INTRODUCTION

Hydrocephalus is a complex condition that was first described by Hippocrates (466–377 BC), who described the associated symptoms of headache, vomiting, visual disturbance, and diplopia.[14] Throughout the years, the understanding of hydrocephalus has evolved, so it is identified as abnormal CSF physiology that results in pathological expansion of cerebral ventricles.[12] Although, many theories have been formulated to explain the molecular mechanism for development of hydrocephalus, the precise pathophysiology still unclear.[13,14] Hydrocephalus is one of the most common brain disorders that are estimated to possess mean prevalence of 85/100,000.[11] Substantial burden for both individual and society has been caused...
by the chronic state of hydrocephalus.\(^{[7]}\) It is a debilitating condition which can present at any age and encompasses heterogeneous pathogenesis.\(^{[10]}\) Hydrocephalus causes are numerous, including but not limited to, tumors, congenital or non-congenital aqueductal stenosis, or genetic syndromes. It may also complicate a wide range of conditions such as infections, head injury, malformations, and subarachnoid hemorrhage.\(^{[10]}\) Although there is no cure for hydrocephalus, early diagnosis and surgical intervention can improve morbidity, mortality, and quality of life.\(^{[6]}\)

During the past decades, as a result of advancements in radiological imaging and basic neuroscientific study tool our understanding of hydrocephalus and our ability to manage and control it effectively.\(^{[16]}\) These advancements are reflected in scientific articles, particularly in those most influential papers that covers different aspects including natural history, pathophysiology, epidemiology, etiology, diagnostic, and treatment strategies. An understanding of the available literature and the most heavily cited works can be used for scientific and clinical purposes.

Bibliometric analysis is defined as a statistical evaluation that aims to quantify the impact of scientific articles. The term “Bibliometrics” was first employed by Alan Pritchard in 1969.\(^{[10]}\) A citation analysis is the most common bibliometric method which serves to review and evaluate the most-cited articles in a specific research area. It aims to identify landmark publications and recognize the level of contribution made by authors, specialties, institutions, countries, and journals.\(^{[9]}\) There is certainly a considerable number of articles that are insufficiently valued by their citation counts (CCs) despite their importance. Nonetheless, the CC remains the accepted method internationally to assess an article’s impact.

At present, citation analysis has been applied to identify articles in multiple medical and surgical fields.\(^{[15,18-20]}\) Many analyses addressed neurosurgical topics such as meningioma,\(^{[3]}\) acoustic neuroma,\(^{[2]}\) low grade glioma,\(^{[9]}\) idiopathic intracranial hypertension,\(^{[67]}\) and yet none have been performed solely on hydrocephalus. We aimed to conduct a bibliometric analysis of the 100 most-cited works on hydrocephalus to analyze the current scientific production and to guide the health-care providers in this area.

**MATERIALS AND METHODS**

**Search strategy**

In March 2020, a title specific search was accomplished using Scopus database to identify the top 100 most cited articles on hydrocephalus. The search keyword that was used was hydrocephalus; another search keyword like “dilated ventricles, high intracranial pressure” was eliminated due to the non-specificity of the result to hydrocephalus. The search result was sorted in descending order according to CC. Google scholar CC was obtained by performing article title search and logging the CC of the article according to Google scholar database.

**Data**

Data of importance were collected and a comparative analysis between the published articles at basic six levels were made; article title, authors block, affiliation of the 1\textsuperscript{st} author, country of origin, journal of publication, year of publication, CC according to Scopus database, and CC according to Google scholar database. The top 100 articles were categorized after studying the top 100 articles’ abstracts to the following two categories and seven subcategories; hydrocephalus (Clinical/Epidemiological/Historical, Genetic Association, in intracranial hemorrhage, \textit{in utero} Surgical Management, Pathophysiology, Radiological Assessment, RCT on shunt Valve types, Surgical Management), Normal pressure Hydrocephalus (Clinical/Epidemiological, Guideline, Pathophysiology, Radiological Assessment, Surgical Management, and In Alzheimer disease).

**Bibliometric parameters**

Contemporarily, quantifying the importance of articles is achieved using bibliometric parameters which involve the CC of articles, Journal’s SCImago Journal Rank (SJR), and Journal’s Source-normalized Impact per paper (SNIP) for journals. The CC accounts for the number of accounted citations of a pertinent article since its publication. The SJR score, which signifies the journals influence by the number of citations the journal has received and the source of the received citation. The SNIP is a parameter which symbolizes how discipline specific is the journals based on the discipline of the journals in which citations was received.

**RESULTS**

**Article analysis**

The title specific search yielded a total of 12,044 articles. The top 100 articles based on the CC were collected and the following data were recorded (Title, 1\textsuperscript{st} author, journal, year of publication, CC according to Scopus, and CC according to Google scholar) [Table 1]. Altogether, the top 100 articles accumulated a total of 20,177 CCs and an average CC of 201 citations. The percentage of self-citation in our bibliometric review accounted for only 6.6% according to Scopus data base. The most cited article was published in The New England Journal of Medicine by Adams et al. by the Massachusetts Medical Society in 1965 which addressed “Symptomatic Occult Hydrocephalus With Normal Cerebrospinal fluid pressure: a treatable Syndrome” for which it received 896 citations according to Scopus.
Table 1: The list of the top 100 most-cited articles on hydrocephalus.

| Rank | Title | 1st Author | Journal | Year | CY | Scopus “CC” | Google Scholar “CC” |
|------|-------|------------|---------|------|----|-------------|-------------------|
| 1st  | Symptomatic occult hydrocephalus with “Normal” | Adams R.D. | The New England Journal of Medicine | 1965 | 16.3 | 896 | 1619 |
| 2nd  | The special clinical problem of symptomatic hydrocephalus with normal cerebrospinal fluid pressure. Observations on cerebrospinal fluid hydrodynamics | Hakim S. | Journal of the Neurological Sciences | 1965 | 13.3 | 732 | 1266 |
| 3rd  | Randomized trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus | Drake J.M. | Neurosurgery | 1998 | 23.1 | 509 | 653 |
| 4th  | X-linked spastic paraplegia (SPG1), MASA syndrome and X-linked hydrocephalus result from mutations in the L1 gene | Jouet M. | Nature Genetics | 1994 | 13.2 | 344 | 433 |
| 5th  | Neuropathological changes caused by hydrocephalus | Del Bigio M.R. | Acta Neuropathologica | 1993 | 12.3 | 333 | 433 |
| 6th  | Fetal surgery for myelomeningocele and the incidence of shunt-dependent hydrocephalus | Bruner J.P. | Journal of the American Medical Association | 1999 | 15.5 | 326 | 435 |
| 7th  | Acute hydrocephalus after aneurysmal subarachnoid hemorrhage | Van Gijn J. | Journal of Neurosurgery | 1985 | 9.3 | 324 | 465 |
| 8th  | Idiopathic normal pressure hydrocephalus: A systematic review of diagnosis and outcome | Hebb A.O. | Neurosurgery | 2001 | 15.5 | 294 | 443 |
| 9th  | The forkhead/winged helix gene Mf1 is disrupted in the pleiotropic mouse mutation congenital hydrocephalus | Jume T. | Cell | 1998 | 12.6 | 277 | 347 |
| 10th | Alzheimer’s disease, normal-pressure hydrocephalus, and senescent changes in CSF circulatory physiology: A hypothesis | Silverberg G.D. | Lancet Neurology | 2003 | 16.1 | 273 | 389 |
| 11th | Catheter Shunts for Fetal Hydronephrosis and Hydrocephalus | Manning F.A. | New England Journal of Medicine | 1986 | 7.6 | 259 | 290 |
| 12th | Normal-pressure hydrocephalus: Evaluation with cerebrospinal fluid flow measurements at MR imaging | Bradely Jr. W.G. | Radiology | 1996 | 10.6 | 254 | 400 |
| 13th | Radiological assessment of hydrocephalus: New theories and implications for therapy | Gretiz D. | Neurosurgical Review | 2004 | 15.4 | 247 | 417 |
| 14th | The physics of the cranial cavity. Hydrocephalus and normal pressure hydrocephalus: mechanical interpretation and mathematical model | Hakim S. | Surgical Neurology | 1976 | 5.5 | 244 | 422 |
| 15th | Hydrocephalus: A previously unrecognized predictor of poor outcome from supratentorial intracerebral hemorrhage | Diringer M.N. | Stroke | 1998 | 10.8 | 237 | 341 |
| 16th | The predictive value of conductance to outflow of CSF in normal pressure hydrocephalus | Borgesen S.E | Brain | 1982 | 6.2 | 234 | 362 |
| 17th | Shunting normal-pressure hydrocephalus: Do the benefits outweigh the risks?: A multicenter study and literature review | Vanneste J. | Neurology | 1992 | 8.1 | 228 | 328 |
| 18th | Dysfunction of axonal dynein heavy chain Mdnah5 inhibits ependymal flow and reveals a novel mechanism for hydrocephalus formation | Ibanez-Tallon I. | Human Molecular Genetics | 2004 | 14.1 | 225 | 307 |
| 19th | Aberrant splicing of neural cell adhesion molecule L1 mRNA in a family with X-linked hydrocephalus | Rosenthal A. | Nature Genetics | 1992 | 7.9 | 222 | 280 |
| 20th | Dysfunctional cilia lead to altered ependymal and choroid plexus function, and result in the formation of hydrocephalus | Baniz B. | Development | 2005 | 14.7 | 220 | 292 |

(Contd...)
Table 1: (Continued).

| Rank | Title                                                                 | 1st Author | Journal                                      | Year | CY | Scopus “CC” | Google Scholar “CC” |
|------|----------------------------------------------------------------------|------------|----------------------------------------------|------|----|------------|---------------------|
| 21st | Risk factors for repeated cerebrospinal shunt failures in pediatric patients with hydrocephalus | Tuli S.    | Journal of Neurosurgery                      | 2000 | 11.0 | 219        | 333                 |
| 22nd | Guidelines for management of idiopathic normal pressure hydrocephalus: Second edition | Mori E.   | Neurologia Medico-Chirurgica                 | 2012 | 27.3 | 218        | 307                 |
| 23rd | Treatment of hydrocephalus by direct shunt from ventricle to jugular vein. | Nulsen F.E. | Surgical forum                               | 1951 | 3.1  | 215        | 427                 |
| 24th | Dutch normal-pressure hydrocephalus study: Prediction of outcome after shunting by resistance to outflow of cerebrospinal fluid | Boon A.J.W. | Journal of Neurosurgery                      | 1997 | 9.2  | 212        | 288                 |
| 25th | Comparative analysis of the gait disorder of normal pressure hydrocephalus and Parkinson’s disease | Stolze H. | Journal of Neurology Neurosurgery and Psychiatry | 2001 | 11.1 | 211        | 308                 |
| 26th | Male infertility, impaired sperm motility, and hydrocephalus in mice deficient in sperm-associated antigen 6 | Sapiro R.  | Molecular and Cellular Biology               | 2002 | 11.7 | 210        | 247                 |
| 27th | Diagnosis and management of normal-pressure hydrocephalus            | Vanneste J.A.L. | Journal of Neurology | 2000 | 10.5 | 210        | 320                 |
| 28th | Increased central nervous system production of extracellular matrix components and development of hydrocephalus in transgenic mice overexpressing transforming growth factor-β1 | Wyss. Coray T. | American Journal of Pathology | 1995 | 8.3  | 207        | 245                 |
| 29th | Hydrocephalus: Overdrainage by ventricular shunts. A review and recommendations | Pudenz R.H. | Surgical Neurology                           | 1991 | 7.1  | 207        | 256                 |
| 30th | CSF spaces in idiopathic normal pressure hydrocephalus: Morphology and volumetry | Kitagaki H. | American Journal of Neuroradiology          | 1998 | 9.4  | 206        | 274                 |
| 31st | Management problems in acute hydrocephalus after subarachnoid hemorrhage | Hasan D.   | Stroke                                       | 1989 | 6.6  | 204        | 321                 |
| 32nd | Benign forms of intracranial hypertension-“toxic” and “otitic” hydrocephalus | Foley J.   | Brain                                       | 1955 | 3.1  | 204        | 393                 |
| 33rd | Diagnosis and management of idiopathic normal-pressure hydrocephalus: A prospective study in 151 patients | Marmarou A. | Journal of Neurosurgery                      | 2005 | 13.5 | 203        | 309                 |
| 34th | Lack of cadherins Celsr2 and Celsr3 impairs ependymal ciliogenesis, leading to fatal hydrocephalus | Tissir F.  | Nature Neuroscience                          | 2010 | 20.2 | 202        | 252                 |
| 35th | Management of hydrocephalus by endoscopic third ventriculostomy in patients with myelomeningocele | Teo C.     | Pediatric Neurosurgery                       | 1996 | 8.4  | 201        | 261                 |
| 36th | Hydrocephalus as a cause of disturbances of gait in the elderly       | Fisher C.M. | Neurology                                   | 1982 | 5.3  | 201        | 305                 |
| 37th | Risk factors for failure of endoscopic third ventriculostomy for obstructive hydrocephalus | Fukuhara T. | Neurosurgery                               | 2000 | 10.0 | 200        | 270                 |
| 38th | Diagnosis of idiopathic normal pressure hydrocephalus is supported by MRI-based scheme: A prospective cohort study | Hashimoto M. | Cerebrospinal Fluid Research                   | 2010 | 19.7 | 197        | 266                 |
| 39th | Schizencephalies: A study of the congenital clefts in the cerebral mantle: II. Clefts with hydrocephalus and lips separated | Yakovlev P.I. | Journal of Neuropathology and Experimental Neurology | 1946 | 2.6  | 196        | 272                 |
| 40th | Idiopathic normal-pressure hydrocephalus. Results of shunting in 62 patients | Black Mc L.P. | Journal of Neurosurgery | 1980 | 4.9  | 194        | 330                 |

(Contd...)
| Rank  | Title                                                                 | 1st Author       | Journal                          | Year | CY | Scopus “CC” | Google Scholar “CC” |
|-------|----------------------------------------------------------------------|------------------|----------------------------------|------|----|------------|-------------------|
| 41st  | Frontal and occipital horn ratio: A linear estimate of ventricular size for multiple imaging modalities in pediatric hydrocephalus | O'Hayon B.B.     | Pediatric Neurosurgery           | 1998 | 8.7| 191        | 235               |
| 42nd  | Factors related to hydrocephalus after aneurysmal subarachnoid hemorrhage | Dorai Z.         | Neurosurgery                     | 2003 | 11.2| 190       | 322               |
| 43rd  | The current status of endoscopic third ventriculostomy in the management of non-communicating hydrocephalus | Jones R.E.C.     | Minimally Invasive Neurosurgery  | 1994 | 7.3| 190        | 233               |
| 44th  | A survey of the first complication of newly implanted CSF shunt devices for the treatment of nontumoral hydrocephalus - Cooperative survey of the 1991–1992 Education Committee of the ISPN | Di Rocco C.      | Child's Nervous System           | 1994 | 7.3| 189        | 221               |
| 45th  | A randomized, controlled study of a programmable shunt valve versus a conventional valve for patients with hydrocephalus | Pollack I.F.     | Neurosurgery                     | 1999 | 8.9| 186        | 198               |
| 46th  | Anti-siphon and reversible occlusion valves for shunting in hydrocephalus and preventing post shunt subdural hematomas. | Portnoy H.D.     | Journal of neurosurgery          | 1973 | 4.0| 186        | 284               |
| 47th  | Hydrocephalus: Changes in Formation and Absorption of Cerebrospinal | Bering Jr. W.G.  | Journal of neurosurgery          | 1963 | 3.2| 183        | 402               |
| 48th  | The scientific history of hydrocephalus and its treatment           | Aschoff A.       | Neurosurgical Review             | 1999 | 8.6| 181        | 335               |
| 49th  | INPH guidelines, part I: Development of guidelines for idiopathic normal-pressure hydrocephalus: Introduction | Marmarou A.     | Neurosurgery                     | 2005 | 11.9| 179       | 172               |
| 50th  | Hydrocephalus in Uganda: The predominance of infectious origin and primary management with endoscopic third ventriculostomy | Warf B.C.        | Journal of Neurosurgery          | 2005 | 11.9| 178       | 252               |
| 51st  | Intraventricular hemorrhage and hydrocephalus after spontaneous intracerebral hemorrhage: Results from the STICH trial | Bhattathiri P.S. | Acta Neurochirurgica, Supplementum | 2006 | 12.6| 177        | 276               |
| 52nd  | Association of deep white matter infarction with chronic communicating hydrocephalus: Implications regarding the possible origin of normal-pressure hydrocephalus | Bradley Jr. W.G. | American Journal of Neuroradiology | 1991 | 6.1| 176        | 284               |
| 53rd  | Alzheimer's disease comorbidity in normal pressure hydrocephalus: Prevalence and shunt response | Golomb J.        | Journal of Neurology Neurosurgery and Psychiatry | 2000 | 8.8| 175        | 254               |
| 54th  | BDNF serum and CSF concentrations in Alzheimer's disease, normal pressure hydrocephalus and healthy controls | Laske C.         | Journal of Psychiatric Research  | 2007 | 13.4| 174       | 241               |
| 55th  | Vascular Risk Factors and Arteriosclerotic Disease in Idiopathic Normal-Pressure Hydrocephalus of the Elderly | Krauss J.K.      | Stroke                          | 1996 | 7.3| 174        | 232               |
| 56th  | Central nervous system anomalies associated with meningomyelocele, hydrocephalus, and the Arnold-Chiari malformation: Reappraisal of theories regarding the pathogenesis of posterior neural tube closure defects | Gilbert J.N.     | Neurosurgery                     | 1986 | 5.1| 174        | 248               |
| 57th  | Clinical parameters in 74 consecutive patients shunt operated for normal pressure hydrocephalus | Larsson A.       | Acta Neurologica Scandinavica    | 1991 | 6.0| 173        | 225               |

(Contd...)
Table 1: (Continued).

| Rank | Title                                                                 | 1st Author      | Journal                        | Year | CY  | Scopus “CC” | Google Scholar “CC” |
|------|----------------------------------------------------------------------|-----------------|--------------------------------|------|-----|-------------|---------------------|
| 58th | Evidence that oxidative stress is associated with the pathophysiology of inherited hydrocephalus in the H-Tx rat model | Socci D.J.      | Experimental Neurology         | 1999 | 8.2 | 172         | 205                 |
| 59th | CRASH syndrome: Clinical spectrum of Corpus callosum hypoplasia, Retardation, Adducted thumbs, Spastic paraparesis and Hydrocephalus due to mutations in one single gene, L1 | Fransen E.      | European Journal of Human Genetics | 1995 | 6.8 | 171         | 224                 |
| 60th | Endoscopic Third Ventriculostomy in the Treatment of Childhood Hydrocephalus | Kulkarni A.V.   | Journal of Pediatrics           | 2009 | 15.5| 170         | 215                 |
| 61st | Implanted ventricular shunts in the United States: The billion-dollar-a-year cost of hydrocephalus treatment | Patwardhan R.V. | Neurosurgery                   | 2005 | 11.3| 170         | 300                 |
| 62nd | Disruption of the murine nuclear factor I-A gene results in perinatal lethality, hydrocephalus, and agenesis of the corpus callosum | Das Neves L.    | Proceedings of the National Academy of Sciences of the United States of America | 1999 | 8.0 | 168         | 207                 |
| 63rd | Long-term results after ventriculoatrial and ventriculoperitoneal shunting for infantile hydrocephalus | Keucher T.R.    | Journal of Neurosurgery        | 1979 | 4.1 | 168         | 270                 |
| 64th | Dutch normal-pressure hydrocephalus study: Randomized comparison of low- and medium-pressure shunts | Boon A.J.W.     | Journal of Neurosurgery        | 1998 | 7.6 | 167         | 239                 |
| 65th | Measurement of optic nerve sheath diameter by ultrasound: A means of detecting acute raised intracranial pressure in hydrocephalus | Newman W.D.    | British Journal of Ophthalmology | 2002 | 9.2 | 166         | 284                 |
| 66th | Diagnosis, treatment, and analysis of long-term outcomes in idiopathic normal-pressure hydrocephalus. | McGirt M.J.     | Neurosurgery                   | 2005 | 11.0| 165         | 283                 |
| 67th | The Predictive Value of Cerebrospinal Fluid Dynamic Tests in Patients With the Idiopathic Adult Hydrocephalus Syndrome | Malm J.        | Archives of Neurology          | 1995 | 6.5 | 163         | 232                 |
| 68th | Marked cerebrospinal fluid void: Indicator of successful shunt in patients with suspected normal-pressure hydrocephalus | Bradley Jr. W.G.| Radiology                      | 1991 | 5.4 | 158         | 267                 |
| 69th | Factors associated with hydrocephalus after subarachnoid hemorrhage: A report of the cooperative aneurysm study | Graff Radford N.R.| Archives of Neurology            | 1989 | 5.1 | 157         | 250                 |
| 70th | Hospital care for children with hydrocephalus in the United States: Utilization, charges, comorbidities, and deaths | Simon T.D.    | Journal of Neurosurgery: Pediatrics | 2008 | 13.0| 156         | 208                 |
| 71st | Pattern of white matter regional cerebral blood flow and autoregulation in normal pressure hydrocephalus | Momjian S.     | Brain                          | 2004 | 9.8 | 156         | 221                 |
| 72nd | Loss of function of axonemal dynein Mdnah5 causes primary ciliary dyskinesia and hydrocephalus | Ibanez-Tallon I.| Human Molecular Genetics        | 2002 | 8.5 | 153         | 191                 |
| 73rd | Neurodevelopmental outcome of extremely low birth weight infants with posthemorrhagic hydrocephalus requiring shunt insertion | Adams-Chapman I.| Pediatrics                    | 2008 | 12.7| 152         | 176                 |
| 74th | Relationship between cerebrospinal fluid formation, absorption and pressure in human hydrocephalus | Lorenzo A.V.   | Brain                          | 1970 | 3.0 | 152         | 278                 |

(Contd...)
| Rank | Title                                                                 | 1st Author | Journal                                      | Year | CY  | Scopus “CC” | Google Scholar “CC” |
|------|-----------------------------------------------------------------------|------------|----------------------------------------------|------|-----|-------------|---------------------|
| 75th | The value of temporary external lumbar CSF drainage in predicting the outcome of shunting on normal pressure hydrocephalus | Walchenbach R. | Journal of Neurology Neurosurgery and Psychiatry | 2002 | 8.4 | 151         | 236                 |
| 76th | The natural history of hydrocephalus: Detailed analysis of 182 unoperated cases | Laurence K.M. | Archives of Disease in Childhood Biomechanics | 1962 | 2.5 | 147         | 267                 |
| 77th | Reassessment of brain elasticity for analysis of biomechanisms of hydrocephalus | Taylor Z. | Journal of Biomechanics | 2004 | 9.1 | 146         | 225                 |
| 78th | Endoscopic third ventriculostomy in the management of obstructive hydrocephalus: An outcome analysis | Feng H. | Journal of Neurosurgery | 2004 | 9.1 | 146         | 206                 |
| 79th | Management of hydrocephalus in pediatric patients with posterior fossa tumors: The role of endoscopic third ventriculostomy | Sainte-Rose C. | Journal of Neurosurgery | 2001 | 7.7 | 146         | 227                 |
| 80th | Endoscopic third ventriculostomy for obstructive hydrocephalus | Hellwig D. | Neurosurgical Review | 2005 | 9.6 | 144         | 243                 |
| 81st | Stereotactic third ventriculostomy in patients with non-tumoral adolescent/adult onset aqueductal stenosis and symptomatic hydrocephalus | Kelly P.J. | Journal of Neurosurgery | 1991 | 4.9 | 143         | 179                 |
| 82nd | The effect of intrauterine myelomeningocele repair on the incidence of shunt-dependent hydrocephalus | Tulipan N. | Pediatric Neurosurgery | 2003 | 8.1 | 138         | 162                 |
| 83rd | Diagnostic intracranial pressure monitoring and surgical management in idiopathic normal pressure hydrocephalus: A 6-Year review of 214 patients | Eide P.K. | Neurosurgery | 2010 | 13.6 | 136        | 190                 |
| 84th | Accelerated progression of kaolin-induced hydrocephalus in aquaporin-4-deficient mice | Bolch O. | Journal of Cerebral Blood Flow and Metabolism | 2006 | 9.7 | 136         | 194                 |
| 85th | Intracranial venous sinus hypertension: Cause or consequence of hydrocephalus in infants? | Sainte-Rose C. | Journal of Neurosurgery | 1984 | 3.8 | 136         | 183                 |
| 86th | Evaluation of an antibiotic-impregnated shunt system for the treatment of hydrocephalus | Govender S.T. | Journal of Neurosurgery | 2003 | 7.9 | 135         | 166                 |
| 87th | A Surgical Approach to the Treatment of Fetal Hydrocephalus | Clewell W.H. | New England Journal of Medicine | 1982 | 3.6 | 135         | 240                 |
| 88th | A standardized protocol to reduce cerebrospinal fluid shunt infection: The Hydrocephalus Clinical Research Network Quality Improvement Initiative. Clinical article | Kestle J.R.W. | Journal of Neurosurgery: Pediatrics | 2011 | 14.8 | 133        | 162                 |
| 89th | Guidelines for management of idiopathic normal pressure hydrocephalus: Guidelines from the Guidelines committee of idiopathic normal pressure hydrocephalus, the Japanese society of normal pressure hydrocephalus | Ishikawa M. | Neurologia Medico-Chirurgica | 2008 | 11.1 | 133        | 196                 |
| 90th | Chronic hydrocephalus in rats and humans: White matter loss and behavior changes | Del Bigio M.R. | Annals of Neurology | 2003 | 7.8 | 133        | 175                 |
| 91st | The clinical effect of lumbar puncture in normal pressure hydrocephalus | Wikkelso C. | Journal of Neurology Neurosurgery and Psychiatry | 1982 | 3.5 | 132         | 202                 |
| 92nd | Measurement of cerebrospinal fluid flow at the cerebral aqueduct by use of phase-contrast magnetic resonance imaging: Technique validation and utility in diagnosing idiopathic normal pressure hydrocephalus | Luetmer P.H. | Neurosurgery | 2002 | 7.3 | 131         | 206                 |

(Contd...)
### Table 1: (Continued).

| Rank  | Title                                                                 | 1st Author       | Journal                  | Year | CY | Scopus “CC” | Google Scholar “CC” |
|-------|-----------------------------------------------------------------------|------------------|--------------------------|------|----|-------------|---------------------|
| 93rd  | The long-term outlook for hydrocephalus in childhood                  | Casey A.T.H.     | Pediatric Neurosurgery   | 1997 | 5.7| 131         | 182                 |
| 94th  | Cerebrospinal fluid shunting in idiopathic normal-pressure hydrocephalus of the elderly: Effect of periventricular and deep white matter lesions on outcome | Krauss J.K.      | Neurosurgery             | 1996 | 5.5| 131         | 184                 |
| 95th  | Hydrocephalus secondary to cysticercotic arachnoiditis. A long-term follow-up review of 92 cases | Sotelo J.        | Journal of Neurosurgery  | 1987 | 4.0| 131         | 197                 |
| 96th  | Prevalence of idiopathic normal-pressure hydrocephalus                | Jaraj D.         | Neurology                | 2014 | 21.7| 130        | 182                 |
| 97th  | Normal pressure hydrocephalus. Predicting the results of cerebrospinal fluid shunting | Stein S.C.       | Journal of Neurosurgery  | 1974 | 2.8| 130        | 233                 |
| 98th  | A model of pulsations in communicating hydrocephalus                  | Egnor M.         | Pediatric Neurosurgery   | 2002 | 7.2| 129        | 208                 |
| 99th  | Specific patterns of cognitive impairment in patients with idiopathic normal pressure hydrocephalus and Alzheimer's disease: A pilot study | Iddon J.L.       | Journal of Neurology Neurosurgery and Psychiatry | 1999 | 6.1| 129        | 190                 |
| 100th | Intraventricular hemorrhage and hydrocephalus in premature newborns: A prospective study with CT | Burstein J.      | American Journal of Roentgenology | 1979 | 3.1| 129        | 248                 |

CC: Citation count, CY: Citation per year

Database and 1619 citations according to Google Scholar Database. The range of publications started from 1946 to 2014 in which 45 articles were published between 1998 and 2007 which marks the most prolific epoch in publications history of hydrocephalus [Figure 1]. The United States of America contributed to half of top 100 most cited articles on hydrocephalus [Figure 2]. The Canadian hospital for Sick Children University of Toronto published 5 articles in our review as the most contributing institute [Figure 3]. A thorough review of the top 100 articles showed that two major categories were addressed: hydrocephalus in general and normal pressure hydrocephalus. The most studied topic falls under the umbrella of surgical management of hydrocephalus “18 articles” and the pathophysiology of hydrocephalus “14 articles” came as a 2nd in terms of study interest [Table 2]. A summary of the top 5 most cited articles and the relevant information in the study are summarized [Table 3].

**Author and journal analysis**

In our review, around 160 authors have contributed to the top 100 most cited articles on hydrocephalus. The analysis of the contributing authors based on the 1st authors specialty demonstrated that neurosurgeons showed vast interest in hydrocephalus which accounted to approximately half of the articles in our bibliometric review [Figure 4]. A sub-analysis of the top 5 most contributing authors illustrated that Drake, J.M and Mori E both published four articles each

![Figure 1: Trends of highly cited works on hydrocephalus.](image1)

![Figure 2: Top 5 most contributing countries to the most-cited works on hydrocephalus.](image2)
in our review with approximately equal author Hirsch Index (H index) of 65 and 64, respectively [Figure 5]. The enlisted top 100 most cited articles on hydrocephalus were contributed by 46 journals. Journal based quantified inspection illustrated that the top 5 most contributing journals were accountable for producing 43 articles in our review. The Journal of Neurosurgery (JNS) published 17 articles and the 2nd most ranked journal was the Neurosurgery Journal where it produced 12 articles the SNIP and SJR scores emphasized that JNS is more influential and field specific when compared to the neurosurgery journals [Figure 6].

**DISCUSSION**

In the light of this bibliometric based evaluation of the impactful work on hydrocephalus to guide today's learner in the era of informational over satiety to denote important articles that need to be acknowledged.

| Table 3: Summary of the 5 top 5 most cited articles on hydrocephalus. |
|---------------------------------------------------------------|
| **Rank** | **Title** | **Summary** |
|-----------|---------------|-------------|
| 1st       | Symptomatic Occult Hydrocephalus with “Normal” Cerebrospinal fluid pressure: A Treatable Syndrome. | 1st clinical description of normal pressure hydrocephalus and how it diagnosed and the symptomatic relief with surgical ventricular shunting in 3 reported cases. |
| 2nd       | The Special clinical problem of symptomatic hydrocephalus with normal cerebrospinal fluid pressure: observation of Cerebrospinal Fluid Hydrodynamics. | A report of 3 cases where the 1st clinical depiction of normal pressure hydrocephalus syndrome presenting as mental dullness, psychomotor retardation, and incontinence with symptomatic relief after CSF diversion. Hydrodynamic explanation of dynamic press mechanism theory where ventricular elasticity and pressure on larger ventricles are inflicted in developing symptomatology. |
| 3rd       | Randomized Trial of Cerebrospinal Fluid Shunt Valve Design in Pediatric Hydrocephalus. | A comparative trial to assess the functional failure between Standard unidirectional valve, Delta Anti-siphon valve and orbis sigma with anti-siphon and pressure sensitive ring; Shunt failure rate from obstruction and infection in Delta or Orbis-Sigma showed no difference when compared to standard valve. |
| 4th       | X-Linked SPG1, MASA syndrome and X-linked Hydrocephalus result from mutations in the L1 Gene. | 1st genetic associational discovery that states the missense mutation of L1/L1CAM responsible gene in SPG1, Hydrocephalus due to stenosis of aqueduct of sylvius “HSAS, and MASA syndrome. Also, spasticity involvement due to absence of CTS tract denotes that L1 protein have a major role in CTS development. |
| 5th       | Neuropathological Changes Caused by Hydrocephalus | A review on the neuropathological changes of hydrocephalus and changes after intervention showed that the severity depends on the rate of dilation, magnitude of dilation, proximal structures to the dilation and the developmental stage of occurrence. Microvascular disturbance, axonal and myelin changes, astroglial reaction, cortical damage and periventricular extracellular fluid accumulation occurred in hydrocephalic brains. Reversal of hydrocephalus induced neuropathological changes is possible and is correlated with the duration of hydrocephalus and the time of intervention. |

CTS: Corticospinal, SPG1: Spastic Paraplegia G1
The observation of the published work showed that the most impactful articles started from 1946 but interestingly only between 1998 and 2008 almost half of articles in our list were produced which could be related to the radiological advancement and increasing availability of brain imaging that was started in 1980 and continued to increase until 2010 according to a review by Edelman.\(^8\) Notably, the predominance of hydrocephalus management existed in surgical intervention around 50% of our bibliometric analysis was contributed by neurosurgeons which emphasizes the role of neurosurgeons in this field. Various other specialties have contributed to our list as well such as neurology, genetics, radiology, and others indicating the diversity of medical professions dealing with the disease.

The major categories that were encountered when we reviewed the studied topics were mainly addressing hydrocephalus in general and normal pressure hydrocephalus. The majority of the articles were focused on the former \((n = 67)\), in which the most studied subcategory was the surgical management \((n = 18)\) followed by studies looking into the pathophysiology of hydrocephalus, our review also yielded two randomized controlled trials mainly comparing types of shunt valves. It is important to note that none of the studies that our research has yielded discussed medical therapy of hydrocephalus which supports that hydrocephalus is a surgical disease even with the recent advancement in research to medical therapy. The remainder of topics discussed genetic association \((n = 10)\), hydrocephalus in intracranial hemorrhage and studies of radiological nature as well as other categories. Regarding normal pressure hydrocephalus, the most frequently studied topics were clinical or epidemiological review articles \((n = 10)\) followed by surgical management studies \((n = 8)\). A few studies were published focusing on the association with Alzheimer’s disease and others outlining guidelines for management. The predominance of articles in our list studying hydrocephalus could probably be attributed to the incidence of the disease when compared to normal pressure hydrocephalus, as well as the more recent discovery of normal pressure hydrocephalus.

Our first ranked article was published in in 1965 by R. D. Adams titled “symptomatic occult hydrocephalus with normal cerebrospinal fluid pressure a treatable syndrome” which was released in the new England journal of medicine with a total CC of 896 (1619 citations on Google scholar). A follow-up paper after the one published by R. D. Adams and S. Hakim in the same year. The term normal pressure hydrocephalus was first introduced in this paper, which included three case reports of the condition while focusing on the clinical features as well as the diagnostic approach for the described entity, with strong focus was on the symptomology and suspected pathophysiology. The paper also addressed the variations of normal pressure hydrocephalus from other diseases that might mimic the conditions especially dementia as well as interpretations of the available investigations at the time. The paper stressed on the recognition of the syndrome due to the fact that the symptoms can subside with surgical ventricular shunting as demonstrated by their three presented cases.

Earlier in the year of 1965, S. Hakim and R. D. Adams published “The special clinical problem of symptomatic hydrocephalus with normal cerebrospinal fluid pressure, observations on cerebrospinal fluid hydrodynamics.” The study reported three cases of hydrocephalus in the setting of normal cerebrospinal fluid pressure. They also described the triad of symptoms observed in these cases constituting of the
famous triad of mental derangement, gait disturbance and urinary incontinence. The researchers reported recovery of the condition by lowering the cerebrospinal fluid pressure by means of ventriculoatrial shunting, while hypothesizing on the possible mechanism of symptom formation. The article was published in the Journal of the Neurological Sciences receiving a CC of 732 in Scopus database (1266 citations on Google scholar) since its publication, placing it second in our list. Both of the studies paved the way for further clinical research by first describing this treatable entity, its clinical features and management by lowering CSF pressure by surgical shunting which remains the treatment of choice to this day.

Drake, J.M. was our highest-ranking author with the most contribution to our list (total of 4 articles) and an author H index of 63. Followed by Mori, E. with the same number of publications, however, Mori, E had a higher author H index of 65. The remaining authors in our top 5 list with highest contribution were Bradley, W.G., Hashimoto, M. and Ishikawa, M. by contributing three articles each. The authors were ranked based on the number of publications as well as the number of citations in their published works. Drake, J.M. has published one of the three randomized controlled trials in our list “Randomized trial of cerebrospinal fluid shunt valve design in pediatric hydrocephalus” in 1998. The article has made its way to our top ten list by accumulating a CC of 509 (653 citations on Google scholar). The study compared the delta valve, orbis sigma valve which were new at the time and the standard differential-pressure valve. The aim was to assess the shunt failure rate between the excess flow limiting valves and the standard differential pressure valves. Total of 344 patients were randomized and received one of the three valves. The study concluded that there was no significant difference in shunt failure rates after 1 year between the three valves. The article was released in Neurosurgery, which is the second ranking journal in our list with 12 article contribution to our list (SNIP and SJR of 1.523 and 1.29 respectively).

JNS published most of the articles in our list, by releasing 17 papers. One of which titled “Acute hydrocephalus after aneurysmal subarachnoid hemorrhage” published in 1985 by Van Gijn J was ranked 7th in our list by being cited 324 times. The study reported the incidence of hydrocephalus in 200 patients with diagnosed ruptured intracranial aneurysms. Hydrocephalus was evident in 20% of the studied cases. They also discussed the clinical and radiological features as well as management with external ventricular drain. JNS had a SNIP of 2 and a SJR of 1.69. Journal of neurology, neurosurgery and psychiatry (SNIP 2.28 and SJR 3.211), and pediatric neurosurgery (SNIP 0.492 and SJR 0.341) were placed in 3rd and 4th places, respectively, by releasing five articles each, followed by brain with a total contribution of four papers.

CONCLUSION

In this bibliometric analysis, we identified the top 100 most-cited articles with the term “hydrocephalus” using Scopus database. This study delineates the landmark publications in hydrocephalus. It identifies the articles that have addressed the historical development and provided key studies which highlight the important progress made in the field. The data presented reveals several characteristic related to the top contributions, including authors, institutions, type of study, and journal. The findings indicate that papers originating from outstanding institutions in North America and UK, published in high impact journals had the highest citations. Recognizing the most influential publications will provide an important framework to an enhanced understanding of the scientific advancements made in the field and identify potential area of research. It also serves as an efficient guide to achieving evidence-based clinical practice to optimize the outcome, which will help in reducing the disease burden.

Limitations

Inherent limitations exist when performing a citation analysis on a certain clinical topic. The database specific limitation exists where only one database was used to perform this review study. The extent of self-citation among all authors was not significant in our identified studies. The significance of highlighting the most-cited works on hydrocephalus does not necessarily confer the influence of any given article but it merely reflects and justify why the scientific committee have given it a high number of citations.

Declaration of patient consent

Patient’s consent not required as there are no patients in this study.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Adams RD, Fisher CM, Hakim S, Ojemann RG, Sweet WH. Symptomatic occult hydrocephalus with normal cerebrospinal-fluid pressure. N Engl J Med 1965;273:117-26.
2. Alfaifi A, AlMutairi O, Allhaidan M, Alsaleh S, Ajlan A. The top 50 most-cited articles on acoustic neuroma. World Neurosurg 2018;111:e454-64.
3. Almutairi O, Albakr A, Al-Habib A, Ajlan A. The top-100 most-cited articles on meningoia. World Neurosurg

Surgical Neurology International • 2022 • 13(176) | 11
Albrahim, et al.: Top 100 articles on hydrocephalus

2017;107:1025-32.e5.
4. Aschoff A, Kremer P, Hashemi B, Kunze S. The scientific history of hydrocephalus and its treatment. Neurosurg Rev 1999;22:67-93; discussion 94-5.
5. Atci IB, Yilmaz H, Samanci MY. The top 50 most-cited articles on low-grade glioma: A bibliometric analysis. Br J Neurosurg 2019;33:171-5.
6. Del Bigio MR, Di Curzio DL. Nonsurgical therapy for hydrocephalus: A comprehensive and critical review. Fluids Barriers CNS 2016;13:3.
7. Dewan MC, Rattani A, Mekary R, Glancz LJ, Yunusa I, Baticulon RE, et al. Global hydrocephalus epidemiology and incidence: Systematic review and meta-analysis. J Neurosurg 2019;130:1065-79.
8. Edelman RR. The history of MR imaging as seen through the pages of radiology. Radiology 2014;273 Suppl 2:S181-200.
9. Garner RM, Hirsch JA, Albuquerque FC, Fargen KM. Bibliometric indices: Defining academic productivity and citation rates of researchers, departments and journals. J Neurointerv Surg 2018;10:102-6.
10. Hugar JG, Bachlapur MM, Anandhalli G. Research contribution of bibliometric studies as reflected in web of science from 2013 to 2017. Libr Philos Pract 2019;4:1-10.
11. Isaacs AM, Riva-Cambrin J, Yavin D, Hockley A, Pringsheim TM, Jette N, et al. Age-specific global epidemiology of hydrocephalus: Systematic review, metaanalysis and global birth surveillance. PLoS One 2018;13:e0204926.
12. Kahle KT, Kulkarni AV, Limbrick DD Jr., Warf BC. Hydrocephalus in children. Lancet 2016;387:788-99.
13. Krishnamurthy S, Li J. New concepts in the pathogenesis of hydrocephalus. Transp Pediatr 2014;3:185-94.
14. Levine DN. Intracranial pressure and ventricular expansion in hydrocephalus: Have we been asking the wrong question? J Neurol Sci 2008;269:1-11.
15. Nadri H, Rahimi B, Timpka T, Sedghi S. The top 100 articles in the medical informatics: A bibliometric analysis. J Med Syst 2017;41:150.
16. Rekate HL. The definition and classification of hydrocephalus: A personal recommendation to stimulate debate. Cerebrospinal Fluid Res 2008;5:2.
17. Samanci Y, Samanci B, Sahin E. Bibliometric analysis of the top-cited articles on idiopathic intracranial hypertension. Neurol India 2019;67:78-84.
18. Tao T, Zhao X, Lou J, Bo L, Wang F, Li J, et al. The top cited clinical research articles on sepsis: A bibliometric analysis. Crit Care 2012;16:R110.
19. Yin X, Cheng F, Wang X, Mu J, Ma C, Zhai C, et al. Top 100 cited articles on rheumatoid arthritis A bibliometric analysis. Medicine (United States) 2019;98:e14523.
20. Zhang WJ, Ding W, Jiang H, Zhang YF, Zhang JL. National representation in the plastic and reconstructive surgery literature: A bibliometric analysis of highly cited journals. Ann Plast Surg 2013;70:231-4.

How to cite this article: Albrahim M, Almutairi OT, Alhussinan MA, Alotaibi FE, Bafaquh M. Bibliometric overview of the Top 100 most cited articles on hydrocephalus. Surg Neurol Int 2022;13:176.