A Systematic Review of Neurosurgical Care in Low-Income Countries

Hannah K. Weiss[1,2], Roxanna M. Garcia[2,3], Jesutofunmi A. Omiye[4], Dominique Vervoort[5], Robert Riestenberg[1,2], Ketan Yerneni[1,2], Nikhil Murthy[2], Annie B. Wescott[6], Peter Hutchinson[7], Gail Rosseau[8]

Key words
- Global health
- Global neurosurgery
- Hydrocephalus
- Literature review
- Low-income countries
- Research
- Traumatic brain injury

Abbreviations and Acronyms
LCoGS: Lancet Commission on Global Surgery
LIC: Low-income country
TBI: Traumatic brain injury

From the [1]Feinberg School of Medicine, Northwestern University, Chicago, Illinois; [2]Department of Neurosurgery, Northwestern University, Chicago, Illinois; [3]Institute for Public Health and Medicine (IPHAM), Center for Healthcare Studies, Northwestern University, Chicago, Illinois, USA; [4]College of Medicine, University of Ibadan, Nigeria; [5]Program in Global Surgery and Social Change, Harvard Medical School, Boston, Massachusetts; [6]Galter Health Sciences Library & Learning Center, Northwestern University, Chicago, Illinois, USA; [7]Division of Neurosurgery, Department of Clinical Neurosciences, Addenbrooke's Hospital and University of Cambridge, Cambridge, United Kingdom; and [8]Midwest Neurosurgical Associates, Oak Brook, Illinois, USA

To whom correspondence should be addressed: Roxanna M. Garcia, M.D., M.S., M.P.H. [E-mail: roxymgarcia@gmail.com]

Citation: World Neurosurg. X (2020) 5:100068. https://doi.org/10.1016/j.wnsx.2019.100068

Journal homepage: www.journals.elsevier.com/world-neurosurgery-x

Available online: www.sciencedirect.com

OBJECTIVE: **More than 5 billion individuals lack access to essential surgical care. Neurosurgical care is especially limited in low-income countries (LICs). Studies describing neurosurgical care in LICs are critical for understanding global disparities in access to neurosurgical procedures. To better understand these disparities, we conducted a systematic review of the literature identifying neurosurgical patients in LICs.**

METHODS: **MEDLINE (PubMed), Embase (embase.com), and Cochrane Library (Wiley) databases were systematically searched to retrieve studies describing neurosurgical care in LICs as defined by the World Bank Country and Lending Groups income classification. All databases were searched from their inception; no date or language limits were applied. All the articles were blindly reviewed by 2 individuals. Data from eligible studies were extracted and summarized.**

RESULTS: **Of the 4377 citations screened, 154 studies met inclusion criteria. The number of publications substantially increased over the study period, with 49% ($n = 76$) of studies published in the last 5 years. Twenty-six percent ($n = 40$) of studies had a first author, and 30% ($n = 46$) had a senior author, affiliated with a country different from the LIC of study. The most common neurosurgical diagnosis was traumatic brain injury (24%, $n = 37$), followed by hydrocephalus (26%, $n = 40$), and neoplastic intracranial mass (10%, $n = 16$). Of LICs, 43% ($n = 15/35$) had no published neurosurgical literature.**

CONCLUSIONS: **There is a significant deficit in the literature on neurosurgical care in LICs. Efforts must focus on supporting research initiatives in LICs to improve publication bias and understand disparities in access to neurosurgical care in the lowest-resource countries.**

INTRODUCTION

More than 5 billion individuals lack access to safe, timely, affordable, and essential surgical and anesthesia care when needed.[1] Neurosurgical care can require complex resources and a specialized workforce, which is often limited in low-income countries (LICs). Limited access to neurosurgical care can contribute significantly to disability and mortality. These disparities disproportionally affect individuals with trauma, with an estimated prevalence of traumatic brain injury (TBI) between 55 and 69 million individuals each year, with its greatest burden in LICs.[2,3] Among pediatric populations, access to safe neurosurgical care significantly affects children with hydrocephalus, one of the most prevalent and increasing pediatric neurosurgical conditions in LICs.[4] In contrast, the research and academic productivity from LICs reaching the global community were found to have significant deficits in LICs and lower middle-income countries since the release of the Lancet Commission on Global Surgery (LCoGS) in 2015.[1]

Access to safe, timely, and affordable essential surgical and anesthetic care has become a global health priority since the establishment of the LCoGS, and the release of the World Health Assembly Resolution WHA68.15 in 2015.[5,6] There have been several significant sustainable trainings and education programs in LICs, such as Uganda, Papua New Guinea, and Haiti, which have established formal neurosurgical training programs locally.[7-10] Despite such efforts, neurosurgical care remains significantly limited in most LICs. Individual studies have reported the success of these programs, but there remains no centralized database for neurosurgical care available for tracking global progress and impact of reported works from LICs. Without proper data collection, global neurosurgery, like all other surgical specialties, will be limited in implementing sustainable changes that can help reduce

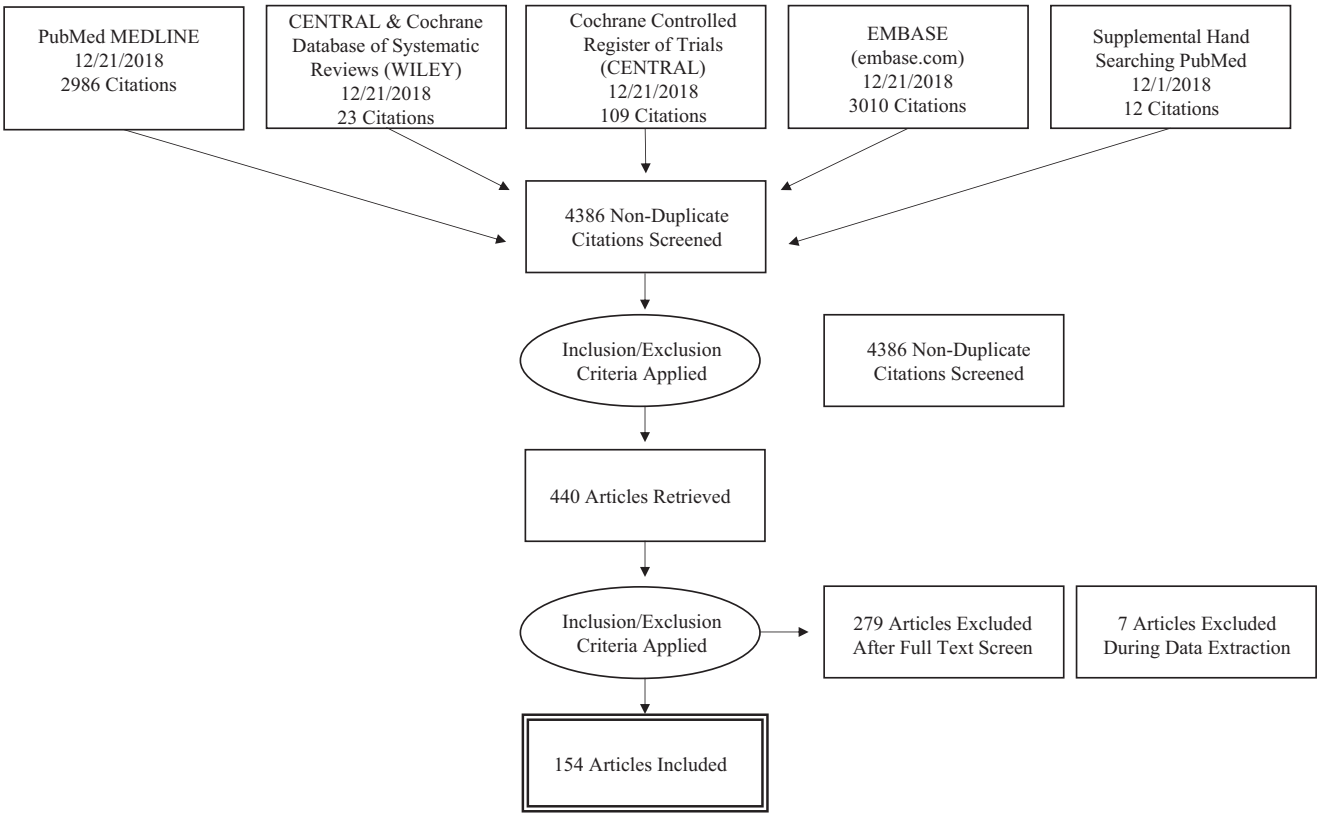

Figure 1. PRISMA flow diagram of systematic review of neurosurgical studies on low-income countries, outlining the number of initial nonduplicate citations screened, the articles excluded, and the final 154 included articles.

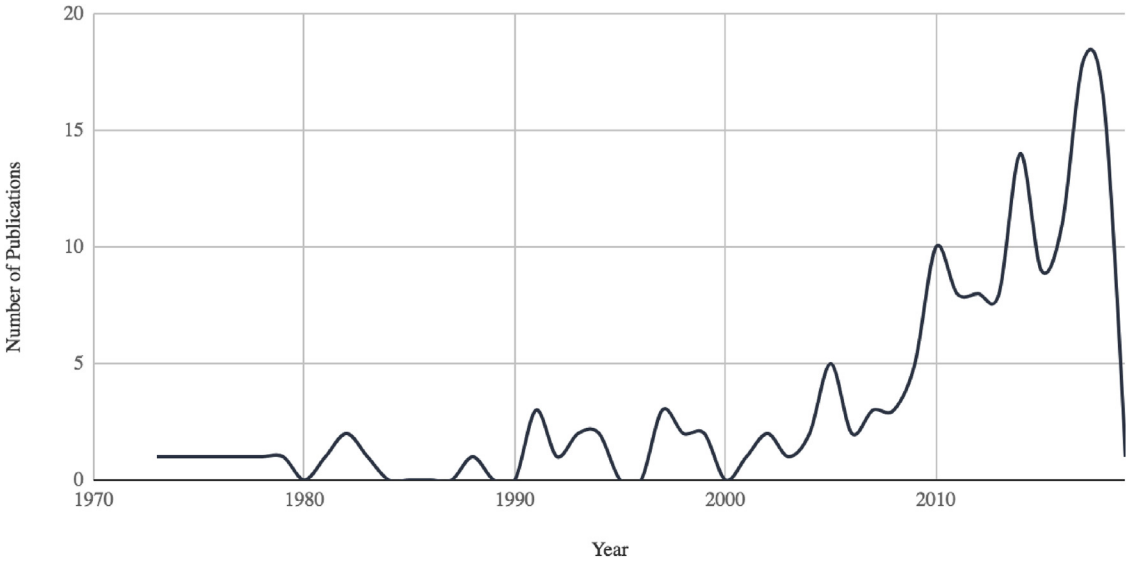

Figure 2. Neurosurgical studies on low-income countries by year, showing the number of neurosurgical studies per year as identified in this systematic review.

Table 1. Extracted Data from Neurosurgical Studies on Low-Income Countries between 1973 and 2019

	Studies (N = 154), % (n)
Study design	
Cohort	37 (57)
Cross-sectional	51 (78)
Randomized controlled trial	1 (1)
Case series	12 (18)
Language	
English	74 (114)
French	26 (40)
Multisite study	7 (11)
Multicenter study	3 (5)
Short-term surgical trip	6 (10)
Author affiliation same as country of study	
First author	74 (114)
Senior author	70 (108)
Type of center	
Public	58 (89)
Private	14 (22)
University	22 (34)
Charity	2 (3)
Unknown	4 (6)
Trauma procedure(s)	29 (45)
Elective procedure(s)	59 (91)
Both trauma and elective procedures	11 (17)
Pediatric study	55 (84)
Primary neurosurgical diagnosis	
Traumatic brain injury/head trauma	24 (37)
Hydrocephalus	26 (40)
Neoplastic intracranial mass	10 (16)
Spine trauma	8 (13)
Elective spine	6 (10)
Pediatric spine	6 (9)
Vascular	6 (10)
Cerebral abscess	5 (8)
Peripheral nerve	2 (3)
Epilepsy	1 (2)
Spine infection	1 (2)
Documented clinical data	
Time of symptom onset to care	27 (41)
Mechanism of injury (studies including trauma only)	77 (48)
Access to imaging	36 (56)
Comorbidities	9 (14)
Documented demographic data	
Age	
Mean age	55 (85)
Median age	16 (24)
Age range	51 (78)
Gender	62 (96)
Total females	8613
Total males	13,010
Home location	16 (24)
Distance home to health care system	6 (9)
Socioeconomic status	5 (7)
Education level	3 (4)
Ethnic origin	3 (5)
Marginalized population	0
Patient outcome data	
Complications	49 (75)
Follow-up	46 (71)
Quality of life	10 (15)
Disease-free survival	20 (31)
Overall survival	66 (102)

these access barriers. Efforts to characterize the neurosurgical workforce in LICs and global burden of disease have established a foundation for understanding the number of neurosurgeons and neurosurgical disease globally.[11,3] The best publicly available estimates from LICs on disease burden come from the Institute of Health Metrics and Evaluation (www.healthdata.org). Although there has been substantial work in characterizing neurosurgical workforce, there have been limited attempts to characterize neurosurgical research and publications. Reported studies share insightful information for increasing access to care in other low-resource settings and also provide a window into the resources available in some of the most impoverished parts of the world.

Successful ongoing efforts have provided neurosurgical care to a few individuals in LICs. As neurosurgical programs continue to expand, it remains unclear which individuals within LICs are receiving care. To better understand these disparities in access to neurosurgical care, we conducted a systematic review of the literature identifying patients and neurosurgical procedures performed in LICs.

METHODS

Literature Search and Strategy

A systematic search for all publications describing neurosurgical patients in LICs was conducted to identify all eligible articles. A research librarian (A.B.W.) collaborated with the review authors (H.W. and R.G.) to develop a comprehensive search strategy. MEDLINE (PubMed), Embase (embase.com), and the Cochrane Library (Wiley) databases were searched on December 21, 2018. The search strategy included title/abstract and controlled vocabulary terms for LICs and neurosurgical procedures. Database-specific logic and wildcards were applied. All databases were searched back to their inception without application of language or date restrictions. Supplemental hand searching was performed to identify additional records. The complete search strategies, including research terms, are available in **Appendix 1**.

Data Extraction and Selection Criteria

Results were exported to a citation management system (EndNote) for multipass deduplication. Unique records were then uploaded to Rayyan online screening system and independently reviewed by 2 review authors (H.W. and R.G.). Included studies had to meet the following criteria: 1) studies describing neurosurgical patients and 2) studies describing patients receiving care in LICs, as defined by the World Bank Country and Lending Groups classification.[12] Case reports with <10 patients and studies describing military

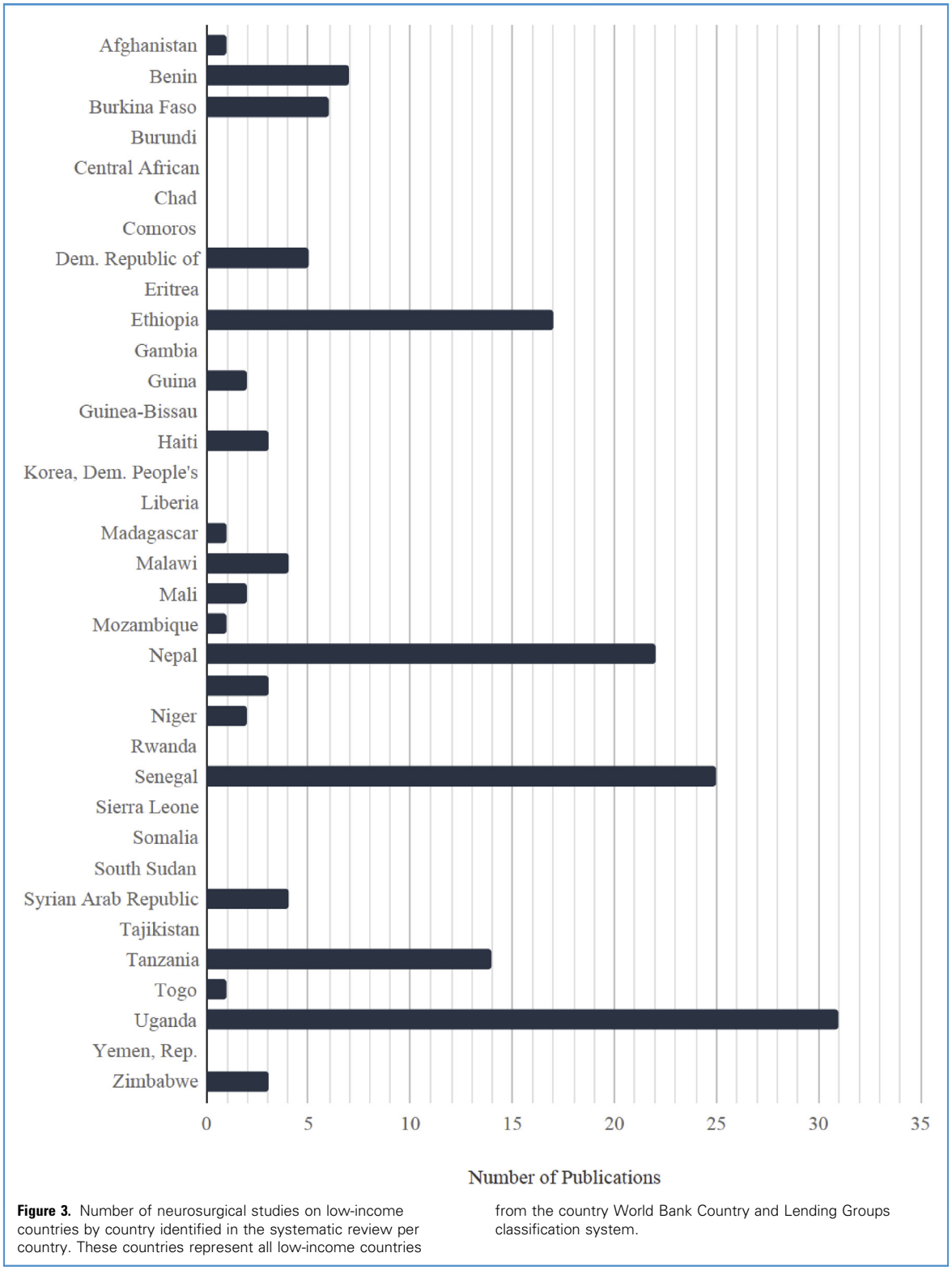

Figure 3. Number of neurosurgical studies on low-income countries by country identified in the systematic review per country. These countries represent all low-income countries from the country World Bank Country and Lending Groups classification system.

response aid/relief were excluded. Language was not restricted. Articles were translated during the review process and included studies written in French were translated and data were extracted by an author fluent in French (D.V.). Discrepancies were resolved through discussion and consensus between the reviewers.

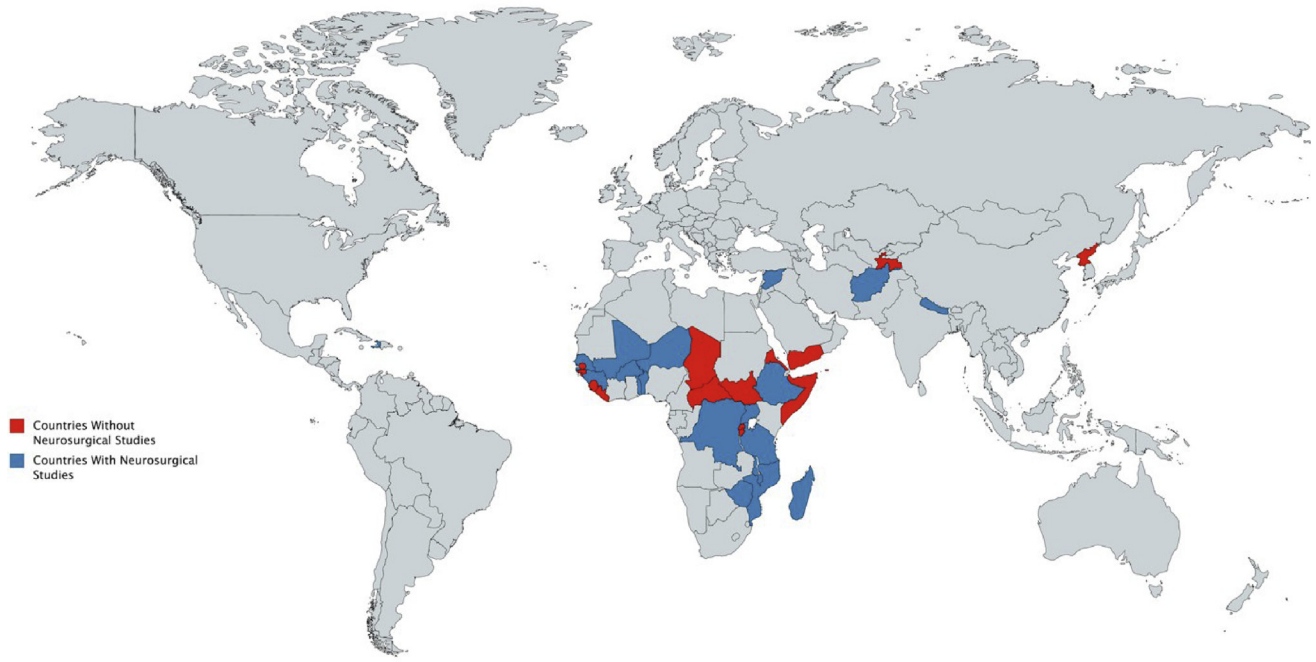

Figure 4. Low-income countries with and without published neurosurgical studies. World map designating countries that have neurosurgical studies identified in this systematic review. Red indicates countries without any published studies describing neurosurgical patients. Blue indicates countries with 1 published neurosurgical study.

Data extracted from each eligible study included article characteristics, including author and affiliation, hospital characteristics, patient characteristics, primary neurosurgical diagnoses and procedures, and demographic and outcomes data documented in the article. Primary study measures included data on the published articles, such as publication year, country of study, and affiliation of authors. Secondary study measures included variables documented in the study, including demographic data (e.g., age, gender, and socioeconomic status), clinical data (e.g. elective vs. trauma procedure, long-term vs. short-term surgical trips), and outcomes data (follow-up documentation, postoperative complications, and overall survival). Author affiliation was determined by identifying the documented affiliated institute from the article. Short-term surgical trips were defined as studies describing neurosurgical care provided by visiting surgeons, affiliated with a hospital outside the LIC of study. Multicenter studies were defined as studies occurring at multiple provinces, states, or countries. Multisite studies were defined as studies occurring at multiple health care centers but in the same city or region. Pediatric studies were defined as studies including only patients aged 18 years and younger. Data extracted from each study were summarized and presented by study measures.

RESULTS

Literature Search Results

The initial search resulted in 6260 articles. After duplicate articles were removed (n = 1883), 4386 unique articles were identified. After the initial screening, 3946 articles did not meet inclusion criteria, most often because they were not from an LIC, were off topic, or did not describe neurosurgical patients. The text of the remaining 440 articles was fully reviewed. After full text review, 286 studies were excluded. There were 3 studies in which the full text could not be retrieved.[4,5,13] Supplemental hand searching resulted in 8 additional included articles. A total of 154 articles met final inclusion criteria (see **Figure 1** for PRISMA [Preferred Reporting Items for Systematic Reviews and Meta-Analyses] flowchart). Among the final articles, 51% (n = 78) were cross-sectional studies and 37% (n = 57) were cohort studies, with only 12% (n = 18) being large case series and 1% (n = 1) being randomized controlled studies. Eleven articles (7%) had the exact replication of patient population,[14-24] and 22 (14%) had some overlap of patient population.[25-46]

The 154 articles were published between 1973 and 2019, with 49% of articles (n = 76) being from the last 5 years (2014–2018; see **Figure 2**). Most of the articles were in English (74%, n =114), with 26% (n = 40) being published in French (**Table 1**). Uganda had the most neurosurgical publications, making up 20% of all articles (n = 31), followed by Nepal (14%, n = 22) and Senegal (16%, n = 25; **Figure 3**). Of all LICs, 43% (n = 15/35) had no neurosurgical studies identified (**Figure 4**). Public hospitals made up most study locations (58%, n = 89), with only 14% (n = 22) of studies from private hospitals and 22% (n = 34) from university hospitals. Of all included studies, only 7% (n = 11) were multisite studies, and 3% (n = 5) were multicenter studies. Studies from short-term visiting surgical trips made up 6% (n = 10) of studies. The overall proportion of first and

senior authors affiliated with the country of study was 74% (n = 114) and 70% (n = 108), respectively.

Patient Characteristics and Demographics

The included studies describe 20,321 patients after duplicates were removed. The clinical characteristics reported by each study were highly variable. Approximately, 67% (n = 103) reported on 1 specific neurosurgical diagnosis, and 32% (n = 50) had multiple diagnoses. The most common neurosurgical diagnosis was TBI/head injury (24%, n = 37), followed by hydrocephalus (26%, n = 40), neoplastic intracranial mass (10%, n = 16), and spine trauma (8%, n = 13). Approximately 59% (n = 91) described elective surgical procedures and 29% (n = 45) described traumatic injuries; the remaining studies (11%, n = 17) described both trauma and elective surgical procedures. Among the studies with primary trauma procedures, 77% (n = 48) specified the mechanism of injury.

The mean age was documented in 55% (n = 85), median age in 16% (n = 24), and age range in 51% (n = 78) of articles. Pediatric studies made up 55% (n = 84) of all included articles. The mean age among all articles was 22.8 years, ranging from newborn to 95 years old. Gender was documented in 62% of studies (n = 96). The overall male/female ratio of all articles documenting gender was 1.5. When excluding studies describing solely traumatic injuries, the male/female ratio was 1.2, whereas the male/female ratio in studies identifying only trauma injuries was 3.6.

Minimal other demographic variables were reported. Location of home was documented in 16% of studies (n = 24), and distance from home to a healthcare facility was documented in 6% of studies (n = 9). Articles reporting demographic data such as socioeconomic status (5%, n = 7), education level (3%, n = 4), ethnic origin (3%, n = 5), and marginalized group (0%, n = 0) were limited. Access to imaging was specified in 36% of articles (n = 56) and relevant patient comorbidities were reported in 9% of articles (n = 14).

Patient Outcomes

The composition and reporting of patient outcomes varied substantially. Complications were documented in 49% of studies (n = 75), and follow-up was documented in 46% (n = 71). Among the studies that included data on patient follow-up, the mean follow-up rate was 80% with a mean follow-up time of 14 months (6 days–8 years). Twenty percent (n = 31) documented disease-free survival and 66% (n = 102) documented overall survival. The reasons for patient mortality were documented in 30% (n = 46) and quality-of-life assessment was documented in only 10% of all studies (n = 15).

DISCUSSION

This systematic review describes published neurosurgical care studies from LICs and shows significant heterogeneity in study quality, patient characteristics, and outcomes reported. The studies primarily comprised cohort and cross-sectional studies, with few high-level evidence randomized controlled studies. The top 2 diagnoses were TBI/head trauma and hydrocephalus, consistent with the literature on the most common neurosurgical diseases globally.[2,47,48] To expand access to neurosurgery, data from LICs are essential to inform these efforts. Although some LICs have limited published research, the number of neurosurgical studies in LICs is increasing, reflecting the increasing interest to improve neurosurgical care globally, as essential and emergency surgical care becomes an important agenda item for global health priorities and universal health care coverage. The increase in neurosurgical studies after 2015 corresponds with the development of the LCoGS, suggesting that the literature on neurosurgery in LICs will continue to increase as global neurosurgery becomes a more formally accepted, established field. In addition, the number of neurosurgical publications from LICs would be expected to increase as access to technology, such as computers and Internet, as well as the frequency of e-publications, continue to increase globally. Despite recent increases in neurosurgical studies, nearly half of all LICs did not have a single published article using our inclusion criteria.

Despite the limitations in published neurosurgical studies from LICS, there has been significant, innovative work in some LICs targeting broad and sustainable practices. One example is Dr. Benjamin Warf's development of the CURE Children's Hospital of Uganda, staffed entirely by individuals from Uganda.[9] The published works of CURE Children's Hospital of Uganda have helped fuel, inform, and direct the establishment of similar projects worldwide.[8] Conversely, in countries lacking basic infrastructure, economic and political stability, as well as war-torn regions (e.g., South Sudan), it is not surprising that there is an absence of neurosurgical publications.

The barriers that exist for publishing neurosurgical articles are multifactorial. Countries with insufficient numbers of neurosurgeons to care for massive populations with high trauma burden face significant challenges in providing basic, essential neurosurgical care, in addition to many LICs, which already have limited neurosurgical care.[49] The neurosurgical workforce in LICs likely has less time and flexibility to develop the skills needed for academic research resulting in publications.[50] Language barriers also contribute to the challenges of interpreting and publishing global neurosurgery research, because nearly one third of the studies identified were in French.

More than a quarter of first and senior authors did not live in the LIC of study, suggesting a considerable focus on the short-term efforts from foreign neurosurgeons. This pattern in authorship may lead to a body of literature missing critical information, such as the valuable insights from cultural perspectives, long-term follow-up, and priorities of the LIC studied. The rate of publications from authors outside LICs also reflects a similar problem of "mission trip" surgical practice, in which neurosurgical care is provided to individuals in low-resource settings, with limited sustainability and unclear effect on long-term care.[51] In an attempt to increase involvement of LIC physicians in academic neurosurgery, a few formal opportunities are offered within the global neurosurgery community. The Foundation for International Education in Neurological Surgery (http://www.fiens.org) has been supporting training for several decades and offers a travel fellowship, entitled the Basset Global Neurosurgery Fellowship for neurosurgeons from LMICs. In addition, the American Association of Neurological Surgeons (www.aans.org) offers an International Visiting Surgeon Fellowship,

aimed at providing access to training in North America for LIC or lower-middle income neurosurgeons. Academic institutions such as Oregon Health and Science University through the Global Neurosurg Collaborative and Brain Initiative have supported visiting scholars. In addition, the Harvard Program for Global Surgery and Social Change (https://www.pgssc.org) and the National Institutes of Health Fogarty International Center have provided opportunities for trainees and intensive research in global neurosurgery. These existing educational opportunities provide individuals from LICs with unique insight into how to contribute to the global landscape of academic neurosurgery, and further opportunities would likely broaden LIC involvement with research.

Potential solutions for developing more robust research efforts in LICs include establishing research methodology courses, both on the ground and online through webinars, and promoting trainee research networks. In addition, building networks between high-income countries and LICs, as well as within LICs, and further encouraging studies led by LICs and emphasizing that first and senior authors should be from the host country, will promote greater research contributions from LICs. Creating simple efficient data collection methods, as shown in GNOS (Global Neurotrauma Outcomes Study),[52] will simplify and streamline the data collection process, building research capacity in LICs and improving understanding of neurosurgical care and access globally.

There are important limitations of this systematic review. Publication bias is the principal limitation. We elected to exclude case reports, which were few and did not contribute meaningfully to the results. Author affiliation was determined by the affiliation data listed on the article and was not further investigated to determine history of previous work in the LIC of study, because the hospital association details as provided at the time of the included study were considered to be adequate for estimating author affiliation. Another important limitation is that the specific surgical specialty that generally provides spine surgery may vary substantially based on country, city, or even hospital. Orthopedic studies were not explored in this study, but future analysis of orthopedic studies in LICs may help further uncover publications on spinal surgery in certain LICs. Data reported in neurosurgical articles showed marked heterogeneity in documented patient outcomes, consistent with the neurosurgical literature from high-income countries (e.g., it is more relevant for certain neurosurgical diagnoses and procedures to report complications and follow-up). The variation in reported demographic variables was also substantial. In juxtaposition with clinical neurosurgical research performed in the United States, in which demographic variables such as age, gender, race, ethnicity, and socioeconomic status are typically reported, neurosurgical studies from LICs reported limited demographic data beyond age and gender. Some studies even excluded these basic population characteristics. Neurosurgical care is limited in LICs, but it remains challenging to determine who receives this limited resource. A structured set of demographic variables to collect when performing neurosurgical clinical research in LICs, or a widespread database incorporating basic demographic information, may help elucidate disparities in care even in these settings in which resources are low.

CONCLUSIONS

Publications from LICs describing neurosurgical care are limited, likely in part because of the limited number of neurosurgeons and researchers. Existing publications vary substantially, and limited demographic data are reported, making it challenging to analyze the populations receiving neurosurgical care. This gap in the literature could be improved by creating opportunities to mentor and increase support for research efforts in LICs. In addition, establishing a standardized list of suggested demographic variables to collect when performing global neurosurgical research in LICs, and collaborating to continue to expand neurosurgical care in LICs, will play significant roles in improving care in these countries, locally and globally.

DECLARATION OF COMPETING INTEREST

P.H. is supported by the NIHR Global Health Research Group on Neurotrauma (http://neurotrauma.world), NIHR Research Professorship and the NIHR Cambridge BRC. R.G. serves as the StrokeNet research fellow under grant U24 NS107233-01 and Fogarty Global Health Trainee. Research reported in this article was supported by the Fogarty International Center and National Institute of Mental Health, of the National Institutes of Health under award number D43 TW010543. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

REFERENCES

1. Alkire BC, Raykar NP, Shrime MG, et al. Global access to surgical care: a modelling study. *Lancet Glob Health*. 2015;3:e316-323.

2. Roozenbeek B, Maas AI, Menon DK. Changing patterns in the epidemiology of traumatic brain injury. *Nat Rev Neurol*. 2013;9:231-236.

3. Global, regional, and national burden of traumatic brain injury and spinal cord injury, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol*. 2019;18:56-87.

4. Stagno V, Mugamba J, Ssenyonga P, Kaaya BN, Warf BC. Presentation, pathology, and treatment outcome of brain tumors in 172 consecutive children at CURE Children's Hospital of Uganda. The predominance of the visible diagnosis and the uncertainties of epidemiology in sub-Saharan Africa. *Childs Nerv Syst*. 2014;30:137-146.

5. Meara JG, Hagander L, Leather AJM. Surgery and global health: a Lancet Commission. *Lancet*. 2014;383:12-13.

6. Price R, Makasa E, Hollands M. World Health Assembly Resolution WHA68.15: "Strengthening Emergency and Essential Surgical Care and Anesthesia as a Component of Universal Health Coverage"—addressing the public health gaps arising from lack of safe, affordable and accessible surgical and anesthetic services. *World J Surg*. 2015;39:2115-2125.

7. Kaptigau WM, Rosenfeld JV, Kevau I, Watters DA. The establishment and development of neurosurgery services in Papua New Guinea. *World J Surg*. 2016;40:251-257.

8. Shah AH, Barthélemy E, Lafortune Y, et al. Bridging the gap: creating a self-sustaining neurosurgical residency program in Haiti. *Neurosurg Focus*. 2018;45:E4.

9. Haglund MM, Kiryabwire J, Parker S, et al. Surgical capacity building in Uganda through twinning, technology, and training camps. *World J Surg*. 2011;35:1175-1182.

10. Haglund MM, Warf B, Fuller A, et al. Past, present, and future of neurosurgery in Uganda. *Neurosurgery*. 2017;80:656-661.

11. Global, regional, and national burden of neurological disorders, 1990-2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol*. 2019;18:459-480.

12. World Bank. Data: Country Classification, Low-Income Countries. World Bank Country and Lending Groups. Available at: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519. Accessed November 1, 2018.

13. Servadei F, Tropeano MP, Spaggiari R, et al. The footprint of publications from low- and low middle income countries in the Neurosurgical literature: a study from 2015 to 2017. *World Neurosurg*. 2019;130:e822-e830.

14. Abdelgadir J, Elahi C, Corley J, et al. Trends in neurosurgical care in Western Uganda: an interrupted time series analysis. *Neurosurg Focus*. 2018;45:E15.

15. Attebery JE, Mayegga E, Louis RG, Chard R, Kinasha A, Ellegala DB. Initial audit of a basic and emergency neurosurgical training program in rural Tanzania. *World Neurosurg*. 2010;73:290-295.

16. Fletcher A, Sims-Williams H, Wabulya A, Boling W. Stigma and quality of life at long-term follow-up after surgery for epilepsy in Uganda. *Epilepsy Behav*. 2015;52:128-131.

17. Kulkarni AV, Warf BC, Drake JM, et al. Surgery for hydrocephalus in sub-Saharan Africa versus developed nations: a risk-adjusted comparison of outcome. *Childs Nerv Syst*. 2010;26:1711-1717.

18. Thioub M, Mbaye M, Thiam AB, et al. Pediatric intracranial aneurysms in Senegal: a series of 10 cases treated in unfavorable socio-economic conditions. *Childs Nerv Syst*. 2019;35:165-168.

19. Warf BC. Hydrocephalus in Uganda: the predominance of infectious origin and primary management with endoscopic third ventriculostomy. *J Neurosurg*. 2005;102(1 suppl):1-15.

20. Warf BC. Comparison of 1-year outcomes for the Chhabra and Codman-Hakim Micro Precision shunt systems in Uganda: a prospective study in 195 children. *J Neurosurg*. 2005;102(4 suppl):358-362.

21. Warf BC. Comparison of endoscopic third ventriculostomy alone and combined with choroid plexus cauterization in infants younger than 1 year of age: a prospective study in 550 African children. *J Neurosurg*. 2005;103(6 suppl):475-481.

22. Warf BC. Congenital idiopathic hydrocephalus of infancy: the results of treatment by endoscopic third ventriculostomy with or without choroid plexus cauterization and suggestions for how it works. *Childs Nerv Syst*. 2013;29:935-940.

23. Warf BC, Dagi AR, Kaaya BN, Schiff SJ. Five-year survival and outcome of treatment for postinfectious hydrocephalus in Ugandan infants. *J Neurosurg Pediatr*. 2011;8:502-508.

24. Warf BC, Kulkarni AV. Intraoperative assessment of cerebral aqueduct patency and cisternal scarring: impact on success of endoscopic third ventriculostomy in 403 African children. *J Neurosurg Pediatr*. 2010;5:204-209.

25. Agrawal A, Kumar A, Agrawal CS, Pratap A, et al. One year of neurosurgery in the eastern region of Nepal. *Surg Neurol*. 2008;69:652-656 [discussion: 656].

26. Bajracharya A, Agrawal A, Yam B, Agrawal C, Lewis O. Spectrum of surgical trauma and associated head injuries at a university hospital in eastern Nepal. *J Neurosci Rural Pract*. 2010;1:2-8.

27. Bajracharya S, Singh M, Singh GK, Shrestha BP. Clinico-epidemiological study of spinal injuries in a predominantly rural population of eastern Nepal: a 10 years' analysis. *Indian J Orthop*. 2007;41:286-289.

28. Eaton JC, Hanif AB, Charles AG. Outcomes after exploratory burr holes for traumatic brain injury in a resource poor setting. *J Am Coll Surg*. 2017;225:S106-S107.

29. Eaton J, Hanif AB, Mzumara S, Charles A. The utility of local anesthesia for neurosurgical interventions in a low-resource setting: a case series. *World J Surg*. 2018;42:1248-1253.

30. Fuller AT, Haglund MM, Lim S, et al. Pediatric neurosurgical outcomes following a neurosurgery health system intervention at Mulago National Referral Hospital in Uganda. *World Neurosurg*. 2016;95:309-314.

31. Gandaho HJ, Adeleye AO, Kerekou A, Yekpe P, Djrolo F. Constraints in the neurosurgical management of pituitary tumours in an African developing country: a 5-year observational study from Benin Republic. *Afr J Med Med Sci*. 2016;45:261-267.

32. Gandaho HJ, Soumaila M, Hoinsou-Hans I, Djrolo GM, Zevounou AA, Adeleye AO. Main neurosurgical pathologies in Benin Republic. *J Neurosci Rural Pract*. 2016;7:S52-S56.

33. Kuo BJ, Vaca SD, Vissoci JRN, et al. A prospective neurosurgical registry evaluating the clinical care of traumatic brain injury patients presenting to Mulago National Referral Hospital in Uganda. *PLoS One*. 2017;12:e0182285.

34. Leidinger A, Piquer J, Kim EE, Nahonda H, Qureshi MM, Young PH. Treating pediatric hydrocephalus at the Neurosurgery Education and Development Institute: the reality in the Zanzibar Archipelago, Tanzania. *World Neurosurg*. 2018;117:e450-e456.

35. Leidinger A, Piquer J, Kim EE, Nahonda H, Qureshi MM, Young PH. Experience in the early surgical management of myelomeningocele in Zanzibar. *World Neurosurg*. 2019;121:e493-e499.

36. Sims-Williams HJ, Sims-Williams HP, Mbabazi Kabachelor E, Warf BC. Renal outcomes in children with operated spina bifida in Uganda. *Int J Nephrol*. 2018;2018:6278616.

37. Tran TM, Fuller AT, Kiryabwire J, et al. Distribution and characteristics of severe traumatic brain injury at Mulago National Referral Hospital in Uganda. *World Neurosurg*. 2015;83:269-277.

38. Vaca SD, Xu LW, Nalwanga J, et al. Long-term follow-up of pediatric head trauma patients treated at Mulago National Referral Hospital in Uganda. *J Neurosurg Pediatr*. 2018;23:125-132.

39. Warf B, Ondoma S, Kulkarni A, et al. Neurocognitive outcome and ventricular volume in children with myelomeningocele treated for hydrocephalus in Uganda. *J Neurosurg Pediatr*. 2009;4:564-570.

40. Warf BC, Bhai S, Kulkarni AV, Mugamba J. Shunt survival after failed endoscopic treatment of hydrocephalus. *J Neurosurg Pediatr*. 2012;10:463-470.

41. Warf BC, Campbell JW. Combined endoscopic third ventriculostomy and choroid plexus cauterization as primary treatment of hydrocephalus for infants with myelomeningocele: long-term results of a prospective intent-to-treat study in 115 East African infants. *J Neurosurg Pediatr*. 2008;2:310-316.

42. Warf BC, Mugamba J, Kulkarni AV. Endoscopic third ventriculostomy in the treatment of childhood hydrocephalus in Uganda: report of a scoring system that predicts success. *J Neurosurg Pediatr*. 2010;5:143-148.

43. Warf BC, Tracy S, Mugamba J. Long-term outcome for endoscopic third ventriculostomy alone or in combination with choroid plexus cauterization for congenital aqueductal stenosis in African infants. *J Neurosurg Pediatr*. 2012;10:108-111.

44. Warf BC, Wright EJ, Kulkarni AV. Factors affecting survival of infants with myelomeningocele in southeastern Uganda. *J Neurosurg Pediatr*. 2011;7:127-133.

45. Xu LW, Vaca SD, Nalwanga J, et al. Life after the neurosurgical ward in Sub-Saharan Africa: neurosurgical treatment and outpatient outcomes in Uganda. *World Neurosurg*. 2018;113:e153-e160.

46. Erem G, Bugeza S, Malwadde EK. Outcome at two weeks in patients with Traumatic brain injury following road traffic accidents in an urban tertiary hospital in Uganda. *Cogent Medicine*. 2017;4. https://doi.org/10.1080/2331205X.2017.1326205.

47. Hutchinson PJ, Kolias AG, Tajsic T, et al. Consensus statement from the International Consensus Meeting on the Role of Decompressive Craniectomy in the Management of Traumatic Brain Injury : Consensus statement. *Acta Neurochir (Wien)*. 2019;161:1261-1274.

48. Stagno V, Navarrete EA, Mirone G, Esposito F. Management of hydrocephalus around the world. *World Neurosurg*. 2013;79(2 suppl). S23.e17-S23.e20.

49. Park KB, Johnson WD, Dempsey RJ. Global neurosurgery: the unmet need. *World Neurosurg*. 2016;88:32-35.

50. Cadotte DW, Sedney C, Djimbaye H, Berstein M. A qualitative assessment of the benefits and challenges of international neurosurgical teaching collaboration in Ethiopia. *World Neurosurg*. 2014; 82:980-986.

51. Shrime MG, Sleemi A, Ravilla TD. Charitable platforms in global surgery: a systematic review of their effectiveness, cost-effectiveness, sustainability, and role training. *World J Surg*. 2015;39:10-20.

52. Kolias AG, Rubiano AM, Figaji A, Servadei F, Hutchinson PJ. Traumatic brain injury: global collaboration for a global challenge. *Lancet Neurol*. 2019;18:136-137.

Received 30 August 2019; accepted 29 November 2019

Citation: World Neurosurg. X (2020) 5:100068.
https://doi.org/10.1016/j.wnsx.2019.100068

Journal homepage: ***www.journals.elsevier.com/world-neurosurgery-x***

Available online: ***www.sciencedirect.com***

Appendix 1. Search Terms and Strategies
All Searches Conducted on December 21, 2018

Database	Query			Results
PubMed MEDLINE	((("Developing Countries"[Mesh] OR Developing Countr*[tiab] OR "Least Developed Countries"[tiab] OR "Least Developed Country"[tiab] OR Less-Developed Countr*[tiab] OR Under-Developed Nations[tiab] OR Under-Developed Nation[tiab] OR Underdeveloped Nations[tiab] OR Underdeveloped Nation[tiab] OR Third-World Countr* [tiab] OR Third-World Nations[tiab] OR Third-World Nation[tiab] OR Under-Developed Countr*[tiab] OR Underdeveloped Countr*[tiab] OR Developing Nations[tiab] OR Developing Nation[tiab] OR Less-Developed Nations[tiab] OR Less-Developed Nation[tiab] OR "low and middle income countries"[tiab] OR low-to-middle-income countries[tiab] OR LMIC[tiab] OR Afghanistan[MeSH] OR Benin[MeSH] OR Burkina Faso[MeSH] OR Burundi[MeSH] OR Central African Republic[MeSH] OR Chad[MeSH] OR Comoros[MeSH] OR Democratic Republic of the Congo[MeSH] OR Eritrea[MeSH] OR Ethiopia[MeSH] OR Gambia[MeSH] OR Guinea-Bissau[MeSH] OR Guinea[MeSH] OR Haiti[MeSH] OR "Democratic People's Republic of Korea"[Mesh] OR Liberia[MeSH] OR Madagascar[MeSH] OR Malawi[MeSH] OR Mali[MeSH] OR Mozambique [MeSH] OR Nepal[MeSH] OR Niger[MeSH] OR Rwanda[MeSH] OR Senegal[Mesh] OR Sierra Leone[MeSH] OR Somalia[MeSH] OR South Sudan[MeSH] OR "Syria"[Mesh] OR Tajikistan [Mesh] OR Tanzania[MeSH] OR Togo[MeSH] OR Uganda[MeSH] OR Yemen[MeSH] OR Zimbabwe[MeSH] OR Low-income countr*[tiab] OR "low-income economy"[tiab] OR "low-income economies"[tiab] OR Low-income nation[tiab] OR Low-income nations[tiab] OR Low-Resource countr*[tiab] OR "Low-Resource nation"[tiab] OR "Low-Resource nations"[tiab] OR Resource-limited countr*[tiab] OR Resource-limited nation[tiab] OR Resource-limited nations[tiab] OR Resource-limited setting*[tiab] OR Poor countr*[tiab] OR Afghanistan[tiab] OR Benin[tiab] OR Dahomey[tiab] OR Burkina Faso[tiab] OR Upper Volta[tiab] OR Burundi[tiab] OR Urundi[tiab] OR Central African Republic[tiab] OR Ubangi-Shari[tiab] OR Chad[tiab] OR Comoros[tiab] OR Mayotte[tiab] OR "Democratic People's Republic of Korea"[tiab] OR North Korea[tiab] OR "Democratic Republic of Congo"[tiab] OR "Democratic Republic of the Congo"[tiab] OR "Congo, Dem. Rep"[tiab] OR Kinshasa[tiab] OR "Belgian Congo"[tiab] OR Zaire[tiab] OR Katanga[tiab] OR Eritrea[tiab] OR Ethiopia[tiab] OR Gambia[tiab] OR Guinea-Bissau[tiab] OR Guinea[tiab] OR Haiti[tiab] OR Liberia[tiab] OR Madagascar[tiab] OR "Malagasy Republic"[tiab] OR Malawi[tiab] OR Nyasaland[tiab] OR Mali[tiab] OR Mozambique [tiab] OR "Portuguese East Africa"[tiab] OR Nepal[tiab] OR Niger[tiab] OR Rwanda[tiab] OR Ruanda[tiab] OR Senegal[tiab] OR Sierra Leone[tiab] OR Somalia[tiab] OR South Sudan[tiab] OR "Syria"[tiab] OR "Syrian Arab Republic"[tiab] OR Tajikistan[tiab] OR Tadzhik SSR[tiab] OR Tadzhik S.S.R.[tiab] OR Tadzhikistan[tiab] OR "Tadzhik Soviet Socialist Republic"[tiab] OR Tanzania[tiab] OR Zanzibar[tiab] OR Tanganyika[tiab] OR Togo[tiab] OR Togolese Republic[tiab] OR Uganda[tiab] OR Yemen[tiab] OR Aden[tiab] OR Zimbabwe[tiab] OR Southern Rhodesia[tiab]))) AND (((((neurological[tiab] OR cerebro*[tiab] OR brain[tiab] OR "central nervous system"[tiab] OR spinal cord[tiab] OR meninges[tiab])) AND (surgical*[tiab] OR surger* [tiab] OR operation*[tiab] OR operate*[tiab] OR operating[tiab] OR procedur*[tiab]))) OR (("Neurosurgical Procedures"[Mesh] OR "Neurosurgery"[Mesh] OR "Central Nervous System/surgery"[Mesh] OR "Nervous System Diseases/surgery"[Mesh] OR Neurosurg*[tiab]))))				2986
Cochrane CENTRAL	ID	Search	Hits	132
	#1	MeSH descriptor: [Afghanistan] explode all trees	39	
	#2	MeSH descriptor: [Benin] explode all trees	46	
	#3	MeSH descriptor: [Burkina Faso] explode all trees	133	
	#4	MeSH descriptor: [Burundi] explode all trees	12	
	#5	MeSH descriptor: [Central African Republic] explode all trees	12	
	#6	MeSH descriptor: [Chad] explode all trees	3	
	#7	MeSH descriptor: [Comoros] explode all trees	1	
	#8	MeSH descriptor: [Democratic Republic of the Congo] explode all trees	87	
	#9	MeSH descriptor: [Eritrea] explode all trees	1	
	#10	MeSH descriptor: [Ethiopia] explode all trees	163	
	#11	MeSH descriptor: [Gambia] explode all trees	220	
	#12	MeSH descriptor: [Guinea-Bissau] explode all trees	89	
	#13	MeSH descriptor: [Guinea] explode all trees	7	
	#14	MeSH descriptor: [Haiti] explode all trees	52	
	#15	MeSH descriptor: [Democratic People's Republic of Korea] explode all trees	5	

#16	MeSH descriptor: [Liberia] explode all trees	22
#17	MeSH descriptor: [Madagascar] explode all trees	36
#18	MeSH descriptor: [Malawi] explode all trees	295
#19	MeSH descriptor: [Mali] explode all trees	89
#20	MeSH descriptor: [Mozambique] explode all trees	71
#21	MeSH descriptor: [Nepal] explode all trees	249
#22	MeSH descriptor: [Niger] explode all trees	36
#23	MeSH descriptor: [Rwanda] explode all trees	49
#24	MeSH descriptor: [Senegal] explode all trees	87
#25	MeSH descriptor: [Sierra Leone] explode all trees	31
#26	MeSH descriptor: [Somalia] explode all trees	17
#27	MeSH descriptor: [South Sudan] explode all trees	0
#28	MeSH descriptor: [Syria] explode all trees	19
#29	MeSH descriptor: [Tajikistan] explode all trees	3
#30	MeSH descriptor: [Tanzania] explode all trees	497
#31	MeSH descriptor: [Togo] explode all trees	13
#32	MeSH descriptor: [Uganda] explode all trees	582
#33	MeSH descriptor: [Yemen] explode all trees	8
#34	MeSH descriptor: [Zimbabwe] explode all trees	174
#35	MeSH descriptor: [Developing Countries] explode all trees	799
#36	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26 OR #27 OR #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35	3646
#37	("Developing Country" OR "developing countries" OR "Least Developed Countries" OR "Least Developed Country" OR "Less-Developed Country" OR "less-developed countries" OR "Under-Developed Nations" OR "Under-Developed Nation" OR "Underdeveloped Nations" OR "Underdeveloped Nation" OR "Third-World Country" OR "third-world countries" OR "Third-World Nations" OR "Third-World Nation" OR "Under-Developed Country" OR "under-developed countries" OR "Underdeveloped Country" OR "underdeveloped countries" OR "Developing Nations" OR "Developing Nation" OR "Less-Developed Nations" OR "Less-Developed Nation" OR low-and-middle-income-countries OR low-to-middle-income-countries OR LMIC OR "Low-income country" OR "Low-income countries" OR "low-income economy" OR "low-income economies" OR "Low-income nation" OR "Low-income nations" OR "Low-Resource country" OR "Low-Resource countries" OR "Low-Resource nation" OR "Low-Resource nations" OR "Resource-limited setting" OR "Resource-limited settings" OR "Resource-limited country" OR "resource limited countries" OR "Resource-limited nation" OR "Resource-limited nations" OR "poor countries" OR "Poor country" OR Afghanistan OR Benin OR Dahomey OR "Burkina Faso" OR "Upper Volta" OR Burundi OR Urundi OR "Central African Republic" OR Ubangi-Shari OR Chad OR Comoros OR Mayotte OR "Democratic People's Republic of Korea" OR "North Korea" OR "Democratic Republic of Congo" OR "Democratic Republic of the Congo" OR "Congo, Dem. Rep" OR Kinshasa OR "Belgian Congo" OR Zaire OR Katanga OR Eritrea OR Ethiopia OR Gambia OR Guinea-Bissau OR Guinea OR Haiti OR Liberia OR Madagascar OR "Malagasy Republic" OR Malawi OR Nyasaland OR Mali OR Mozambique OR "Portuguese East Africa" OR Nepal OR Niger OR Rwanda OR Ruanda OR Senegal OR "Sierra Leone" OR Somalia OR "South Sudan" OR "Syria" OR "Syrian Arab Republic" OR Tajikistan OR "Tadzhik SSR" OR "Tadzhik S.S.R." OR Tadzhikistan OR "Tadzhik Soviet Socialist Republic" OR Tanzania OR Zanzibar OR Tanganyika OR Togo OR "Togolese Republic" OR Uganda OR Yemen OR Aden OR Zimbabwe OR "Southern Rhodesia"):ti,ab,kw	12132

Continues

Appendix 1. Continued

Database		Query	Results	
	#38	#36 OR #37	12132	
	#39	MeSH descriptor: [Neurosurgical Procedures] explode all trees	5466	
	#40	MeSH descriptor: [Neurosurgery] explode all trees	77	
	#41	MeSH descriptor: [Central Nervous System] explode all trees and with qualifier(s): [surgery - SU]	371	
	#42	(Neurosurg*):ti,ab,kw	2494	
	#43	#39 OR #40 OR #41 OR #42	7530	
	#44	((neurological OR cerebro* OR brain OR "central nervous system")):ti,ab,kw	69466	
	#45	((surgical OR surger* OR operat* OR procedur*)):ti,ab,kw	306305	
	#46	#44 AND #45	20034	
	#47	#43 OR #46	26039	
#48	#38 AND #47	132		
Embase	('developing country'/exp OR 'low income country'/exp OR 'developing countr*':ab,ti OR 'least developed countries':ab,ti OR 'least developed country':ab,ti OR 'less-developed countr*':ab,ti OR 'under-developed nations':ab,ti OR 'under-developed nation':ab,ti OR 'underdeveloped nations':ab,ti OR 'underdeveloped nation':ab,ti OR 'third-world countr*':ab,ti OR 'third-world nations':ab,ti OR 'third-world nation':ab,ti OR 'under-developed countr*':ab,ti OR 'underdeveloped countr*':ab,ti OR 'developing nations':ab,ti OR 'developing nation':ab,ti OR 'less-developed nations':ab,ti OR 'less-developed nation':ab,ti OR 'low and middle income countries':ab,ti OR 'low-to-middle-income countries':ab,ti OR lmic:ab,ti OR 'afghanistan'/exp OR 'benin'/exp OR 'burkina faso'/exp OR 'burundi'/exp OR 'central african republic'/exp OR 'chad'/exp OR 'comoros'/exp OR 'democratic republic congo'/exp OR 'eritrea'/exp OR 'ethiopia'/exp OR 'gambia'/exp OR 'guinea bissau'/exp OR 'guinea'/exp OR 'haiti'/exp OR 'north korea'/exp OR 'liberia'/exp OR 'madagascar'/exp OR 'malawi'/exp OR 'mali'/exp OR 'mozambique'/exp OR 'nepal'/exp OR 'niger'/exp OR 'rwanda'/exp OR 'senegal'/exp OR 'sierra leone'/exp OR 'somalia'/exp OR 'south sudan'/exp OR 'syrian arab republic'/exp OR 'tajikistan'/exp OR 'tanzania'/exp OR 'togo'/exp OR 'uganda'/exp OR 'yemen'/exp OR 'zimbabwe'/exp OR 'low-income countr*':ab,ti OR 'low-income economy':ab,ti OR 'low-income economies':ab,ti OR 'low-income nation':ab,ti OR 'low-income nations':ab,ti OR 'low-resource countr*':ab,ti OR 'low-resource nation':ab,ti OR 'low-resource nations':ab,ti OR 'resource-limited countr*':ab,ti OR 'resource-limited nation':ab,ti OR 'resource-limited nations':ab,ti OR 'resource-limited setting*':ab,ti OR 'poor countr*':ab,ti OR afghanistan:ab,ti OR benin:ab,ti OR dahomey:ab,ti OR 'burkina faso':ab,ti OR 'upper volta':ab,ti OR burundi:ab,ti OR urundi:ab,ti OR 'central african republic':ab,ti OR 'ubangi shari':ab,ti OR chad:ab,ti OR comoros:ab,ti OR mayotte:ab,ti OR 'democratic people s republic of korea':ab,ti OR 'north korea':ab,ti OR 'democratic republic of congo':ab,ti OR 'democratic republic of the congo':ab,ti OR 'congo, dem. rep':ab,ti OR kinshasa:ab,ti OR 'belgian congo':ab,ti OR zaire:ab,ti OR katanga:ab,ti OR eritrea:ab,ti OR ethiopia:ab,ti OR gambia:ab,ti OR 'guinea bissau':ab,ti OR guinea:ab,ti OR haiti:ab,ti OR liberia:ab,ti OR madagascar:ab,ti OR 'malagasy republic':ab,ti OR malawi:ab,ti OR nyasaland:ab,ti OR mali:ab,ti OR mozambique:ab,ti OR 'portuguese east africa':ab,ti OR nepal:ab,ti OR niger:ab,ti OR rwanda:ab,ti OR ruanda:ab,ti OR senegal:ab,ti OR 'sierra leone':ab,ti OR somalia:ab,ti OR 'south sudan':ab,ti OR 'syria':ab,ti OR 'syrian arab republic':ab,ti OR tajikistan:ab,ti OR 'tadzhik ssr':ab,ti OR 'tadzhik s.s.r.':ab,ti OR tadzhikistan:ab,ti OR 'tadzhik soviet socialist republic':ab,ti OR tanzania:ab,ti OR zanzibar:ab,ti OR tanganyika:ab,ti OR togo:ab,ti OR 'togolese republic':ab,ti OR uganda:ab,ti OR yemen:ab,ti OR aden:ab,ti OR zimbabwe:ab,ti OR 'southern rhodesia':ab,ti) AND ('neurosurgery'/exp OR neurosurg*:ab,ti OR (('neurological':ab,ti OR cerebro*:ab,ti OR brain:ab,ti OR 'central nervous system':ab,ti OR 'spinal cord':ab,ti OR meninges:ab,ti) AND (surgical*:ab,ti OR surger*:ab,ti OR operat*:ab,ti OR procedur*:ab,ti)))			3010