st	Locke et al., 1976	Acute spinal epidural hematoma secondary to aspirin induced prolonged bleeding	<i>Surgical Neurology</i>	74	1.68
44 th	Sullivan et al., 1999	Follow-up of conservatively managed epidural hematomas: Implications for timing of repeat CT	<i>American Journal of Neuroradiology</i>	73	3.47
42 nd	Uribe J et al., 2003	Delayed postoperative spinal epidural hematomas	<i>Spine Journal</i>	73	4.29
43 rd	Stoll & Sanchez. 2002	Epidural hematoma after epidural block: Implications for its use in pain management	<i>Surgical Neurology</i>	73	4.05
45 th	Cooper. 1967	Spontaneous spinal epidural hematoma. Case report.	<i>Journal of neurosurgery</i>	71	1.33
47 th	Alexiadou-Rudolf et al., 1998	Acute nontraumatic spinal epidural hematomas: An important differential diagnosis in spinal emergencies	<i>Spine</i>	69	3.13
48 th	Rothfus et al., 1987	MR imaging in the diagnosis of spontaneous spinal epidural hematomas	<i>Journal of Computer Assisted Tomography</i>	69	2.09
46 th	Liu et al., 2008	Spontaneous spinal epidural hematoma: analysis of 23 cases	<i>Surgical Neurology</i>	69	5.75
49 th	Chen et al., 1993	The expectant treatment of "asymptomatic" supratentorial epidural hematomas	<i>Neurosurgery</i>	68	2.52
50 th	Lee et al., 1998	Factors influencing the functional outcome of patients with acute epidural hematomas: Analysis of 200 patients undergoing surgery	<i>Journal of Trauma - Injury, Infection and Critical Care</i>	66	3
51 st	Saito et al., 1994	Spinal epidural hematoma with spontaneous recovery demonstrated by magnetic resonance imaging	<i>Spine</i>	66	2.75
52 nd	Sklar E et al., 1999	MRI of acute spinal epidural hematomas	<i>Journal of Computer Assisted Tomography</i>	63	3
53 rd	Avrahami et al., 1989	MR demonstration of spontaneous acute epidural hematoma of the thoracic spine	<i>Neuroradiology</i>	63	2.03
54 th	Amiri et al., 2013	Postoperative spinal epidural hematoma (SEH): Incidence, risk factors, onset, and management	<i>Spine Journal</i>	61	8.71
55 th	Aono et al., 2011	Incidence of postoperative symptomatic epidural hematoma in spinal decompression surgery: Clinical article	<i>Journal of Neurosurgery: Spine</i>	60	6.66
57 th	Schutzman et al., 1993	Epidural hematomas in children	<i>Annals of Emergency Medicine</i>	59	2.18
56 th	Jamjoom, 1996	Acute spontaneous spinal epidural hematoma: The influence of magnetic resonance imaging on diagnosis and treatment	<i>Surgical Neurology</i>	59	2.46
60 th	Seelig et al., 1984	Traumatic acute epidural hematoma: Unrecognized high lethality in comatose patients	<i>Neurosurgery</i>	58	1.61
58 th	Connolly et al., 1996	Management of spinal epidural hematoma after tissue plasminogen activator: A case report	<i>Spine</i>	58	2.42
61 st	Yonekawa et al., 1975	Spontaneous spinal epidural hematoma during pregnancy	<i>Surgical Neurology</i>	58	1.28
59 th	Wagner et al., 1996	Spontaneous resolution of a large spinal epidural hematoma: Case report	<i>Neurosurgery</i>	58	2.42
62 nd	Su et al., 2008	Contralateral acute epidural hematoma after decompressive surgery of acute subdural hematoma: Clinical features and outcome	<i>Journal of Trauma - Injury, Infection and Critical Care</i>	57	4.75

Table I: Cont.

Rank	Authors	Title	Journal	CC	CY
64 th	Bidzinski, 1966	Spontaneous spinal epidural hematoma during pregnancy. Case report.	<i>Journal of Neurosurgery</i>	56	1.03
63 rd	Onishchuk & Carlsson, 1992	Epidural hematoma associated with epidural anesthesia: Complications of anticoagulant therapy	<i>Anesthesiology</i>	56	2
65 th	Helperin & Cohen, 1971	Hematoma following epidural anesthesia: report of a case.	<i>Anesthesiology</i>	55	1.12
66 th	Bergström et al., 1977	Computed tomography of cranial subdural and epidural hematomas: Variation of attenuation related to time and clinical events such as rebleeding	<i>Journal of Computer Assisted Tomography</i>	53	1.23
67 th	Wester, 1999	Decompressive surgery for 'pure' epidural hematomas: Does neurosurgical expertise improve the outcome?	<i>Neurosurgery</i>	52	2.47
68 th	Gingrich, 1968	Spinal epidural hematoma following continuous epidural anesthesia.	<i>Anesthesiology</i>	52	1
69 th	Miyagi et al., 1998	Spinal epidural vascular malformation presenting in association with a spontaneously resolved acute epidural hematoma	<i>Journal of Neurosurgery</i>	50	2.27
70 th	Sawin et al., 1995	Spinal epidural hematoma following coronary thrombolysis with tissue plasminogen activator. Report of two cases	<i>Journal of Neurosurgery</i>	50	2
73 rd	Jos et al., 1983	Posterior fossa epidural hematomas: A review and synthesis	<i>Surgical Neurology</i>	49	1.32
72 nd	Segal et al., 1996	Cervical epidural hematoma after chiropractic manipulation in a healthy young woman: Case report	<i>Neurosurgery</i>	49	2.04
74 th	Hernandez et al., 1982	Recurrent paraplegia with total recovery from spontaneous spinal epidural hematoma	<i>Annals of Neurology</i>	49	1.29
71 st	Liao et al., 2009	Surgical treatment of spontaneous spinal epidural hematoma: A 5-year experience - Clinical article	<i>Journal of Neurosurgery: Spine</i>	49	4.45
75 th	Matsumura et al., 2008	Clinical management for spontaneous spinal epidural hematoma: diagnosis and treatment	<i>Spine Journal</i>	47	3.92
77 th	Muhonen et al., 1995	Cervical epidural hematoma secondary to an extradural vascular malformation in an infant: Case report	<i>Neurosurgery</i>	47	1.88
76 th	Kahraman et al., 2006	The accuracy of near-infrared spectroscopy in detection of subdural and epidural hematomas	<i>Journal of Trauma - Injury, Infection and Critical Care</i>	47	3.36
79 th	Smith et al., 1991	The danger of an ultra-early computed tomographic scan in a patient with an evolving acute epidural hematoma	<i>Neurosurgery</i>	46	1.59
80 th	Weaver et al., 1981	Spontaneous resolution of epidural hematomas. Report of two cases	<i>Journal of Neurosurgery</i>	46	1.18
78 th	Noth et al., 1993	Spinal epidural hematoma in a hemophilic infant	<i>Journal of Pediatric Hematology/Oncology</i>	46	1.7
83 rd	Ammirati & Tomita, 1984	Posterior fossa epidural hematoma during childhood	<i>Neurosurgery</i>	45	1.25
82 nd	Penar et al., 1987	Spontaneous spinal epidural hematoma	<i>International Surgery</i>	45	1.36
81 st	Narawong et al., 1988	Conservative management of spinal epidural hematoma in hemophilia	<i>Pediatric Neurology</i>	45	1.41
86 th	Aoki, 1988	Rapid resolution of acute epidural hematoma. Report of two cases	<i>Journal of Neurosurgery</i>	44	1.37
85 th	Bozbuğa et al., 1999	Posterior fossa epidural hematomas: Observations on a series of 73 cases	<i>Neurosurgical Review</i>	44	2.09
87 th	Russman & Kazi, 1971	Spinal epidural hematoma and the brown-séquard syndrome	<i>Neurology</i>	44	0.9
84 th	Truumees et al., 2012	Epidural hematoma and intraoperative hemorrhage in a spine trauma patient on pradaxa (Dabigatran)	<i>Spine</i>	44	5.5
90 th	Zuccarello et al., 1981	Epidural hematomas of the posterior cranial fossa	<i>Neurosurgery</i>	43	1.1
89 th	Van et al., 1998	Spontaneous spinal epidural hematoma associated with thrombolysis and anticoagulation therapy: Report of three cases	<i>Clinical Neurology and Neurosurgery</i>	43	1.95
88 th	Lefranc et al., 1999	Traumatic epidural hematoma of the cervical spine: Magnetic resonance imaging diagnosis and spontaneous resolution	<i>Neurosurgery</i>	43	2.04
96 th	Boyd & Pear, 1972	Chronic spontaneous spinal epidural hematoma. Report of two cases.	<i>Journal of Neurosurgery</i>	42	0.87
94 th	Milo et al., 1987	Delayed epidural hematoma a review	<i>Acta Neurochirurgica</i>	42	1.27
95 th	Stone et al., 1979	Epidural hematomas of the posterior fossa	<i>Surgical Neurology</i>	42	1.02

Table 1: Cont.

Rank	Authors	Title	Journal	CC	CY
93 rd	Hamilton & Wallace, 1992	Nonoperative management of acute epidural hematoma diagnosed by CT: The neuroradiologist's role	American Journal of Neuroradiology	42	1.5
91 st	Resar et al., 1996	Skull infarction and epidural hematomas in a patient with sickle cell anemia	Journal of Pediatric Hematology/Oncology	42	1.75
92 nd	Hynson et al., 1996	Epidural hematoma associated with enoxaparin	Anesthesia and Analgesia	42	1.75
97 th	Kao et al., 2014	Symptomatic epidural hematoma after lumbar decompression surgery	Geochemistry International	41	6.83
98 th	Xu et al., 2009	Epidural steroid injection resulting in epidural hematoma in a patient despite strict adherence to anticoagulation guidelines: Case report	Journal of Neurosurgery: Spine	41	3.72
99 th	Kirazli et al., 2004	Spinal Epidural Hematoma Associated with Oral Anticoagulation Therapy	American Journal of Physical Medicine and Rehabilitation	41	2.56
100 th	Ghaly, 2001	Recovery after high-dose methylprednisolone and delayed evacuation: A case of spinal epidural hematoma	Journal of Neurosurgical Anesthesiology	41	2.16

CC: Citation count, **CY:** Citation per year.

DISCUSSION

The significance of bibliometric studies is not necessarily evaluating the quality of research or its impact on clinical practice. Instead, they can provide a historical overview of the research conducted in a given field and reflect enormous changes in clinical practice over the years. In the first two decades (1966-1974) and (1975-1984), the literature on EDH focused prominently on spinal EDH. Most of the published papers were case reports describing cases of spontaneous spinal EDH as well as instances of spinal EDH following epidural anesthesia or the use of anticoagulant or antiplatelet medications. Notably, as computed tomography (CT) was introduced to the medical field after 1970, the correlation between the impact time of trauma and the radiological appearance of EDH on CT scans became the main area of interest. However, the management of EDH was not thoroughly studied at the time. Three articles focusing on the management of spontaneous as well as traumatic spinal EDH were published, with diverse opinions on surgical versus conservative management.

In the following decade (1985-1994), studies on the management of EDH started to flourish. Non-operative treatment options were discussed for both traumatic and non-traumatic cases of spinal and cranial EDHs. The introduction of magnetic resonance imaging (MRI) in the 1980s had a significant clinical impact on the management of EDH. The clinical significance of MRI in the diagnosis and follow-up of spinal EDH was a subject of interest during this decade. Later on, MRI served as the most accurate diagnostic tool for spinal EDH, replacing the former practice of using CT scans and myelography. Articles on spinal EDH after the administration of epidural anesthesia continued to be produced during this decade, with all articles sharing the same evidence level as those in the previous two decades.

The peak of publications in our review was found to be between 1995 and 2004. In the 1990s, a significant number of clinical trials were published on the effectiveness of low-molecular-weight heparin (enoxaparin) as both preventive and therapeutic treatment options for various thromboembolic events. Similarly, the utility of tissue plasminogen activator (tPA) in the treatment of ischemic stroke was also a subject of multiple clinical trials in the same era. Both of these contributed to the literature on spinal EDHs, with six articles being produced on the same subject. Other subjects addressed during this decade included the timing for repeating CT scans in patients treated conservatively, the utility of angiographic studies in the diagnosis of spontaneous spinal EDH, and operative options and their outcomes.

Starting from 2004, studies with higher levels of evidence were published, focusing mainly on incidence, risk factors, management, outcomes, and predictors of good recovery. The highest evidence-level in our list were systematic review and meta-analysis while clinical trials were not included.

Spinal EDH

Spinal EDH was extensively discussed in the literature, comprising two-thirds of the articles on our list. Diverse

categories were studied, including the incidence, diagnosis, etiology, management, and outcomes of the disease. However, studies on cranial EDHs were not as popular. Spinal EDH was considered an emerging clinical entity having various etiologies and treatment options, and MRIs were frequently performed. The difficulty in its evaluation prior to the MRI era could explain why spinal EDH received more attention upon the introduction of MRI.

The most-cited article on Spinal EDH, which ranked 1st overall, is "Surgical management of spinal epidural hematoma: Relationship between surgical timing and neurological outcome" by Lawton et al., published in the *Journal of Neurosurgery* in 1995. It gained 412 CC and 16.48 CY. In this article, the surgical management of spinal EDH was discussed in depth, demonstrating how diagnosing and managing this disease with efficient timing maximize neurological recovery (18). The second most cited article on spinal EDH is Groen and Ponsen's "The spontaneous spinal epidural hematoma. A study of etiology," which also ranked 2nd overall. This paper was published in the *Journal of the Neurological Sciences* in 1990 and received 267 CC and 8.9 CY. As vascular anomalies were discussed since the 1960s as a possible cause of spontaneous spinal EDH, Groen and Ponsen concluded that most cases resulted from a ruptured vertebral venous plexus and that a cluster-type artery can be mistakenly considered a vascular anomaly (10).

Cranial EDH

Cranial EDHs were the subject of 25 articles in our list. Early articles focused on the recognition of EDH on CT scan and then shifted towards discussing management options and predictors of poor prognosis. The most-cited article on cranial EDH, which ranked 9th overall, is "Surgical management of acute epidural hematomas" by Bullock et al., published in 2006 in *Neurosurgery* as part of the guidelines for the surgical management of traumatic brain injury. This paper received 183 CC and 13.07 CY and is considered a landmark paper in the management of traumatic brain injury; it provides the indications, timing, and operative options for traumatic EDH that are currently implemented in clinical practice. The surgical indications include an EDH with a volume of 30 cm³ or more, regardless of the patient's GCS, with craniotomy for hematoma evacuation being performed as soon as possible, specifically when a patient has a GCS below 9 and unequal pupils. The authors also concluded that an EDH with a volume less than 30 cm³, thickness less than 15 mm, and a midline shift less than a 5 mm in patients with a GCS more than 8 can be managed conservatively with serial CT scanning and close neurological monitoring (19). A noteworthy article on the cranial entity is "Acute epidural hematoma: an analysis of factors influencing the outcome of patients undergoing surgery in coma" by Lobato et al., published in the *Journal of Neurosurgery* in 1988. The authors studied the impact of surgical timing on the outcomes, concluding that patients who were operated on early (within 6 hours or between 6 and 12 hours) had a higher mortality rate than those who were operated on late (12 to 48 hours after injury). However, patients who were operated on early presented with poor clinical conditions, rendering worse outcomes (7).

Clinical Category

Clinical studies were the most common in our review, and they were initially focused on sporadic cases of spontaneous spinal EDH. Subsequently, posterior fossa and spinal EDHs were studied in a larger number of patients, with a focus on management outcomes and prognostications. The second top-cited paper in the clinical category (ranked 14th overall, spinal EDH article) is "The syndrome of spontaneous spinal epidural hematoma. Report of three cases" by Markham et al., published in the *Journal of Neurosurgery* in 1976. It received 120 CC and 2.26 CY. The authors described three cases of spontaneous spinal EDH and reviewed an additional 46 cases from the literature. They concluded that spontaneous spinal EDH is a distinct clinical entity that needs to be considered in patients presenting with symptoms of spinal cord compression (24). The third top-cited article in the clinical category (ranked 17th overall, spinal EDH article), with 111 CC and 4.11 CY, is Gundry and Heithoff's "Epidural hematoma of the lumbar spine: 18 Surgically confirmed cases," published in *Radiology* in 1993. In this paper, 18 cases of surgically treated lumbar spine EDH were reported. Concomitant disk abnormalities were observed in 78% of the patients. It was postulated that a displaced disk may lead to the tearing of adjacent veins, resulting in EDH formation (12).

Etiology Category

Etiology was the second most studied category. Earlier studies were focused on epidural anesthesia and coagulopathies as causes of spinal EDHs and then shifted to emphasizing thrombolysis and anticoagulants as risk factors for spinal EDHs. After 2000, the risk factors of traumatic spinal EDH and, more recently, the risk of EDH following lumbar spine surgery were studied. The second most cited article in this category (ranked 7th overall, spinal EDH article), with 207 CC and 6.9 CY, is "Spontaneous spinal epidural hematoma with associated platelet dysfunction from excessive garlic ingestion: A case report" by Rose et al., published in *Neurosurgery* in 1990. In this paper, the authors interestingly proposed that excessive garlic ingestion can result in platelet dysfunction and, therefore, contribute to the pathogenesis of spontaneous spinal EDH (30).

Management Category

Articles centered on the management of EDH were popular after the 1990s. Earlier studies on spinal EDHs were focused on conservative options, while later studies discussed the role of decompressive surgery and the optimal timing for decompression. For cranial EDHs, earlier articles discussed both operative and non-operative options. In 2006, Bullock et al. (5) defined the surgical indications for EDH. A noteworthy article on the management of EDH is Groen's "Non-operative treatment of spontaneous spinal epidural hematomas: A review of the literature and a comparison with operative cases" (ranked 12th overall) published in *Acta Neurochirurgica* in 2004. It received 145 CC and 9.06 CY. This article compared cases of conservatively treated spontaneous spinal EDH with those surgically treated. The authors concluded that surgical decompression and hematoma evacuation should

be the mainstays of treatment, and the decision to pursue conservative treatment has to be weighed based on the severity of the neurological deficits (11).

Diagnosis category

In the diagnosis category, most of the papers were published in the 1990s, with the initial studies focusing on cranial EDH, specifically on CT scans, and then shifting to MRI findings of both cranial and spinal EDH. The most-cited paper in this category (4th highest overall under the category of spinal EDH) is “Spontaneous spinal epidural hematoma: Findings at MR imaging and clinical correlation,” published by Holtås et al. in *Radiology* in 1996. It received 228 CC and 9.5 CY. The authors reviewed the radiological images of 13 patients, demonstrating the hematoma location in the anterior epidural space in 8 patients, the posterior epidural space in 4 patients, and both anterior and posterior epidural spaces in one patient. Additionally, the earliest descriptions of signal changes were described by Holtås et al. based on signal changes on T1-weighted MRI, which went from isointense in the early period to hyperintense in the intermediate period (14).

Prognosis category

The trend of publication in the prognosis category started with case reports describing predictors of good recovery in spontaneous spinal EDH. Subsequently, retrospective studies were produced addressing the functional outcomes of spinal EDH, the impact of time on surgical outcomes of spontaneous spinal EDH, and the prognostic impact of anisocoria on the clinical outcome of cranial EDH. One of the most-cited articles in this category is Foo and Rossier’s “Preoperative neurological status in predicting the surgical outcome of spinal epidural hematomas,” which received 220 CC and 5.64 CY (ranked 5th overall, spinal EDH article). It was published in *Surgical Neurology* in 1981. In this paper, the authors discussed the predictors and outcomes of patients with spontaneous spinal EDH treated surgically. Return to normal function was noted in 95.3% of the patients presenting with incomplete sensorimotor lesions, 87% of those with incomplete sensory but complete motor lesions, and 45.3% of those with complete sensorimotor lesions. Foo and Rossier concluded that post-operative recovery is mainly dependent on the preoperative neurological status. Nonetheless, the absence of sensory or motor function pre-operatively does not necessarily lead to poor prognosis (8).

Epidemiology category

Epidemiological studies contributed to five articles on our list, all published between 2006 and 2013. All five focused mainly on addressing the incidence and risk factors of postoperative spinal EDH and the risk of spinal EDH following epidural anesthesia. The most-cited paper in this category, which ranked 6th on our list, is “Incidence of epidural hematoma, infection, and neurologic injury in obstetric patients with epidural analgesia/anesthesia” by Ruppen et al. It was published in *Anesthesiology* in 2006, and received 213 CC and 15.21 CY. It also consists of the highest evidence level in the list. This meta-analysis estimated the risk of spinal EDH following epidural anesthesia in obstetrics practice to be 1–11 per million (31).

Pathophysiology category

One article was published in the pathophysiology category, and it was ranked 8th overall among the spinal EDH articles. Beatty and Winston’s “Spontaneous cervical epidural hematoma. A consideration of etiology,” published in the *Journal of Neurosurgery* in 1984, has 205 CC and 5.75 CY. In this paper, the authors proposed that the source of bleeding in cases of cervical EDH is mainly arterial and that this observation can be extrapolated to spontaneous EDH at other spinal levels (4). Publications prior to this article speculated on the venous origin of EDH; this article marked the shift to pathophysiological thinking of EDH, due to which it received a high number of citations.

Limitations

Bibliometric studies have their limitations and usability in the literature. The following are the inherited limitations to bibliometrics: There is an overrepresentation of old studies compared to recent ones, which can be minimized by using the citation count per year, but this still does not lead to the identification of recent highly impactful publications. Self-citation among authors acts as an over-quantification bias, but this was minimal in our bibliometric review on EDH. The understanding that highly cited works are highly impactful is not completely accurate; many impactful or field-changing studies often do not get included in bibliometric studies. EDH-specific limitations exist in our search; “extradural hematoma” was not used as a search keyword in our study, due to which some highly cited articles were omitted even though they were relevant. The Scopus database covers the full citation profiling of articles between 1970 and 2020, and the articles’ citations before 1970 might have been underrepresented.

■ CONCLUSION

The literature on EDH started with case reports describing various etiologies and risk factors, specifically for spinal EDH. Subsequently, diagnostic studies were popular, and they mainly addressed the utility of MRI in the diagnosis of spinal EDH. Later, more papers were produced on the surgical indications, management options, timing of surgery, and outcomes of EDHs. This paper can serve as a valuable tool to guide clinicians and scientists in evidence-based practice as it reflects the publication trends and research interests related to EDH.

■ AUTHORSHIP CONTRIBUTION

Study conception and design: SBA, OTA

Data collection: OTA, MAA

Analysis and interpretation of results: OTA, SBA, MAA

Draft manuscript preparation: SBA, OTA, AA

Critical revision of the article: SBA, OTA, TE, AYA, MB

Other (study supervision, fundings, materials, etc...): AYA, MB

All authors (SBA, OTA, MAA, TE, AA, AYA, MB) reviewed the results and approved the final version of the manuscript.

■ REFERENCES

- Alfaifi A, AlMutairi OT, Allhaidan M, Alsaleh S, Ajlan A: The top 50 most-cited articles on acoustic neuroma. *World Neurosurgery* 111:e454-e464, 2018
- Almutairi O, Albakr A, Al-Habib A, Ajlan A: The top-100 most-cited articles on meningioma. *World Neurosurgery* 107:1025-1032, 2017
- Alotaibi NM, Nassiri F, Badhiwala JH, Witiw CD, Ibrahim GM, Macdonald RL, Lozano AM: The most cited works in aneurysmal subarachnoid hemorrhage: A bibliometric analysis of the 100 most cited articles. *World Neurosurgery* 89:587-592, 2016
- Beatty RM, Winston KR: Spontaneous cervical epidural hematoma: A consideration of etiology. *J Neurosurg* 61(1):143-148, 1984
- Bullock MR, Chesnut R, Ghajar J, Gordon D, Hartl R, Newell DW, ... Wilberger JE: Surgical management of acute epidural hematomas. *Neurosurgery* 58, S7-15, 2006 Discussion Siiv.
- Cordobés F, Lobato RD, Rivas JJ, Muñoz MJ, Chillón D, Portillo JM, Lamas E: Observations on 82 patients with extradural hematoma: Comparison of results before and after the advent of computerized tomography. *J Neurosurg* 54(2):179-186, 1981
- Fernández-Abinader JA, González-Colón K, Feliciano CE, Mosquera-Soler AM: Traumatic brain injury profile of an elderly population in Puerto Rico. *P R Health Sci J* 36(4):237-239, 2017
- Foo D, Rossier AB: Preoperative neurological status in predicting surgical outcome of spinal epidural hematomas. *Surg Neurol* 15(5):389-401, 1981
- Freytag E: Autopsy findings in head injuries from firearms. Statistical evaluation of 254 cases. *Arch Pathol* 76:215-225, 1963
- Groen RJ, Ponssen H: The spontaneous spinal epidural hematoma: A study of the etiology. *J Neurol Sci* 98(2-3):121-138, 1990
- Groen RJM: Non-operative treatment of spontaneous spinal epidural hematomas: a review of the literature and a comparison with operative cases. *Acta Neurochir* 146(2):103-110, 2004
- Gundry CR, Heithoff KB: Epidural hematoma of the lumbar spine: 18 surgically confirmed cases. *Radiology* 187(2):427-431, 1993
- Heiskanen O: Epidural hematoma. *Surgical Neurology* 4(1):23-26, 1975
- Holtås S, Heiling M, Lönntoft M: Spontaneous spinal epidural hematoma: Findings at MR imaging and clinical correlation. *Radiology* 199(2):409-413, 1996
- Ibrahim GM, Carter Snead III O, Rutka JT, Lozano AM: The most cited works in epilepsy: Trends in the "Citation Classics". *Epilepsia* 53(5):765-770, 2012
- Jeong YH, Oh JW, Cho S, Korean Trauma Data Bank System Committee: Clinical outcome of acute epidural hematoma in Korea: Preliminary report of 285 cases registered in the Korean trauma data bank system. *Korean J Neurotrauma* 12(2):47-54, 2016
- Kim HJ, Yoon DY, Kim ES, Lee K, Bae JS, Lee JH: The 100 most-cited articles in neuroimaging: A bibliometric analysis. *Neuroimage* 139:149-156, 2016
- Lapadula G, Federico C, Paolini S, Missori P, Domenicucci, M: Epidural hematoma with detachment of the dural sinuses. *J Neurosci Rural Pract* 5(2):191-194, 2014
- Lawton MT, Porter RW, Heiserman JE, Jacobowitz R, Sonntag VK, Dickman CA: Surgical management of spinal epidural hematoma: Relationship between surgical timing and neurological outcome. *J Neurosurg* 83(1):1-7, 1995
- Lefavre KA, Shadgan B, O'Brien PJ: 100 most cited articles in orthopaedic surgery. *Clin Orthop Relat Res* 469(5):1487-1497, 2011
- Li L, Ma X, Pandey S, Deng X, Chen S, Cui D, Gao L: The most-cited works in severe traumatic brain injury: A bibliometric analysis of the 100 most-cited articles. *World Neurosurg* 113:e82-e87, 2018
- Lobato RD, Rivas JJ, Cordobes F, Alted E, Perez C, Sarabia R, Cabrera A, Cabrera, Diez I, Gomez P, Diez I, Gomez P, Lamas E: Acute epidural hematoma: An analysis of factors influencing the outcome of patients undergoing surgery in coma. *J Neurosurg* 68(1):48-57, 1981
- Mariam N, Cavanna AE: The most cited works in Tourette syndrome. *J Child Neurol* 27(10):1250-1259, 2012
- Markham JW, Lynge HN, Stahlman GE: The syndrome of spontaneous spinal epidural hematoma: Report of three cases. *J Neurosurg* 26(3):334-342, 1967
- Mazhari S: The 100 top-cited articles published in psychiatric journals. *J Psychiatr Pract* 19(4):327-338, 2013
- Moed HF: New developments in the use of citation analysis in research evaluation. *Arch Immunol Ther Exp* 57(1):13-18, 2009
- Murray MR, Wang T, Schroeder GD, Hsu WK: The 100 most cited spine articles. *Eur Spine J* 21(10):2059-2069, 2012
- Nason GJ, Tareen F, Mortell A: The top 100 cited articles in urology: An update. *Can Urol Assoc J* 7(1-2):E16, 2013
- Ponce FA, Lozano AM: The most cited works in Parkinson's disease. *Mov Disord* 26(3):380-390, 2011
- Rose KD, Croissant PD, Parliament CF, Levin MB: Spontaneous spinal epidural hematoma with associated platelet dysfunction from excessive garlic ingestion: A case report. *Neurosurgery* 26(5):880-882, 1990
- Ruppen W, Derry S, McQuay H, Moore RA: Incidence of epidural hematoma, infection, and neurologic injury in obstetric patients with epidural analgesia/anesthesia. *Anesthesiology* 105(2):394-399, 2006
- Soon WC, Marcus H, Wilson M: Traumatic acute extradural haematoma—Indications for surgery revisited. *Br J Neurosurg* 30(2):233-234, 2016