The Role of the Pediatric Neurosurgeon in the Management of Hydrocephalus Internationally

Nicole E. Hernandez, MS[1], Shelly Wang, MD, MPH[1,2], John Ragheb, MD[1,2]

1. Division of Neurosurgery, Brain Institute, Nicklaus Children's Hospital, Miami, FL, USA.
2. Department of Neurosurgery, University of Miami, Miami, FL, USA.

Abstract:

The recent emphasis on surgery as an essential yet neglected component of global health care has drawn attention to the lack of pediatric neurosurgery in low- and middle-income countries (LMICs). Most LMICs have very few neurosurgeons able or willing to care for children, leaving few access to care for readily treatable conditions, like pediatric hydrocephalus and spina bifida. Herein, we review the role of pediatric neurosurgeons to improve hydrocephalus management and medical education in LMICs. A literature search on global pediatric neurosurgery was performed using the Pubmed database from the year 2000 to October 5th, 2021. The majority of current pediatric neurosurgical efforts focus on the management of hydrocephalus. Endoscopic third ventriculostomy (ETV) with or without choroid plexus cauterization (CPC) has emerged as an effective alternative to ventriculoperitoneal (VP) shunting for CSF diversion in LMICs. Neurosurgical programs in LMICs are most successful when twinning is used to pair the program with an established center in a high-income country (HIC). Multiple international pediatric neurosurgical efforts aim to provide medical expertise, infrastructure, and surgical education to LMICs. The next step in developing sustainable surgery programs in LMICs includes establishing local training programs. Existing global pediatric neurosurgery programs are most successful when partnered to an experienced center in a HIC. A lack of funding, resources, and training programs all pose barriers to increasing the pediatric neurosurgical capacity in LMICs. Future global neurosurgery efforts may look to other neurosurgical conditions with high burdens of disease in LMICs, like epilepsy.

KEYWORDS: global neurosurgery, pediatric neurosurgery, hydrocephalus

Corresponding author:

Shelly Wang, MD, MPH

Division of Neurosurgery, Brain Institute, Nicklaus Children's Hospital, Miami, FL, USA.

Email: Shelly.Wang@Nicklaushealth.org

Introduction

Global health efforts have only recently shifted to include surgical intervention. In 2005, the World Health Organization (WHO) established a global initiative that focused on surgery for the first time.[1] The WHO campaign created a forum for all stakeholders involved in global surgery to determine recommendations for establishing global surgery programs in low- and middle-income countries (LMICs).[2] Even then, this change only came about in the last 10 to 15 years, and global health efforts rarely focus on specialties like pediatric neurosurgery.[3] There is a great discrepancy between the availability of neurosurgeons in high-income countries (HICs) and LMICs. In HICs, there is approximately one neurosurgeon per 100,000 people, but in LMICs there is one neurosurgeon for one million people.[4] As many as 90% of patients that require surgery in LMICs do not have access to a neurosurgeon.[5] The greatest deficit of neurosurgeons is seen in Southeast Asia.[6] Limited resources, poor healthcare infrastructure, and few sustainable training programs all pose barriers to neurosurgery in LMICs. These barriers are even higher for pediatric neurosurgery, as the development of surgical care for children often lags behind that of adults. Despite these barriers, the number of neurosurgery programs in LMICs has increased over time, especially following the WHO initiative.[7] Efforts focused on improving access to hydrocephalus care have led to a shift in treatment, away from cerebrospinal fluid (CSF) ventriculoperitoneal (VP) shunting, toward techniques that avoid shunt placement, such as standalone endoscopic third ventriculostomy (ETV) or coupled with choroid plexus cauterization (CPC). More recently, the need for surgery to treat intractable epilepsy in LMICs was identified, although few pediatric epilepsy programs exist outside of HICs.[8] Academic work in global neurosurgery has grown rapidly since the 1980s. A Pubmed review showed 136 results for a search using the MeSH terms global surgery and neurosurgery with 23 results coming from the 80s and the rest published between 1990 and 1999.

Methods

A literature search was conducted using the Pubmed database from the year 2000 to October 5th, 2021, to identify current and contemporary pediatric neurosurgery efforts in global surgery. The following MeSH terms were used: global surgery, neurosurgery, pediatric, developing countries, pediatric hydrocephalus, and tuberculosis (TB) meningitis. This review was limited to English-language literature only.

Results

Literature Search

The literature search using Pubmed for the MeSH terms global surgery and neurosurgery yielded 2,945 results. Of these, there were 2,706 manuscripts published from the time period studied. Children, from newborns to a 18 years, were the subjects of 422 publications. The search was narrowed to focus on treatment of pediatric hydrocephalus in LMICs using terms like developing countries, pediatric hydrocephalus, and TB meningitis.

Burden of Disease

To meet the general need for only necessary neurosurgical cases, an estimated additional 20,000 neurosurgeons would be needed worldwide.[7] These calculations often underestimate the need for pediatric populations, which require surgeries that improve quality of life and long term neurodevelopmental outcomes. However, pediatric populations also have a greater burden of disease requiring neurosurgical intervention that can be addressed in LMICs.[7] Some neurosurgical conditions, like pediatric hydrocephalus, are even more common in LMICs.[9,10] The increased incidence of perinatal infections leads to an increased occurrence of post-infectious hydrocephalus.[11,12] In LMICs where tuberculosis is prevalent, such as countries in Africa and Southeast Asia, tuberculosis meningitis can lead to post-infectious hydrocephalus which has high mortality rates if left untreated.[13] Due to its prevalence and the feasibility of surgical intervention, hydrocephalus is the condition most treated by pediatric neurosurgeons in LMICs. The highest rates of pediatric hydrocephalus are in Africa, Latin America, and Southeast Asia.[9] In Sub-Saharan Africa alone, an estimate of 225,000 cases of infantile hydrocephalus develop each year. There is also a great need for pediatric neurosurgery in Haiti.[3] Early surgical intervention is proven to decrease childhood morbidity highlighting the importance of adequate neurosurgical capacity in areas of need.[14] Hydrocephalus has the possibility of placing a higher burden of disability than other conditions that global health efforts address and considering that it is one of the more treatable neurosurgical conditions, it is clear why initial global neurosurgery efforts have led with pediatric hydrocephalus management.[9] The cost-benefit ratio for treating pediatric hydrocephalus in LMICs was estimated using a year's worth of data from the CURE Children's Hospital of Uganda. The total cost of neurosurgical intervention over the year was compared to the benefit of money that will not be spent on disability-adjusted life years (DALYs) for these children. The cost-benefit ratio for treating hydrocephalus in infants is seven to one, further supporting increased access to pediatric neurosurgery in LMICs.[11] At a single center in Haiti, the increased neurosurgical capacity for treating infantile hydrocephalus is estimated to produce $2.5 to $5.5 million economic benefit in one year by decreasing the number of disability-adjusted life years.[15]

Surgical Management of Hydrocephalus: VPS vs. ETV CPC

Since the inception of global neurosurgery programs, VP shunting remains the standard of care for hydrocephalus, in most LMICs.[16] Still, about 40% of VP shunts placed in LMICs fail within 2 years.[17] VP shunting is also associated with a 5-9% post-operative infection rate.[18] Furthermore, managing a child with hydrocephalus and a VP shunt requires on-going care and monitoring for post-operative complications, shunt failures or malfunctions, and infections.[19]

Endoscopic third ventriculostomy (ETV), coupled with choroid plexus cauterization (CPC) in the infantile population, is an alternative to VP shunting for CSF diversion. It has emerged as a popular management technique for hydrocephalus, especially in LMICs, as it avoids the need for costly shunt hardware. A patient's potential success with ETV can be approximated by the ETV Success Score; older patients with obstructive etiologies, without prior shunts, yield the

most favorable results.[20] For etiologies that have higher success rates, like myelomeningocele, as many as 76% of patients can have their hydrocephalus managed with ETV CPC.[21] In some cases, ETVs are less likely to fail than VP shunts over time, and most ETVs that fail will do so in the first six months following surgery.[22,23] In studies comparing VP shunting and ETV CPC in a LMIC, similar failure rates, complications, and cognitive outcomes were shown.[23,24] Patients treated with ETV CPC may have better outcomes reported due to selection bias as etiologies that tend to have worse outcomes, like post-infectious hydrocephalus, may be treated with a VP shunt over ETV CPC at the surgeon's discretion.[12] A recent randomized controlled trial assessing the neurocognition of children who underwent VP shunting or ETV CPC, also demonstrated comparable outcomes.[23] Since VP shunting and ETV CPC can have similar outcomes, one of the main advantages of ETV CPC is the possibility of shunt independence.[21] A study on myelomeningocele patients found a 72% success rate for an initial ETV CPC and if an ETV is repeated the success rate increased to 78% for the cohort.[25] Similar results have been reported for other etiologies including encephalocele, where a study reported an 80% success rate after five years and congenital idiopathic hydrocephalus, where another study determined a 72.4% success rate at four year follow-up.[21,26]

Pediatric Neurosurgical Training

Successful pediatric neurosurgery programs in LMICs include training neurosurgeons and developing training programs in that country. Surgeons from LMICs that attend training programs in HICs may choose not to return in their country of origin to practice.[27] For the physicians that do return, the neurosurgeons often practice below their training level due to a lack of resources.[27] This coupled with the lack of pediatric neurosurgery training programs in LMICs leaves many patients without adequate access to neurosurgical intervention. Establishing training programs is difficult, however, as there is usually only one educator from a HIC that stays for short periods to work with the trainees in the LMIC. Pediatric neurosurgery training programs also increase the number of surgeons very slowly. The workforce can only be expanded as quickly as the length of time it takes to train a neurosurgeon. Generally, the trained neurosurgeons treat both children and adults as the number of neurosurgeons in LMICs is limited, although some subspecialty fellowships exist.[6,16] For this reason, training non-neurosurgeons to treat conditions like traumatic brain injuries has been suggested. While training general surgeons to do simpler neurosurgical procedures would expand the capacity for treating neurosurgical cases, opponents suggest that this may do more harm than good.[28,29] A coalition of African neurosurgeons responded to the trend of training general surgeons in LMICs to do neurosurgical procedures by arguing that sometimes the procedures themselves carry more risks than lack of treatment and that bad neurosurgical technique can have fatal complications.[29] There is also the argument that if other physicians are trained to perform neurosurgical procedures local governments and institutions will not invest in training programs for neurosurgeons. The establishment of neurosurgery training programs in LMICs is already limited by a lack of funds and limited availability of mentors for trainees.[30]

Training programs in LMICs generally emphasize the importance of post-operative and follow-up care as the partners from HICs may not stay for long after the surgical intervention. Most global neurosurgery residency programs create their curriculum to follow guidelines set by the Accreditation Council for Graduate Medical Education International and the Foundation of International Education in Neurological Surgery.[31] Both aim to provide training that will meet the neurosurgical need of the local program and establish sustainable academic expansion in a low resource setting. The establishment of neurosurgery programs in LMICs face several challenges. Local experts are not always consulted when programs are established in LMICs although their involvement would likely provide meaningful insight and improve the sustainability of such programs. Furthermore, many global surgery efforts treat all LMICs as a monolith when in reality there is unlikely one solution to increase neurosurgical capacity that would apply to all countries in need.[29] For instance, in Haiti specific limitations like political instability and vulnerability to natural disasters act as barriers to global health efforts.[32] However, many limitations to global surgery programs are shared amongst LMICs.

Current Efforts

About 30% of the global disease burden is surgical.[33] Traditionally, global surgery efforts relied on volunteer surgeons who worked out of surgical camps and shared operating rooms. Now, more institutional programs affiliated with academic centers and hospitals in HICs are focused on creating more sustainable surgery programs.[28] An example of an existing partnership that focuses on treating pediatric hydrocephalus is found at the Hospital Bernard-Mevs/Project Medishare in Haiti.[31] Prior to the establishment of this program, Haiti only had 0.05 neurosurgeons per 100,000 people.[34] Project Medishare, which was initially focused on primary care in the Haitian Plateau region, rapidly evolved after the 2010 earthquake with establishment of Haiti's first trauma center.[31] Initially, 20% of the patients brought to the trauma center were neurological cases requiring a surgical evaluation.[34] Over time, only 3% of surgical cases required neurosurgical intervention. However, this number does not reflect the need for neurosurgical care for the many other neurologic conditions that affect the pediatric population.[35] After the 2010 earthquake, volunteer medical staff from the United States provided critical care to address any neurological trauma patients. This led to the realization of the neurosurgical need that exists in Haiti and urged neurosurgeons to begin a monthly rotation to train Haitian clinicians in basic neurosurgical procedures. Over time, this relationship expanded to the neurosurgical training partnership that exists through Project Medishare today.[31] Experiences from Project Medishare in Haiti, the CURE Children's Hospital of Uganda, the Kijabe Hospital in Kenya, and the Ukraine Paediatric Fellowship Program exemplify how training programs can improve access to pediatric neurosurgery in LMICs.[31,30,36]

Surgeons participating in global health efforts recommend establishing local surgery programs to best serve patients in the community. The most common approach is through "twinning" by matching one or more HIC centers a with one center in an LMIC through a supportive partnership.[28] In these partnerships, the center in the HIC would offer neurosurgical services at first while they help identify and address local

resource needs with the goal of a sustainable program. Participants from the center in the HIC would educate and train the surgical staff in the LMIC, while providing guidance for research and expansion efforts. The Duke University Medical Center collaborated with the National Hospital of Uganda in a "two-pronged twinning" approach that offered supplies and surgical training.[28] Over two years, this approach had a significant increase in the number and complexity of neurosurgical cases and effectively increased the surgical capacity of the program in Uganda. This type of program has increased in number since the early 2000s.

Pediatric neurosurgery programs established in LMICs aim to have equal surgical outcomes to centers in HICs. Initially, overwhelming patient need, late presentation due to lack of access resulting in large numbers of children with advanced disease, a lack of local experience and surgical capacity causes LMICs to have resulted in worse surgical outcomes.[10] Low case volumes in LMICs, due to limited surgical capacity, are associated with high mortality rates for neurosurgical procedures.[5] Over time, the surgical outcomes are expected to improve with experience. A more recent study on ETV CPC outcomes in patients with infantile hydrocephalus in Haiti has shown comparable success rates and shunt independence to other pediatric neurosurgical centers in LMICs.[37] As pediatric neurosurgery programs in LMICs grow and gain experience surgical outcomes are expected to improve.

Discussion

Hydrocephalus is one of the most common focuses of global pediatric neurosurgery programs. Endoscopic third ventriculostomy (ETV) with or without choroid plexus cauterization (CPC) is noted as an effective alternative to ventriculoperitoneal (VP) shunting in LMICs where regular follow up and the possibility for multiple interventions needed is less feasible than in HICs. Overall, global pediatric neurosurgical efforts aim to provide medical expertise, infrastructure, and surgical education. The establishment of local training programs are most successful when paired with a HIC using the twinning method and when existing local clinicians are involved.

Limitations and Future Directions in Hydrocephalus Management

Several limitations exist in addressing the pediatric neurosurgical need in countries with limited resources. Namely, the healthcare infrastructure in LMICs makes specialized surgeries, like pediatric neurosurgery, difficult.[32] Following the devastating earthquake in 2010, a volunteer neurosurgeon working in the tent hospitals set up immediately after the earthquake, remarked on the challenges faced like working in surgical suites that did not have specialized lighting and minimal suction.[38] Aside from a lack of materials, the health systems in LMICs may not be prepared to handle a larger surgical caseload. Many times the materials used in the surgical programs established by partners in HICs are donated used equipment or nearly outdated disposables.[32] Access to safe and timely neurosurgical care requires an effective and well-resourced existing healthcare system in place to be succesful.[5] For instance, visiting

neurosurgeons from HICs or neurosurgeons that trained in HICs can only ethically perform surgeries that the current healthcare system in the LMIC can support.[39] Global neurosurgery efforts need to invest in existing local healthcare systems to create sustainable solutions to meeting neurosurgical need.[40] The Ukraine Pediatric Fellowship Program (UPFP) is an example of how to improve existing healthcare systems by working with local pediatric physicians to ensure that neurosurgery programs are self-sufficient long term.[36] The UPFP established endowed funds that could support the program while coordinating specified time points for education and mentorship with the partners at the Hospital for Sick Children in Canada. The creation of sustainable neurosurgical programs in LMICs increases the capacity for neurosurgery, but they also have their limitations. The medical mission model where surgeons from HICs volunteer in LMICs for short periods is proven to be an impractical solution to meeting the long term surgical need.[41] Sustainable programs in global surgery should focus on educating professionals in the LMICs and transferring skills that will allow the program to continue and grow.

Once programs are established, partnerships in LMICs need to focus on decentralizing care. Often the few neurosurgeons available in a LMIC practice only in urban areas, like the capital.[42] This leaves patients in rural areas still without access to the care they need. Programs established to increase the availability of neurosurgical care in LMICs should consider this to improve the access of all communities.

Study Limitations

This non-systematic review was limited by several factors related to the parameters of the study. When analyzing data from LMICs we only used English-language literature so viewpoints from manuscripts published in other languages spoken in these centers were not able to be included. Similarly, neurosurgery programs established in LMICs may focus on clinical efforts and often do not participate in the dissemination of research until the program is more experienced. This creates a paucity of data from the countries with the greatest need for neurosurgery and limited our analysis. Similarly, selection bias in which papers were included further limited our study. The study focused on original research published in the last twenty years to obtain an understanding of the contemporary management of hydrocephalus, especially after ETV CPC was implemented as an alternative to VP shunting in the early 2000s. The selection of studies was not random, but rather our analysis focused on neurosurgery programs in LMICs that treat pediatric hydrocephalus. The use of other databases, in addition to Pubmed, may have provided more results and can be considered for further analysis of global neurosurgical efforts in managing hydrocephalus or other neurosurgical conditions in LMICs.

Conclusions

The recent emphasis on global surgery has allowed pediatric neurosurgery to become available in LMICs where it was very limited if at all available before. Currently, global pediatric neurosurgery focuses on hydrocephalus. Recent introduction and data on the use of ETV CPC, in addition to VP shunting, has opened new frontier for a more feasible and sustainable method of hydrocephalus treatment in limited resource settings. Studies thus far prove that VP shunting and ETV CPC have similar success

rates, complications, and cognitive outcomes when used to treat pediatric hydrocephalus even in LMICs, which may have less experience than centers in HICs. A lack of funding, resources, and training programs all pose barriers to increasing the pediatric neurosurgical capacity. Future global neurosurgery efforts may look to other neurosurgical conditions with high burdens of diseased in LMICs, like epilepsy.

References

1. World Health Organization (WHO). WHO Global Initiative for Emergency and Essential Surgical Care (GIEESC). Accessed September 17, 2021. https://www.who.int/initiatives/who-global-initiative-for-emergency-and-essential-surgical-care
2. Spiegel DA, Abdullah F, Price RR, Gosselin RA, Bickler SW. World Health Organization Global Initiative for Emergency and Essential Surgical Care: 2011 and Beyond. *World J Surg*. 2013;37(7):1462-1469. doi:10.1007/s00268-012-1831-6
3. Farmer PE, Kim JY. Surgery and Global Health: A View from Beyond the OR. *World J Surg*. 2008;32(4):533-536. doi:10.1007/s00268-008-9525-9
4. Dua T, Boer HMD, Prilipko LL, Saxena S. Epilepsy Care in the World: Results of an ILAE/IBE/WHO Global Campaign Against Epilepsy Survey. *Epilepsia*. 2006;47(7):1225-1231. doi:10.1111/j.1528-1167.2006.00595.x
5. Meara JG, Leather AJM, Hagander L, et al. Global Surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Int J Obstet Anesth*. 2015;25:75-78. doi:http://dx.doi.org/10.1016/j.ijoa.2015.09.006
6. Dewan MC, Rattani A, Fieggen G, et al. Global neurosurgery: the current capacity and deficit in the provision of essential neurosurgical care. Executive Summary of the Global Neurosurgery Initiative at the Program in Global Surgery and Social Change. *J Neurosurg*. 2018;130(4):1055-1064. doi:10.3171/2017.11.JNS171500
7. Fuller AT, Barkley A, Du R, et al. Global neurosurgery: a scoping review detailing the current state of international neurosurgical outreach. *J Neurosurg*. 2020;134(4):1316-1324. doi:10.3171/2020.2.JNS192517
8. Watila MM, Xiao F, Keezer MR, et al. Epilepsy surgery in low- and middle-income countries: A scoping review. *Epilepsy Behav*. 2019;92:311-326.
9. Dewan MC, Rattani A, Mekary R, et al. Global hydrocephalus epidemiology and incidence: systematic review and meta-analysis. *J Neurosurg*. 2018;130(4):1065-1079. doi:10.3171/2017.10.JNS17439
10. Muir RT, Wang S, Warf BC. Global surgery for pediatric hydrocephalus in the developing world: a review of the history, challenges, and future directions. *Neurosurg Focus*. 2016;41(5):E11. doi:10.3171/2016.7.FOCUS16273
11. Warf BC, Alkire BC, Bhai S, et al. Costs and benefits of neurosurgical intervention for infant hydrocephalus in sub-Saharan Africa: Clinical article. *J Neurosurg Pediatr*. 2011;8(5):509-521. doi:10.3171/2011.8.PEDS11163
12. Warf BC, Dagi AR, Kaaya BN, Schiff SJ. Five-year survival and outcome of treatment for postinfectious hydrocephalus in Ugandan infants: Clinical article. *J Neurosurg Pediatr*. 2011;8(5):502-508. doi:10.3171/2011.8.PEDS11221
13. Robertson FC, Lepard JR, Mekary RA, et al. Epidemiology of central nervous system infectious diseases: a meta-analysis and systematic review with implications for neurosurgeons worldwide. *J Neurosurg*. 2018;130(4):1107-1126. doi:10.3171/2017.10.JNS17359
14. Kahle KT, Kulkarni AV, Limbrick DD, Wharf B. Hydrocephalus in children. *The Lancet*. 2016;387(10020):788-799. doi:http://dx.doi.org/10.1016/ S0140-6736(15)60694-8

15. Hubbard ZS, Shah AH, Ragheb M, Wang S, Jernigan S, Ragheb J. Economic benefit of neurosurgical intervention for infant hydrocephalus in Haiti. *J Neurosurg Pediatr*. 2019;24(3):306-314. doi:10.3171/2019.4.PEDS18563
16. Dewan MC, Onen J, Bow H, Ssenyonga P, Howard C, Warf BC. Subspecialty pediatric neurosurgery training: a skill-based training model for neurosurgeons in low-resourced health systems. *Neurosurg Focus*. 2018;45(4):E2. doi:10.3171/2018.7.FOCUS18249
17. Kulkarni AV, Riva-Cambrin J, Butler J, et al. Outcomes of CSF shunting in children: comparison of Hydrocephalus Clinical Research Network cohort with historical controls: Clinical article. *J Neurosurg Pediatr*. 2013;12(4):334-338. doi:10.3171/2013.7.PEDS12637
18. Kestle JRW, Riva-Cambrin J, Wellons JC, et al. A standardized protocol to reduce cerebrospinal fluid shunt infection: The Hydrocephalus Clinical Research Network Quality Improvement Initiative. *J Neurosurg Pediatr*. 2011;8(1):22-29. doi:10.3171/2011.4.PEDS10551
19. Stone JJ, Walker CT, Jacobson M, Phillips V, Silberstein HJ. Revision rate of pediatric ventriculoperitoneal shunts after 15 years: Clinical article. *J Neurosurg Pediatr*. 2013;11(1):15-19. doi:10.3171/2012.9.PEDS1298
20. Kulkarni AV, Drake JM, Mallucci CL, Sgourus S, Roth J, Constantini S. Endoscopic Third Ventriculostomy in the Treatment of Childhood Hydrocephalus. *J Pediatr*. 2009;155(2):254-259.e1. doi:10.1016/j.jpeds.2009.02.048
21. Warf BC. Hydrocephalus associated with neural tube defects: characteristics, management, and outcome in sub-Saharan Africa. *Childs Nerv Syst*. 2011;27(10):1589. doi:10.1007/s00381-011-1484-z
22. Drake JM. Endoscopic Third Ventriculostomy in Pediatric Patients: The Canadian Experience. *Neurosurgery*. 2007;60(5):881-886. doi:10.1227/01.NEU.0000255420.78431.E7
23. Kulkarni AV, Schiff SJ, Mbabazi-Kabachelor E, et al. Endoscopic Treatment versus Shunting for Infant Hydrocephalus in Uganda. *N Engl J Med*. 2017;377(25):2456-2464. doi:10.1056/NEJMoa1707568
24. Kestle J, Drake J, Milner R, et al. Long-Term Follow-Up Data from the Shunt Design Trial. *Pediatr Neurosurg*. 2000;33(5):230-236. doi:10.1159/000055960
25. 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: Clinical article. *J Neurosurg Pediatr*. 2008;2(5):310-316. doi:10.3171/PED.2008.2.11.310
26. 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(6):935-940. doi:10.1007/s00381-013-2072-1
27. Haglund MM, Fuller AT. Global neurosurgery: innovators, strategies, and the way forward. *J Neurosurg*. 2019;131(4):993-999. doi:10.3171/2019.4.JNS181747
28. 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. doi:https://doi.org/10.1007/s00268-011-1080-0
29. Figaji A, Taylor A, Mahmud MR, et al. On progress in Africa, by African experts. *Lancet Neurol*. 2018;17(2):114.

30. Mansouri A, Okechi H, Albright AL, Bernstein M. Reconnaissance Mission to the Neurosurgical Department in Kijabe Hospital, Kenya: A Call for the Submission of Ideas and Strategies. *World Neurosurg*. 2014;81(3):e14-e16. doi:10.1016/j.wneu.2013.11.006
31. Shah AH, Barthélemy E, Lafortune Y, et al. Bridging the gap: creating a self-sustaining neurosurgical residency program in Haiti. *Neurosurg Focus*. 2018;45(4):E4. doi:10.3171/2018.7.FOCUS18279
32. Weil AG, Fallah A, Bhatia S, Ragheb J. Pediatric Neurosurgery in the Developing World: The Haiti Experience. *J Craniofac Surg*. 2015;26(4):1061–1065. doi:10.1097/SCS.0000000000001681
33. Shrime MG, Bickler SW, Alkire BC, Charlie M. Global burden of surgical disease: an estimation from the provider perspective. *Lancet Glob Health*. 2015;3:S8-S9.
34. Barthelemy EJ, Benjamin E, Edouard Jean-Pierre MY, et al. A Prospective Emergency Department–Based Study of Pattern and Outcome of Neurologic and Neurosurgical Diseases in Haiti. *World Neurosurg*. 2014;82(6):948-953. doi:http://dx.doi.org/10.1016/j.wneu.2013.10.012
35. Centers for Disease Control and Prevention. Post-Earthquake Injuries Treated at a Field Hospital - Haiti, 2010. *Morb Mortal Wkly Rep*. 2011;59(51 & 52):1673-1677.
36. Romach MK, Rutka JT. Building Healthcare Capacity in Pediatric Neurosurgery and Psychiatry in a Post-Soviet System: Ukraine. *World Neurosurg*. 2017;111:166-174. doi:10.1016/j.wneu.2017.11.178
37. Shah AH, LaFortune Y, Ibrahim GM, et al. Endoscopic third ventriculostomy with choroid plexus cauterization for the treatment of infantile hydrocephalus in Haiti. *J Neurosurg Pediatr*. 2020;25(4):411-416. doi:10.3171/2019.10.PEDS19433
38. Wang MY. Devastation after the Haiti Earthquake: A Neurosurgeon's Journal. *World Neurosurg*. 2010;73(5):438-441.
39. Bernstein M. Ethical dilemmas encountered while operating and teaching in a developing country. *Can J Surg*. 2004;47(3):170-172.
40. Park K, Johnson WD, Dempsey RJ. Global Neurosurgery: The Unmet Need. *World Neurosurg*. 2016;88:32-35. doi:http://dx.doi.org/10.1016/j.wneu.2015.12.048
41. Bae JY, Groen RS, Kushner AL. Surgery as a public health intervention: common misconceptions versus the truth. *Bull World Health Organ*. 2011;89(6):394. doi:10.2471/BLT.11.088229
42. Kahamba JF, Assey AB, Dempsey RJ, Qureshi M, Hartl R. The Second African Federation of Neurological Surgeons Course in the East, Central, and Southern Africa Region Held in Dar es Salaam, Tanzania, January 2011 - ClinicalKey. *World Neurosurg*. 2013;80(3):255-259. doi:10.1016/j.wneu.2011.07.021