Top-cited articles in cerebrospinal fluid leak (rhinorrhea and otorrhea) (1945–2018)

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Abstract

Introduction: As scientific knowledge has grown in biomedicine, it has also become necessary to develop tools to manage and understand the body of evidence. In that sense, bibliometrics has become a consolidated discipline for analyzing scientific activity, enabling the characterization of a particular field or area of knowledge by means of the quantification of the bibliographic characteristics of scientific publications.

Objective: The objective of this study was to determine the most frequently cited articles in the field of cerebrospinal fluid rhinorrhea and otorrhea.

Methods: The searches took place on the Clarivate Analytics Web of Science platform, which includes the MEDLINE database. The study period was limited to 1945–2018.

Results: The 101 most cited articles in the field of cerebrospinal fluid leak were published in 36 journals, and the most important specialties contributing to the literature were neurosurgery and otorhinolaryngology. Of the 101 top-cited articles, 70% were published from 1990 to 2018, with two distinct periods of high scientific productivity: 1990–1999 and 2000–2009. In the first period, the main topic of research interest was endoscopic sinus surgery for cerebrospinal fluid fistulas, whereas from 2000 to 2009, documents focused more on surgical aspects of extended skull base approaches. The articles received 73–767 citations. The top article over the whole study period was “A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap” by Hadad et al., which was published 2006 in Laryngoscope. Its publication represented an inflection point in the literature on cerebrospinal fluid leak and endoscopic skull base surgery, and it gave rise to numerous other research publications.

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Introduction

Cerebrospinal fluid (CSF) leak describes the discharge of CSF from the intracranial cavity through an osseous defect within the skull base. The underlying dura mater and adherent pia-arachnoid mater are disrupted, resulting in a communication between the intracranial cavity, the subarachnoid space and either the nasal or middle ear cavity. The condition was first described as a pathologic entity in 1899 by Clair Thompson. While CSF leaks may occur spontaneously, common etiologies of CSF rhinorrhea include trauma, neoplasms, and prior surgery. CSF otorrhea is usually associated with craniocerebral trauma (e.g. skull fracture involving the temporal bone), neurosurgical procedures, or other conditions. Patients with CSF leak can present with a variety of symptoms such as clear nasal discharge and headache or complications such as pneumocephalus, meningitis or brain abscess.

As scientific knowledge has grown in biomedicine, it has also become necessary to develop tools to manage and understand the body of evidence. In that sense, bibliometrics has become a consolidated discipline for analyzing scientific activity, enabling the characterization of a particular field or area of knowledge by means of the quantification of the bibliographic characteristics of scientific publications. Nowadays, identifying citation classics and top-cited papers is one of the key methodologies used to systematically evaluate research performance. This information can help optimize the allocation of resources, reorient research support, rationalize research organizations, restrict research in particular fields, and augment research productivity. Across different fields, the scope of scientific literature has broadened to achieve a more multidisciplinary vision. This expanded focus justifies the review of the most important papers to help guide future research and practice. In that sense, several medical specialties have ranked articles within their fields by citation frequency.

In otorhinolaryngology, several factors have contributed to a growth in research output: the academic development of the field and training programs; significant advances in information and communication technology, which allow studies and experiments to be rapidly performed, written, reviewed, published, and cited; the increase in cooperative practices and multidisciplinary research approaches; the growing need to publish in order to secure academic promotions and research funding; and the existence of a larger critical mass and evidence base, driving further research advances in the field. Research on the etiology, diagnosis and treatment for CSF leak has also increased over the last few decades, but while several studies have analyzed the top cited documents in otorhinolaryngology, none have specifically focused on CSF leak.

The present study identifies and analyzes the characteristics of the 100 most cited articles on CSF rhinorrhea and otorrhea. This information could help researchers and professionals understand the research areas that are generating the most impact on the field, the countries that are making the largest contribution, and the main journals used to disseminate advances.

Methods

We opted to identify documents about CSF leak by means of the Medical Subject Headings (MeSH) thesaurus, a detailed instrument for controlled terminology. The MEDLINE database included the terms "Cerebrospinal fluid rhinorrhea" and "Cerebrospinal fluid otorrhea" in 1966 to define respective CSF discharges through the nose or through the external auditory meatus/otorrhea. However, it was not until 2005 that the database included a composite descriptor for "Cerebrospinal fluid leak" to define any discharge of CSF through a hole in the skull bone.

The study period was limited to 1945–2018. The searches took place on the Clarivate Analytics Web of Science (WoS) platform, which includes MEDLINE database, on January 21, 2019. The WoS Core Collection provides information on the number of times a particular article has been cited by other articles. This strategy yielded a total of 4155 documents from the MEDLINE database. After excluding 25 editorials and 1021 documents that were not indexed in the WoS Core Collection, we had a total of 3109 articles, from which we aimed to identify the 100 most cited papers. In fact, we included 101 articles because the papers ranked 100 and 101 received the same numbers of citations. Data collected for each article included the full reference (author’s names, journal title and publication year), impact factor (in the Journal Citation Report [JCR] 2017), WoS category of the journal, countries of authors, and type of document (article, review, case report, meta-analysis, trial). Citation density was determined by dividing the number of citations received by the position of the journal in the JCR category.

Results

Table 1 lists the full references and citation data for the 101 top-cited articles in the literature on CSF leak. Laryngoscope was the most prolific journal, publishing 20 articles,
Table 1  Distribution of the top 101 cited-papers on Cerebrospinal Fluid Leak group with country, citations and citation density.

| Rank | Publication                                                                 | Country of origin, 1st author | Countries of origin, rest of authors | Citations (n) | Citation density |
|------|-----------------------------------------------------------------------------|--------------------------------|--------------------------------------|---------------|-----------------|
| 1    | Hadad G, Bassagasteguy L, Carrau RL, Mataza JC, Kassam A, Snyderman CH, Mintz A. A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. Laryngoscope. 2006;116(10):1882-6. | USA                            | Argentina                          | 767           | 69.7            |
| 2    | Hegazy HM, Carrau RL, Snyderman CH, Kassam A, Zweig J. Transnasal endoscopic repair of cerebrospinal fluid rhinorrhea: a meta-analysis. Laryngoscope. 2000;110(7):1166-72. | USA                            | USA                                 | 272           | 16.0            |
| 3    | Kassam AB, Prevedello DM, Carrau RL, Snyderman CH, Thomas A, Gardner P, Zanation A, Duz B, Stefko ST, Byers K, Horowitz MB. Endoscopic endonasal skull base surgery: analysis of complications in the authors’ initial 800 patients. J Neurosurg. 2011;114(6):1544-68. | USA                            | USA                                 | 268           | 44.7            |
| 4    | Ommaya AK, Di Chiro G, Baldwin M, Pennybacker JB. Non-traumatic cerebrospinal fluid rhinorrhea. J Neurol Neurosurg Psychiatry. 1968;31(3):214-25. | USA                            | Turkey                              | 252           | 5.1             |
| 5    | Black PM, Zervas NT, Candia GL. Incidence and management of complications of trans-phenoidal operation for pituitary adenomas. Neurosurgery. 1987;20(6):920-4. | USA                            | USA                                 | 248           | 8.3             |
| 6    | Gormley WB, Sekhar LN, Wright DC, Kamerer D, Schessel D. Acoustic neuromas: results of current surgical management. Neurosurgery. 1997;41(1):50-8; discussion 58-60. | USA                            | USA                                 | 222           | 11.1            |
| 7    | Mattos DE, Kennedy DW. Endoscopic management of cerebrospinal fluid leaks and cephaloceles. Laryngoscope. 1990;100(8):857-62. | USA                            | USA                                 | 201           | 7.4             |
| 8    | May M, Levine HL, Mester SJ, Schaitkin B. Complications of endoscopic sinus surgery: analysis of 2108 patients incidence and prevention. Laryngoscope. 1994;104(9):1080-3. | USA                            | USA                                 | 200           | 8.7             |
| 9    | Lanza DC, O’Brien DA, Kennedy DW. Endoscopic repair of cerebrospinal fluid fistulae and encephaloceles. Laryngoscope. 1996;106(9 Pt 1):1119-25. | USA                            | USA                                 | 200           | 9.5             |
| 10   | Frank G, Pasquini E, Doglietto F, Mazzatenta D, Scarretta V, Farneti G, Calbucci F. The endoscopic extended trans-phenoidal approach for craniofaryngiomas. Neurosurgery. 2006 Jul;59(1 Suppl 1):ONS75-83; discussion ONS75-83. | Italy                          | Italy                              | 175           | 15.9            |
| 11   | Brodie HA, Thompson TC. Management of complications from 820 temporal bone fractures. Am J Otol. 1997;18(2):188-97. | USA                            | USA                                 | 166           | 8.3             |
| 12   | Esposito F, Dusick JR, Fatemi N, Kelly DF. Graded repair of cranial base defects and cerebrospinal fluid leaks in transsphenoidal surgery. Neurosurgery. 2007;60(4 Suppl 2):295-303; discussion 303-4. | USA                            | Italy                              | 150           | 15.0            |
| 13   | Hosobuchi Y. Direct surgical treatment of giant intracranial aneurysms. J Neurosurg. 1979;51(6):743-56. | USA                            | USA                                 | 149           | 3.9             |
| Rank | Publication                                                                                                                                                                                                 | Country of origin, 1st author | Countries of origin, rest of authors | Citations (n) | Citation density |
|------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------|--------------------------------------|----------------|-----------------|
| 14   | Hubbard JL, McDonald TJ, Pearson BW, Laws ER Jr. Spontaneous cerebrospinal fluid rhinorrhea: evolving concepts in diagnosis and surgical management based on the Mayo Clinic experience from 1970 through 1981. Neurosurgery. 1985;16(3):314-21. | USA                           | USA                                  | 144            | 4.5             |
| 15   | Boulware DR, Meya DB, Muzoora C, Rolfe MA, Huppler Hullsiek K, Musubire A, Taseera K, Nabeta HW, Schutz C, Williams DA, Rajasingham R, Rhein J, Thienemann F, Lo MW, Nielsen K, Bergemann TL, Kambugu A, Manabe YC, Janoff EN, Bohjanen PR, Meintjes G; COAT Trial Team. Timing of antiretroviral therapy after diagnosis of cryptococcal meningitis. N Engl J Med. 2014 26;370(26):2487-98. | USA                           | Uganda                                | 140            | 46.7            |
| 16   | Lanman TH, Brackmann DE, Hittelberger WE, Subin B. Report of 190 consecutive cases of large acoustic tumors (vestibular schwannoma) removed via the translabyrinthine approach. J Neurosurg. 1999;90(4):617-23. | USA                           | USA                                  | 139            | 7.7             |
| 17   | Park JI, Strelzow VV, Friedman WH. Current management of cerebrospinal fluid rhinorrhea. Laryngoscope. 1983;93(10):1294-300.                                                                                                                                                  | USA                           | USA                                  | 128            | 3.8             |
| 18   | Phelps PD, Reardon W, Pembery M, Bellman S, Luxom L. X-linked deafness, stapes gushers and a distinctive defect of the inner ear. Neuroradiology. 1991;33(4):326-30.                                                                 | UK                            | UK                                   | 125            | 4.8             |
| 19   | LEWIN W. Cerebrospinal fluid rhinorrhoea in closed head injuries. Br J Surg. 1954;42(171):1-18.                                                                                                                                                                           | UK                            | -                                    | 124            | 2.0             |
| 20   | Harvey RJ, Parmar P, Sacks R, Zanation AM. Endoscopic skull base reconstruction of large dural defects: a systematic review of published evidence. Laryngoscope. 2012;122(2):452-9.                                             | Australia                     | USA                                  | 122            | 24.4            |
| 21   | Freedman HM, Kern EB. Complications of intranasal ethmoidectomy: a review of 1000 consecutive operations. Laryngoscope. 1979;89(3):421-34.                                                                                                                                   | USA                           | USA                                  | 122            | 3.2             |
| 22   | Casiano RR, Jassir D. Endoscopic cerebrospinal fluid rhinorrhoea repair: is a lumbar drain necessary? Otolaryngol Head Neck Surg. 1999;121(6):745-50.                                                                                                                            | USA                           | USA                                  | 118            | 6.6             |
| 23   | Zweig JL, Carral RL, Celin SE, Schaitkin BM, Pollice PA, Snyderman CH, Kassam A, Hegazy H. Endoscopic repair of cerebrospinal fluid leaks to the sinonasal tract: predictors of success. Otolaryngol Head Neck Surg. 2000;123(3):195-201.                                         | USA                           | USA                                  | 116            | 6.8             |
| 24   | Shapiro SA, Scully T. Closed continuous drainage of cerebrospinal fluid via a lumbar subarachnoid catheter for treatment or prevention of cranial/spinal cerebrospinal fluid fistula. Neurosurgery. 1992;30(2):241-5.                                           | USA                           | USA                                  | 114            | 4.6             |
| Rank | Publication | Country of origin, 1st author | Countries of origin, rest of authors | Citations (n) | Citation density |
|------|-------------|------------------------------|-------------------------------------|---------------|-----------------|
| 25   | Stone JA, Castillo M, Neelon B, Mukherji SK. Evaluation of CSF leaks: high-resolution CT compared with contrast-enhanced CT and radionuclide cisternography. AJNR Am J Neuroradiol. 1999;20(4):706-12. | USA | USA | 114 | 6.3 |
| 26   | Cannon CR, Jahrsdoerfer RA. Temporal bone fractures. Review of 90 cases. Arch Otolaryngol. 1983;109(5):285-8. | USA | USA | 114 | 3.4 |
| 27   | Cappabianca P, Cavallo LM, Esposito F, Valente V, De Divitiis E. Sellar repair in endoscopic endonasal transsphenoidal surgery: results of 170 cases. Neurosurgery. 2002;51(6):1365-71; discussion 1371-2. | Italy | Italy | 112 | 7.5 |
| 28   | Banks CA, Palmer JN, Chiu AG, O’Malley BW Jr, Woodworth BA, Kennedy DW. Endoscopic closure of CSF rhinorrhea: 193 cases over 21 years. Otolaryngol Head Neck Surg. 2009;140(6):826-33. | USA | USA | 110 | 13.8 |
| 29   | Kassam A, Thomas AJ, Snyderman C, Carrau R, Gardner P, Mintz A, Kanaan H, Horowitz M, Pollack IF. Fully endoscopic expanded endonasal approach treating skull base lesions in pediatric patients. J Neurosurg. 2007;106(2 Suppl):75-86. | USA | USA | 108 | 10.8 |
| 30   | Narotam PK, van Dellen JR, Bhoola KD. A clinicopathological study of collagen sponge as a dural graft in neurosurgery. J Neurosurg. 1995;82(3):406-12. | South Africa | South Africa | 108 | 4.9 |
| 31   | Shetty PG, Shroff MM, Fatterpekar GM, Sahani DV, Kirtane MV. A retrospective analysis of spontaneous sphenoid sinus fistula: MR and CT findings. AJNR Am J Neuroradiol. 2000;21(2):337-42. | India | India | 108 | 6.4 |
| 32   | Shetty PG, Shroff MM, Sahani DV, Kirtane MV. Evaluation of high-resolution CT and MR cisternography in the diagnosis of cerebrospinal fluid fistula. AJNR Am J Neuroradiol. 1998;19(4):633-9. | India | India | 107 | 5.6 |
| 33   | Jho HD, Ha HG. Endoscopic endonasal skull base surgery: Part 1-The midline anterior fossa skull base. Minim Invasive Neurosurg. 2004;47(1):1-8. | USA | USA | 107 | 8.2 |
| 34   | Stankiewicz JA. Cerebrospinal fluid fistula and endoscopic sinus surgery. Laryngoscope. 1991;101(3):250-6. | USA | - | 105 | 4.0 |
| 35   | Cohen NL, Lewis WS, Ransohoff J. Hearing preservation in cerebellopontine angle tumor surgery: the NYU experience 1974-1991. Am J Otol. 1993;14(5):423-33. | USA | USA | 105 | 4.4 |
| 36   | Yonekawa Y, Ogata N, Imhof HG, Olivecrona M, Strommer K, Kwak TE, Roth P, Groscurth P. Selective extradural anterior clinoidectomy for supra- and parasellar processes. Technical note. J Neurosurg. 1997;87(4):636-42. | Switzerland | Switzerland | 102 | 5.1 |
| 37   | Laws ER Jr, Fode NC, Redmond MJ. Transsphenoidal surgery following unsuccessful prior therapy. An assessment of benefits and risks in 158 patients. J Neurosurg. 1985;63(6):823-9. | USA | USA | 101 | 3.2 |
| 38   | Schlosser RJ, Woodworth BA, Wilensky EM, Grady MS, Bolger WE. Spontaneous cerebrospinal fluid leaks: a variant of benign intracranial hypertension. Ann Otol Rhinol Laryngol. 2006;115(7):495-500. | USA | USA | 101 | 9.2 |
| Rank | Publication                                                                                     | Country of origin, 1st author | Countries of origin, rest of authors | Citations (n) | Citation density |
|------|------------------------------------------------------------------------------------------------|-------------------------------|--------------------------------------|---------------|-----------------|
| 39   | Hoffman RA. Cerebrospinal fluid leak following acoustic neuroma removal. Laryngoscope. 1994;104(1 Pt 1):40-58. | USA                           | -                                    | 101           | 4.4             |
| 40   | Darrouzet V, Martel J, Enée V, Bébéar JP, Guérin J. Vestibular schwannoma surgery outcomes: our multidisciplinary experience in 400 cases over 17 years. Laryngoscope. 2004;114(4):681-8. | France                        | France                                | 100           | 7.7             |
| 41   | Schlosser RJ, Bolger WE. Nasal cerebrospinal fluid leaks: critical review and surgical considerations. Laryngoscope. 2004;114(2):255-65. | USA                           | USA                                  | 99            | 7.6             |
| 42   | Berker M, Hazer DB, Yücel T, Gürlek A, Cila A, Aldur M, Onerci M. Complications of endoscopic surgery of the pituitary adenomas: analysis of 570 patients and review of the literature. Pituitary. 2012;15(3):288-300. | Turkey                        | Turkey                                | 97            | 19.4            |
| 43   | Schlosser RJ, Wilensky EM, Grady MS, Bolger WE. Elevated intracranial pressures in spontaneous cerebrospinal fluid leaks. Am J Rhinol. 2003;17(4):191-5. | USA                           | USA                                  | 97            | 6.9             |
| 44   | Mortara R, Norrell H. Consequences of a deficient sellar diaphragm. J Neurosurg. 1970;32(5):565-73. | USA                           | USA                                  | 97            | 2.1             |
| 45   | Jane JA Jr, Thapar K, Kaptain GJ, Maartens N, Laws ER Jr. Pituitary surgery: transsphenoidal approach. Neurosurgery. 2002;51(2):435-42; discussion 442-4. | USA                           | Canada                                | 96            | 6.4             |
| 46   | MacGee EE, Cauthen JC, Brackett CE. Meningitis following acute traumatic cerebrospinal fluid fistula. J Neurosurg. 1970;33(3):312-6. | USA                           | USA                                  | 96            | 2.0             |
| 47   | Yasargil MG, Fox JL. The microsurgical approach to acoustic neurinomas. Surg Neurol. 1974;2(6):393-8. | Switzerland                   | Switzerland                          | 96            | 2.2             |
| 48   | Di Chiro G, Ommaya AK, Ashburn WL, Briner WH. Isotope cisternography in the diagnosis and follow-up of cerebrospinal fluid rhinorrhea. J Neurosurg. 1968;28(6):522-9. | USA                           | USA                                  | 95            | 1.9             |
| 49   | D’Haens J, Van Rompaey K, Stadnik T, Haentjens P, Poppe K, Velkeniers B. Fully endoscopic transsphenoidal surgery for functioning pituitary adenomas: a retrospective comparison with traditional transsphenoidal microsurgery in the same institution. Surg Neurol. 2009;72(4):336-40. | Belgium                       | Belgium                               | 95            | 11.9            |
| 50   | Woodworth BA, Prince A, Chiu AG, Cohen NA, Schlosser RJ, Bolger WE, Kennedy DW, Palmer JN. Spontaneous CSF leaks: a paradigm for definitive repair and management of intracranial hypertension. Otolaryngol Head Neck Surg. 2008;138(6):715-20. | USA                           | USA                                  | 92            | 10.2            |
| 51   | Morales F, Mostacero E, Marta J, Sanchez S. Vascular malformation of the cerebellopontine angle associated with SUNCTsyndrome. Cephalalgia. 1994;14(4):301-2. | Spain                         | Spain                                 | 92            | 4.0             |
| Rank | Publication                                                                 | Country of origin, 1st author | Countries of origin, rest of authors | Citations (n) | Citation density |
|------|-----------------------------------------------------------------------------|------------------------------|--------------------------------------|---------------|-----------------|
| 52   | Gacek RR, Gacek MR, Tart R. Adult spontaneous cerebrospinal fluid otorrhea: diagnosis and management. Am J Otol. 1999;20(6):770-6. | USA                          | USA                                  | 91            | 5.1             |
| 53   | Shah RN, Surowitz JB, Patel MR, Huang BY, Snyderman CH, Carrau RL, Kassam AB, Germanwala AV, Zanation AM. Endoscopic pedicled nasoseptal flap reconstruction for pediatric skull base defects. Laryngoscope. 2009;119(6):1067-75. | USA                          | USA                                  | 91            | 11.4            |
| 54   | Maira G, Anile C, Albanese A, Cabezas D, Pardi F, Vignati A. The role of transsphenoidal surgery in the treatment of craniopharyngiomas. J Neurosurg. 2004;100(3):445-51. | Italy                        | Italy                                | 90            | 6.9             |
| 55   | Keerl R, Weber RK, Draf W, Wienke A, Schaefer SD. Use of sodium fluorescein solution for detection of cerebrospinal fluid fistulas: an analysis of 420 administrations and reported complications in Europe and the United States. Laryngoscope. 2004;114(2):266-72. | Germany                      | USA                                  | 90            | 6.9             |
| 56   | Stankiewicz JA. Complications of endoscopic sinus surgery. Otolaryngol Clin North Am. 1989;22(4):749-58. | USA                          | –                                    | 90            | 3.2             |
| 57   | Dodson EE, Gross CW, Swerdloff JL, Gustafson LM. Transnasal endoscopic repair of cerebrospinal fluid rhinorrhea and skull base defects: a review of twenty-nine cases. Otolaryngol Head Neck Surg. 1994;111(5):600-5. | USA                          | USA                                  | 90            | 3.9             |
| 58   | Romeo MJ, Espina V, Lowenthal M, Espina BH, Petricoin EF 3rd, Liotta LA. CSF proteome: a protein repository for potential biomarker identification. Expert Rev Proteomics. 2005;2(1):57-70. | USA                          | USA                                  | 89            | 7.4             |
| 59   | Glasscock ME 3rd. The stapes gusher. Arch Otolaryngol. 1973;98(2):82-91. | USA                          | –                                    | 89            | 2.0             |
| 60   | Carrau RL, Snyderman CH, Kassam AB. The management of cerebrospinal fluid leaks in patients at risk for high-pressure hydrocephalus. Laryngoscope. 2005;115(2):205-12. | USA                          | USA                                  | 88            | 7.3             |
| 61   | Brodie HA. Prophylactic antibiotics for posttraumatic cerebrospinal fluid fistulae. A meta-analysis. Arch Otolaryngol Head Neck Surg. 1997;123(7):749-52. | USA                          | –                                    | 88            | 4.4             |
| 62   | Lindstrom DR, Toohill RJ, Loehr TA, Smith TL. Management of cerebrospinal fluid rhinorrhea: the Medical College of Wisconsin experience. Laryngoscope. 2004;114(6):969-74. | USA                          | USA                                  | 87            | 6.7             |
| 63   | Cohen NL, Hammerschlag P, Berg H, Ransohoff J. Acoustic neuroma surgery: an eclectic approach with emphasis on preservation of hearing. The New York University-Bellevue experience. Ann Otol Rhinol Laryngol. 1969;95(1 Pt 1):21-7. | USA                          | USA                                  | 87            | 2.8             |
| 64   | Ray BS, Bergland RM. Cerebrospinal fluid fistula: clinical aspects, techniques of localization, and methods of closure. J Neurosurg. 1969;30(4):399-405. | USA                          | USA                                  | 87            | 1.8             |
| Rank | Citation | Publication |
|------|----------|-------------|
| 65   | 65       | Drayer BP, Wilkins RH, Boehnke M, Horton JA, Rosenbaum AE. Cerebrospinal fluid rhinorrhea demonstrated by metrizamide CT cisternography. AJR Am J Roentgenol. 1977;129(1):149-51. |
| 66   | 66       | Gacek RR, Leipzig B. Congenital cerebrospinal otorrhea. Ann Otol Rhinol Laryngol. 1979;88(3 Pt 1):358-65. |
| 67   | 67       | Hardy DG, Macfarlane R, Baguley D, Moffat DA. Surgery for acoustic neurinoma. An analysis of 100 translabyrinthine operations. J Neurosurg. 1989;71(6):799-804. |
| 68   | 68       | Sekhar LN, Schessel DA, Bucur SD, Raso JL, Wright DC. Partial labyrinthectomy petrous apicectomy approach to neoplastic and vascular lesions of the petroclival area. Neurosurgery. 1999;44(3):537-50; discussion 550-2. |
| 69   | 69       | Komotar RJ, Starke RM, Raper DM, Anand VK, Schwartz TH. Endoscopic endonasal versus open transcranial resection of anterior midline skull base meningiomas. World Neurosurg. 2012;77(5-6):713-24. |
| 70   | 70       | Amico JA, Tenicela R, Johnston J, Robinson AG. A time-dependent peak of oxytocin exists in cerebrospinal fluid but not in plasma of humans. J Clin Endocrinol Metab. 1983;57(5):947-51. |
| 71   | 71       | Mokri B. Spontaneous low pressure, low CSF volume headaches: spontaneous CSF leaks. Headache. 2013;53(7):1034-53. |
| 72   | 72       | Gacek RR. Arachnoid granulation cerebrospinal fluid otorrhea. Ann Otol Rhinol Laryngol. 1990;99(11):854-62. |
| 73   | 73       | Kaufman B, Nulsen FE, Weiss MH, Brodkey JS, White RJ, Sykora GF. Acquired spontaneous, nontraumatic normal-pressure cerebrospinal fluid fistulas originating from the middle fossa. Radiology. 1977;122(2):379-87. |
| 74   | 74       | Simasek M, Blandino DA. Treatment of the common cold. Am Fam Physician. 2007;75(4):515-20. |
| 75   | 75       | Friedman JA, Ebersold MJ, Quast LM. Post-traumatic cerebrospinal fluid leakage. World J Surg. 2001;25(8):1062-6. |
| 76   | 76       | Wormald PJ, McDonogh M. 'Bath-plug' technique for the endoscopic management of cerebrospinal fluid leaks. J Laryngol Otol. 1997;111(11):1042-6. |
| 77   | 77       | Ramakrishnan VR, Kingdom TT, Nayak JV, Hwang PH, Orlandi RR. Nationwide incidence of major complications in endoscopic sinus surgery. Int Forum Allergy Rhinol. 2012;2(1):34-9. |
| 78   | 78       | Leech PJ, Paterson A. Conservative and operative management for cerebrospinal-fluid leakage after closed head injury. Lancet. 1973 12;1(7811):1013-6. |
| Rank | Publication | Country of origin, 1st author | Countries of origin, rest of authors | Citations (n) | Citation density |
|------|-------------|-------------------------------|--------------------------------------|--------------|-----------------|
| 79   | Dahiya R, Keller JD, Litofsky NS, Bankey PE, Bonassar LJ, Megerian CA. Temporal bone fractures: otic capsule sparing versus otic capsule violating clinical and radiographic considerations. J Trauma. 1999;47(6):1079-83. | USA | USA | 81 | 4.5 |
| 80   | Roth M, Lanza DC, Zinreich J, Yousem D, Scanlan KA, Kennedy DW. Advantages and disadvantages of three-dimensional computed tomography intraoperative localization for functional endoscopic sinus surgery. Laryngoscope. 1995;105(12 Pt 1):1279-86. | USA | USA | 81 | 3.7 |
| 81   | Goldhammer Y, Smith JL. Optic nerve anomalies in basal encephalocele. Arch Ophthalmol. 1975;93(2):115-8. | USA | USA | 80 | 1.9 |
| 82   | Spetzler RF, Wilson CB. Management of recurrent CSF rhinorrhea of the middle and posterior fossa. J Neurosurg. 1978;49(3):393-7. | USA | USA | 80 | 2.1 |
| 83   | Wax MK, Ramadan HH, Ortiz O, Wetmore SJ. Contemporary management of cerebrospinal fluid rhinorrhea. Otolaryngol Head Neck Surg. 1997;116(4):442-9. | USA | USA | 80 | 4.0 |
| 84   | Brennan JW, Rowed DW, Nedzelski JM, Chen JM. Cerebrospinal fluid leak after acoustic neuroma surgery: influence of tumor size and surgical approach on incidence and response to treatment. J Neurosurg. 2001;94(2):217-23. | Canada | Canada | 79 | 4.9 |
| 85   | McCormack B, Cooper PR, Persky M, Rothstein S. Extracranial repair of cerebrospinal fluid fistulas: technique and results in 37 patients. Neurosurgery. 1990;27(3):412-7. | USA | USA | 79 | 2.9 |
| 86   | Guerin P, El Fegoun AB, Obeid I, Gille O, Lelong L, Luc S, Bourghli A, Cursole JC, Pointillart V, Vital JM. Incidental durotomy during spine surgery: incidence, management and complications. A retrospective review. Injury. 2012;43(4):397-401. | France | France | 79 | 15.8 |
| 87   | Becker SS, Jackler RK, Pitts LH. Cerebrospinal fluid leak after acoustic neuroma surgery: a comparison of the translabyrinthine, middle fossa, and retrosigmoid approaches. Otol Neurotol. 2003;24(1):107-12. | USA | USA | 78 | 5.6 |

Canada
| Rank | Publication                                                                 | Country of origin, 1st author | Countries of origin, rest of authors | Citations (n) | Citation density |
|------|-----------------------------------------------------------------------------|-------------------------------|---------------------------------------|---------------|-----------------|
| 88   | Charalampaki P, Ayyad A, Kockro RA, Perneckzy A. Surgical complications after endoscopic transsphenoidal pituitary surgery. J Clin Neurosci. 2009;16(6):786-9. | Germany                       | Germany                               | 77            | 9.6             |
| 89   | Hofstetter CP, Singh A, Anand VK, Kacker A, Schwartz TH. The endoscopic, endonasal, transmaxillary transpterygoid approach to the pterygopalatine fossa, infratemporal fossa, petrous apex, and the Meckel cave. J Neurosurg. 2010;113(5):967-74. | USA                           | USA                                   | 77            | 11.0            |
| 90   | Schick B, Ibing R, Brors D, Draf W. Long-term study of endonasal duraplasty and review of the literature. Ann Otol Rhinol Laryngol. 2001;110(2):142-7. | Germany                       | Germany                               | 77            | 4.8             |
| 91   | Calcaterra TC. Extracranial surgical repair of cerebrospinal rhinorrhea. Ann Otol Rhinol Laryngol. 1980;89(2 Pt 1):108-16. | USA                           | -                                     | 76            | 2.1             |
| 92   | Selman WR, Spetzler RF, Wilson CB, Grollmus JW. Percutaneous lumboperitoneal shunt: review of 130 cases. Neurosurgery. 1980;6(3):255-7. | USA                           | USA                                   | 75            | 2.0             |
| 93   | Leng LZ, Greenfield JP, Souweidane MM, Anand VK, Schwartz TH. Endoscopic, endonasal resection of craniopharyngiomas: analysis of outcome including extent of resection, cerebrospinal fluid leak, return to preoperative productivity, and body mass index. Neurosurgery. 2012;70(1):110-23; discussion 123-4. | USA                           | USA                                   | 75            | 15.0            |
| 94   | Ferguson BJ, Wilkins RH, Hudson W, Farmer J Jr. Spontaneous CSF otorrhea from tegmen and posterior fossa defects. Laryngoscope. 1986;96(6):635-44. | USA                           | USA                                   | 75            | 2.4             |
| 95   | Gassner HG, Ponikau JU, Sherris DA, Kern EB. CSF rhinorrhea: 95 consecutive surgical cases with long term follow-up at the Mayo Clinic. Am J Rhinol. 1999;13(6):439-47. | USA                           | USA                                   | 75            | 4.2             |
| 96   | Mirza S, Thaper A, McClelland L, Jones NS. Sinonasal cerebrospinal fluid leaks: management of 97 patients over 10 years. Laryngoscope. 2005;115(10):1774-7. | UK                            | UK                                     | 75            | 6.3             |
| 97   | Luntz M, Balkany T, Hodges AV, Telischi FF. Cochlear implants in children with congenital inner ear malformations. Arch Otolaryngol Head Neck Surg. 1997;123(9):974-7. | USA                           | USA                                   | 74            | 3.7             |
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| 99   | Cumberworth VL, Sudderick RM, Mackay IS. Major complications of functional endoscopic sinus surgery. Clin Otolaryngol Allied Sci. 1994;19(3):248-53. | UK                            | UK                                     | 74            | 3.2             |
| 100  | Drayer BP, Rosenbaum AE. Studies of the third circulation. Amipaque CT cisternography and ventriculography. J Neurosurg. 1978;48(6):946-56. | USA                           | USA                                   | 73            | 1.9             |
| 101  | Meurman OH, Irlaja K, Suopnappi J, Laurent B. A new method for the identification of cerebrospinal fluid leakage. Acta Otolaryngol. 1979;87(3-4):366-9. | Finland                       | Finland                                | 73            | 1.9             |
| Journal                                      | N docs | % docs | Impact factor (2017) | JCR category                                      | Journal category (ranking) |
|----------------------------------------------|--------|--------|----------------------|---------------------------------------------------|----------------------------|
| Laryngoscope                                 | 20     | 19.8   | 2.442                | Medicine, Research and Experimental (73/133)       | Otorhinolaryngology (12/41) |
| Journal of Neurosurgery                      | 17     | 16.8   | 4.319                | Clinical Neurology (37/197)                        | Surgery (14/200)            |
| Annals of Otology, Rhinology & Laryngology   | 6      | 5.9    | 1.513                | Otorhinolaryngology (22/41)                        |                            |
| Archives of Otolaryngology-Head and Neck     | 6      | 5.9    | 2.444                | Otorhinolaryngology (11/41)                        |                            |
| American Journal of Neuroradiology           | 3      | 3.0    | 3.653                | Surgery (67/200)                                  | Otorhinolaryngology (12/41) |
| American Journal of Otology                  | 3      | 3.0    | 2.182                | Clinical neurology (50/197)                        | Neuroimaging (5/14)         |
| American Journal of Rhinology                | 2      | 2.0    | 1.944                | Otorhinolaryngology (13/41)                        | Otorhinolaryngology (15/41) |
| Acta Oto-Laryngologica                       | 1      | 1.0    | 1.161                | Otorhinolaryngology (29/41)                        | Medicine, General and Internal (58/155) |
| American Family Physician                    | 1      | 1.0    | 1.974                |                                                   |                            |
| American Journal of Roentgenology            | 1      | 1.0    | 3.125                | Otorhinolaryngology (7/41)                         | Endocrinology and Metabolism (20/142) |
| British Journal of Surgery                   | 1      | 1.0    | 5.433                | Otorhinolaryngology (8/197)                        | Endocrinology and Metabolism (20/142) |
| Cephalalgia                                  | 1      | 1.0    | 3.886                |                                                   | Endocrinology and Metabolism (20/142) |
| Clinical Otolaryngology                       | 1      | 1.0    | 2.696                |                                                   | Endocrinology and Metabolism (20/142) |
| Clinical Review of Proteomics                | 1      | 1.0    | 3.489                |                                                   | Endocrinology and Metabolism (20/142) |
| Headache                                     | 1      | 1.0    | 3.091                |                                                   | Endocrinology and Metabolism (20/142) |
| International Journal of the Care of the Injured | 1  | 1.0    | 2.199                |                                                   | Endocrinology and Metabolism (20/142) |
| International Forum of Allergy & Rhinology   | 1      | 1.0    | 2.454                |                                                   | Endocrinology and Metabolism (20/142) |
| Journal of Clinical Endocrinology & Metabolism| 1     | 1.0    | 5.789                |                                                   | Endocrinology and Metabolism (20/142) |
| Journal of Clinical Neuroscience              | 1      | 1.0    | 1.640                |                                                   | Endocrinology and Metabolism (20/142) |
| Journal of Laryngology and Otology           | 1      | 1.0    | 967                  |                                                   | Endocrinology and Metabolism (20/142) |
| Journal of Neurology                         | 1      | 1.0    | 7.144                |                                                   | Endocrinology and Metabolism (20/142) |
| Neurosurgery and psychiatry                  | 1      | 1.0    |                      |                                                   | Endocrinology and Metabolism (20/142) |
followed by the Journal of Neurosurgery (n = 17), Neurosurgery (n = 12), Annals of Otology, Rhinology & Laryngology (n = 6), and Otolaryngology-Head and Neck Surgery (n = 6). These 5 journals covered 60.4% of the highest-impact documents (Table 2).

Table 3 lists the JCR categories of the top-cited articles. The leading category was surgery (47.5% of the documents), followed by otorhinolaryngology (46.5%) and clinical neurology (41.6%).

Authors’ country of origin was most commonly the USA (75.2%), followed by the UK (6.9%) and Italy (4%), as shown in Table 4. Most documents were original articles (n = 88), while the other 13 were reviews (n = 12.9). According to the clinical document types assigned in MEDLINE, there were 12 case reports; 4 meta-analyses, and 2 clinical trials.

The articles were published between 1954 and 2018, but scientific activity was concentrated between the two decades of 1990–1999 (n = 30) and 2000–2009 (n = 30). Seven of the top papers were published in both 1997 and 1999, while the years 2004 and 2012 each saw the publication of another six top articles (Table 5).

The MeSH terms for the 101 top documents are listed in Table 6. These were led by “Cerebrospinal fluid rhinorrhea” (n = 81). “Cerebrospinal fluid otorrhea” appeared in 33 documents, while “Surgery” was in 62 documents, “Endoscopy” in 35, “Cerebrospinal fluid” in 9, and “Cerebrospinal fluid shunt” in 7 (Table 6).

Discussion

Although several methodologies exist for determining the impact of journals and articles, the number of citations and citation rank lists are still the dominant methods used for identifying influential work in areas including neurosurgery, otolaryngology, ophthalmology, and others. The analysis of the top-cited documents illustrates how knowledge accumulates over time, therefore this study aimed to determine which articles on CSF leak have had the most influence by ranking the 100 most cited works since 1945. In addition, we analyzed the characteristics of these articles to determine the factors contributing to situating them as the most relevant to other researchers working in the specialty.

The top 101 documents were published in 36 different journals, but half the articles were concentrated in just 5 journals. Otorhinolaryngology and neurosurgery were the dominant specialties, while other disciplines made only nominal contributions to our population of high-impact studies of CSF leak.
recent studies, as measured through the "half life" of publications, among other citation indicators.\footnote{14}

In that regard, scientific evolution in the field of CSF leak has been driven by improvements in diagnostic, imaging, and surgical techniques for its management. One of the most important advances has undoubtedly been the introduction of sinonasal endoscopy for treating the condition.\footnote{15} Endoscopy for fistula closure substantially decreased the morbidity associated with the craniotomy approaches used until the 1940s and increased the closure success rate, which until then had not exceeded 60%.\footnote{16}

Since its introduction in the 1970s by Messenklinger and Stammbberger,\footnote{17--19} endoscopic surgery has progressed tremendously. Beyond its adoption as a treatment for sinonasal pathologies, use of the technique has expanded to other areas, and it is now a major tool for treating skull base pathologies.

Wigang\footnote{20} first discovered endoscopic closure technique in 1981. From then on, the use of this approach spread, and several other authors described their experiences in case series that demonstrated the feasibility and advantages of the method in terms of decreasing morbidity and increasing successful closure.\footnote{21--22} These experiences probably explain why a large number of the most cited papers we identified were published over 30 years ago (29%): these studies were pioneering or landmark contributions to the field.

This evolution has been the reason for the high scientific productivity over the years, which corresponds to two different periods: from 1990 to 1999, and from 2000 to 2009.
In each of these decades, 30 of the 101 top-cited articles were published.

The first period reflects changes in the management of the fistulas, wherein endoscopic sinus surgery is increasingly favored. Over this decade, articles in high-impact journals described authors’ experiences with innovative techniques. This inflection point in the management of the pathology was encapsulated in a meta-analysis published by Hegazy et al. in the year 2000: “Transnasal endoscopic repair of cerebrospinal fluid rhinorrhea: a meta-analysis” in Laryngoscope. In it, the review authors defend and confirm endoscopic surgery as a safe method for CSF fistula closure. This paper had a high impact on the field; the 272 citations it received in the study period make it the second most influential article in our population of documents, with a citation density of 16.

During the second period of highest production (from 2000 to 2009), the topic attracting the most research interest was the expanded endonasal approach to the skull base. Indeed, several articles were published in relation to endoscopic transphenoidal surgery for skull base lesions. But an important drawback of this endoscopic approach was the difficulty in reconstructing large dural defects, which often led to complications such as CSF leaks, meningitis or pneumocephalus. For many years, the typical method of closing the dural defects was by means of onlay and inlay grafts, but this technique was associated with very high rates of postoperative leaks.

In this regard, the introduction of the first endonasal pedicle flap, the nasoseptal flap, represented a major impetus to the rapid development and progress of endoscopic skull base surgery. This innovation decreased initial CSF leak rates from 20% to less than 5%, spurring greater expansion of the endoscopic approach. Thus, the most cited article over the entire study period was by far “A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap”, by Hadad et al., published in 2006 in Laryngoscope. It also ranked as the article with the highest citation density, at 69.7. The 767 citations it received over the following 12 years illustrate the study’s influence on the evolution of the endoscopic skull base surgery, marking a turning point in the history of the CSF leak surgery, endoscopic endonasal surgery, and endoscopic skull base surgery.

Although the most frequent topic of the top-cited articles was endoscopic surgery, other high-impact articles dealt with other subjects, such as clinical and diagnostic features of CSF leak, neurinoma surgery, or the association between CSF leak and temporal bone fractures. The impact of these articles in the literature peaked from the 1970s to the 1990s; however, after that the important evolution of endoscopic skull base surgery eclipsed the publications focusing on CSF fistulas. In any case, most of the articles presented in this study dealt with surgical aspects of CSF leak, reflecting the wider interest in surgical papers compared to diagnostic or clinical studies.

The USA was the largest contributor to CSF leak research. The vast majority (75.2%) of our high-impact publications come from authors and institutions from that country. This finding is consistent with results reported in other surgical fields such as maxillofacial and plastic surgery. In addition to the concentration of resources in the USA and its main-stream position in biomedical research, the Matthew effect of accumulated advantage could also be a factor that favors the concentration of citations among journals and authors from this country. Other countries contributing influential papers to the literature include the UK (n = 7), Italy (n = 4), and Canada (n = 3).

The most significant aspect to point out regarding documentary types is the predominance of case studies (35%), with similar values compared to other surgical areas, such as maxillofacial surgery (31%). Taken alone, clinical case studies do not provide enough evidence for guiding treatment decisions, but when they are collectively considered, appropriately codified and properly integrated into structured information systems, physicians can use the information gleaned as a solid evidence base for comparing cases and checking diagnoses.

The top cited articles were mostly published in otolaryngological and neurosurgical journals, but as in other areas of knowledge, a few generalist journals also stood out for contributing high-impact articles. This is the case of the New England Journal of Medicine, with one document that received 140 citations and had a citation density of 46.7 and an impact factor of 79.260 (2017 JCR). The Lancet also contributed a document to the list, which garnered 81 citations and showed a citation density of 1.8 and an impact factor of 53.254.

The journal of publication is an important factor determining the potential for an article to be cited. General medical journals have a wider audience and larger circulation, so they obtain a higher impact factor than smaller specialist journals. Thus, it is difficult to make individual comparisons between journals or to compare the impact of journals from different thematic categories.

There are several limitations to this type of study. First, although citation analysis is one of the most widely used bibliometric parameters, providing a measure of scientific activity, visibility, use, dissemination, and impact, it does not represent a measure of scientific quality. Second, our search was based on journals with impact factors or under tracking for impact factors. This criterion preferentially favored Western articles, especially those from the USA, the UK, and Canada. Most papers in non-English journals were cited by other papers published in the same language. Therefore, we might have missed a number of highly cited articles related to CSF leak. Third, this study was based on objective citation data, but some landmark CSF leak papers may not have figured among the top-cited papers, as they were cited only until their findings became well known. This phenomenon, termed ‘obliteration by incorporation’, has been observed in other fields. Finally, other factors could also affect the citation rates, such as the journal’s year in review, authors’ self-citations, incomplete citing, and omission bias. Despite these limitations, citation analysis and impact factor are widely used to rank and evaluate articles and journals. However, these assessment methods should be complemented by others such as peer survey and specialist opinion of citation analysis.

**Conclusion**

Our findings offer information related to the dissemination of knowledge in recent decades about the cerebrospinal...
fluid leaks. Two well-defined periods of maximum scientific activity were driven by surgical innovations. This study also shows that the major specialties contributing to the field of CSF leak were otorhinolaryngology and neurosurgery, which were almost equally represented among the most cited documents.

Conflicts of interest

The authors declare no conflicts of interest.

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