PRIORITIZING GLOBAL NEUROSURGERY IN THE FOCUS OF GLOBAL PUBLIC HEALTH: THE ETHICAL, FINANCIAL AND CLINICAL NECESSITIES

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Virtual Connections: Improving Global Neurosurgery Through Immersive Technologies

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The field of neurosurgery has always been propelled by the adoption of novel technologies to improve practice. Although advancements have occurred in the diagnosis, treatment, and long-term outcomes of patients, these have not translated to global patient benefit. Up to five million people each year do not have access to safe and affordable neurosurgical interventions, and those in low- and middle-income countries (LMICs) are disproportionately affected. Current approaches to increase neurosurgical capacity are unlikely to meet the UN Sustainable Development Goals target by 2030, and many of the most successful programs have been disrupted by the travel restrictions of the COVID-19 pandemic. There is therefore a pressing need for creative virtual solutions. An area of growing relevance is the use of immersive technologies: virtual reality (VR) and augmented reality (AR). AR allows additional information to be superimposed onto the surgeon's visual field, thus enhancing intra-operative visualization. This can be used for remote tele-proctoring, whereby an experienced surgeon can virtually assist with a procedure regardless of geographical location. Expert guidance can therefore be given to both neurosurgical trainees and non-neurosurgical practitioners, further facilitating the growing practice of neurosurgical task-shifting in LMICs. VR simulation is another useful tool in remote neurosurgical training, with the potential to reduce the learning curve of complex procedures whilst conserving supplies in low-resource settings. The adoption of immersive technologies into practice is therefore a promising approach for achieving global neurosurgical equity, whilst adapting to the long-term disruptions of the pandemic.

Keywords: virtual reality, augmented reality, global neurosurgery, COVID-19, immersive technologies

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INTRODUCTION

The twenty-first century has seen exponential growth in the development and adoption of novel technologies across many aspects of society, and medicine and surgery is no exception (1). Technology occupies a growing role in healthcare delivery, with particular impact on surgical and perioperative care (2). Neurosurgery in particular has been a speciality driven by technological innovation; advancing the diagnosis, treatment, and long-term outcomes of patients (1).

However, these advancements have not benefitted patients equally worldwide. There is growing disparity in the provision of surgical care globally, with significant inequalities seen in neurosurgical care (3). Up to five million people each year do not have access to safe and affordable neurosurgical interventions, the majority of such patients living in low and middle-income countries (LMICs) (4). This disparity is responsible for significant morbidity and mortality worldwide (5), rendering the search for creative solutions of utmost importance.

In 2015, the United Nations General Assembly adopted a 17-goal action plan to transform the world by 2030. These Sustainable Development Goals set out key aspirations for global healthcare, a crucial component being the provision of surgical care (6). In the same year, the Lancet Commission on Global Surgery was formed to help elucidate the true burden of unmet need in surgical care, identifying important areas for improvement (7). With 10 years remaining until the 2030 deadline, we need systemic change in healthcare systems on an international scale to ensure these vital goals are met.

The development and application of novel technologies will play a vital role in ensuring equity in global neurosurgery, whilst fostering advancements in future neurosurgical care. A particularly promising field is immersive technology, demonstrating potential applications in pre-operative planning, intraoperative guidance, and neurosurgical training. Adoption of these technologies is particularly relevant in the context of the COVID-19 pandemic, as we seek virtual solutions to disruptions in surgical care and education.

CURRENT GLOBAL NEUROSURGICAL LANDSCAPE

In comparison to other surgical specialities, the burden of unmet need in neurosurgery is particularly great. Every year, an estimated 22.6 million patients suffer from neurological disorders or injuries that warrant neurosurgical input. Of these, 13.8 million require surgery, but an estimated 5 million remain untreated each year (4). Episodic service missions from developed countries cannot fill these gaps sustainably (8), and instead international support must center around training and education (5). It is well-accepted that the most successful global health interventions must be designed with the recipient population involved at all stages of development (9), with the resulting approach focusing on the empowerment of local healthcare users and providers (5).

In many LMICs, the neurosurgical workforce capacity is only 1–10% of the minimum expected neurosurgeon ratio per population (4), with over 23,000 more neurosurgeons needed to address this deficit by 2030 (10). Multiple approaches have been considered to address this gap in essential neurosurgical provision; for example, through visiting fellowships in which local surgeons learn from centers in higher-income countries (HICs). However, these fellowships can result in "brain drain" in LMICs, as the neurosurgical workforce is further depleted whilst surgeons train overseas, and may indeed stay for extended periods (11). A solution to this issue is the development of neurosurgical training programs based in, or near the country of need.

One successful example is the CURE program in Sub-Saharan Africa, where surgeons in Uganda and the surrounding countries were trained in an alternative, low-cost procedure to treat hydrocephalus, in response to high disease incidence and limited supply of shunts. The programme has now expanded to 15 global sites (12). A more comprehensive approach to training is through a twinning paradigm, such as the Swedish African Neurosurgical Collaboration. This is a multi-stage model featuring utilization of local resources, targeted donations of equipment, and reciprocal clinical visiting partnerships (8).

Despite these multifaceted approaches to increase neurosurgical capacity in LMICs, the deficit remains. Whilst the global neurosurgical workforce is increasing, 58% of LMICs will not meet the minimum target for neurosurgical workforce density by 2030 (13). An alternative strategy aims to address the gap in care provision without requiring additional neurosurgeons. In task shifting and task sharing, aspects of neurosurgical care are delegated to non-neurosurgeons (i.e., general surgeons, general practitioners, and non-physician clinicians) with differing levels of supervision and autonomy (14). These approaches remain controversial. Whilst task sharing may be the most time-effective way of addressing the lack of access to essential neurosurgical care, it suffers from a lack of longevity, fails to ensure that adequate structures are in place to carry out more complex neurosurgical procedures, and does not address deficits in training numbers.

ROLE OF IMMERSIVE TECHNOLOGIES IN NEUROSURGERY

The term "immersive technologies" primarily refers to the concepts of virtual reality (VR) and augmented reality (AR). In VR, a computer-generated image or environment is simulated, and can be interacted with by the user. AR combines both virtual and real objects in a single view, thus producing a semi-immersive environment (15). Within surgery, immersive technologies can therefore be used to create 3D simulations of anatomical structures, which can then be superimposed onto views of a patient's real anatomy.

Of all the surgical specialities, neurosurgery may benefit most from technologies which improve the visualization of structures. The closed nature of the cranium and spine, and complex micro-anatomy within, poses a natural limitation on operations that can be performed without invasive methods of exposure. Neurosurgical care has been revolutionized by advances in imaging technology, with modern neurosurgery becoming heavily reliant on imaging for surgical success. Routine pre-operative and intra-operative use of computed tomography (CT) and magnetic resonance imaging (MRI) has facilitated the use of less invasive techniques, whilst improving surgical accuracy (1).

These imaging modalities are used in stereotactic surgery, where scans are combined with the intraoperative view to allow for accurate neuro-navigation (1). This is a basic form of augmented reality already in common use in neurosurgery, and so the leap to more complex immersive technologies is a natural one, allowing for information from scans to be assimilated more effectively. Traditional neuro-navigation systems utilize a "heads up" approach, with the computed images displayed separately from the intraoperative field (16). The surgeon must repeatedly switch their view from the computer screen to the operative field, disrupting surgical workflow (15).

Integration of the navigation system with the operative field would remove the need to switch views and would therefore provide a more intuitive experience. The ability to view 3D images superimposed onto the operative field has been shown to provide enhanced visualization of neurovascular structures, and improved intra-operative lesion location in neuro-oncological surgery (17).

Portable forms of immersive technologies, such as smart glasses, could vastly improve the usability of existing navigation systems, extending their use beyond the theater setting for use in pre-operative planning and surgical training. Rather than an AR overlay, a VR model of the patient's individualized anatomy could be created, allowing the surgeon to perform an accurate trial of the surgery with no associated patient risk. The availability of more realistic operative simulations has a wider applications neurosurgical training, allowing for greater understanding of complex anatomy and honing of visuospatial skills (1, 18, 19), thus reducing the learning curve for complex procedures (19).

IMMERSIVE TECHNOLOGIES IN LMICs

The Lancet Commission recognized that novel technologies are key factors in enabling the scaling up and strengthening of surgical care worldwide (9). The adoption of novel technologies will allow for reduced costs, optimize the use of resources, and improve the delivery of care and training (7). Specifically, simulation-based approaches have been identified as a useful tool in surgical training in LMICs, ensuring that critical steps of a high-risk procedure can be practiced in a low-risk environment, preserving patient safety and scarce hospital supplies (7). The NIHR Global Health Research Group in Surgical Technologies (GHRG-ST) are currently trialing surgical simulation training that incorporates immersive technologies in Sierra Leone with promising results (20, 21).

A growing practice in surgical training globally is the intraoperative use of tele-mentoring and tele-proctoring. Rural surgical trainees have highlighted the relevance of surgical tele-mentoring in the acquisition of new surgical techniques and skillsets (22). Tele-proctoring uses internet connectivity to provide an audio and visual connection between surgeons in different geographic locations (23). In this manner, the mentoring surgeon can provide the real-time guidance and assistance typical of traditional surgical mentoring without being physically present. This field could be dramatically enhanced through the application of immersive technologies, allowing the mentoring surgeon to better demonstrate procedural steps through a combination of hand gestures, annotations, and imaging overlaid on the operative field (24). This has been demonstrated in complex surgical procedures, including those performed by local surgeons in LMICs with assistance from mentors in HICs (23–25). Of note is the application in neurosurgical procedures such as endoscopic third ventriculostomy, where guidance could be given with high levels of precision (25).

Although the financial cost of procuring equipment is a common barrier to the adoption of novel technologies in LMICs (9), many of the immersive technology innovations have been designed to make use of existing equipment and software. The use of comparatively low-cost mobile devices is a growing phenomenon in LMICs healthcare systems, with supporting evidence of their efficacy (26). For example, VIPAR is an iPad-based platform that allows mentoring surgeons to project their hands into the display of the mentee surgeon (27). Furthermore, many of the AR and VR headsets can be used *via* a smartphone (20, 21), with further scope to utilize low-cost headsets such as Google Cardboard (16).

This technology may also be used as an adjunct to task shifting and task sharing in neurosurgery, adding an additional level of specialist support to non-neurosurgical practitioners. Such applications have been considered for rural hospitals or military medical centers, where general surgeons may be tasked with performing complex sub-speciality procedures, including craniotomies (28).

These solutions utilize the increasing ease with which we can connect with colleagues across the world, traversing national and continental barriers. It is clear that wearable immersive technologies and web-based communication can contribute to a sustainable model of surgical training in resource-poor locations (29).

RELEVANCE TO COVID-19 PANDEMIC

The COVID-19 pandemic has presented a huge burden to healthcare systems across the globe, particularly in LMICs (30). Beyond the immediate threat of the pandemic, the pre-existing burden of unmet neurosurgical need remains, and has been exacerbated. In neurosurgery, many treatments are time-critical, and any delays to treatment may cause significant morbidity and mortality (31). Additionally, many of the models designed to improve neurosurgical training, such as twinning programmes and exchanges, cannot feasibly take place under international travel restrictions. These limitations on in-person training may remain for some time, risking long-term disruption to surgical care and training; the effects of which will be felt for years to come (32–34).

In response to the pandemic-driven disruption, there has been a surge of innovation in virtual methods of education and collaboration. Worldwide, face-to-face teaching has been replaced by webinars and online courses (31, 33). Proximie is a secure, cloud based AR platform that has been used for surgical education, providing interactive masterclasses and tutorials (16, 35). From classroom to operating room, augmented reality telesurgery has been successfully used to provide expert guidance when operating on COVID-19 positive patients, both limiting the number of professionals in the room and conserving vital supplies of personal protective equipment (36). These virtual solutions are examples of low-cost innovations that can be utilized by LMICs and HICs.

CONCLUSION

Neurosurgery has always been a pioneering speciality, harnessing developing technologies to improve patient care. Immersive technologies are one such tool with growing potential to be adopted over the next decade. A focus for improvement is the global discrepancy in neurosurgical care, which leads to significant morbidity and mortality annually, and exacerbates inequalities between HICs and LMICs. The current COVID-19 pandemic has emerged at this intersection between rapidly developing technologies and the lack of equal access worldwide. The restrictions to daily life have challenged traditional models of surgical care and training, and there has been rapid adoption of novel technologies in response. This innovation presents an opportunity to ensure solutions work to improve neurosurgical care in LMICs as well as HICs. Although it is uncertain what challenges neurosurgery may face in the next 10 years, it is clear that a better connected and equal global neurosurgical workforce will put us in the best position to face these challenges.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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OPINION
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Thrombectomy for Stroke in Brazil—Late Evidence or Promising Future?

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Martins et al. recently published a trial titled "Thrombectomy for Stroke in the Public Health Care System in Brazil"—the RESILIENT trial—in which they randomized 111 patients to receive standard care plus thrombectomy and 110 patients in the control group (standard care alone) (1). Like other trials that have been published since 2015, the authors found that endovascular treatment within 8 h after stroke onset provides better functional outcomes than standard care alone (2–4).

One may argue that the results of the trial are not new and, maybe, it was unethical to randomize patients not to receive thrombectomy. However, this study was necessary to show the feasibility of thrombectomy for stroke in a middle-income country. Actually, this is a welcome study that may foster public health managers to approve the routine use of this treatment modality, which could save near 2 million lives a year if expanded globally (5).

This challenge is a worldwide concern, which led the Society of Vascular and Interventional Neurology to launch the Mission Thrombectomy, aiming for a global expanding of thrombectomy to reduce the morbidity and mortality related to stroke. Despite this effort, many organizational restrictions persist, keeping important inequalities and disparities in the access to thrombectomy (6).

The Brazilian health system (SUS) is based on the principle of health as a citizen's right and the state's duty; it therefore relies on the doctrinal principles of universality, integrality, and equity (7). For instance, these principles have led the country to experience a successful response to HIV infection, with a policy of universal availability of highly active anti-retroviral therapy since 1996 (8).

Fortunately, the accessibility for stroke care has also improved over the last decade, mainly due to the efforts by the National Stroke Policy Act, which defined the requirements and levels of stroke centers, improved the specific budget for stroke care and rehabilitation, and helped funding training health professionals for stroke interventions (9). However, the continental dimensions and the large disparities between the different regions of the country keep the population access for stroke treatment still heterogeneous. The majority of stroke centers are located in capital and large cities, and therefore, the inner parts of the country, as well as rural areas, still lack the gold standard treatment.

With regard to thrombectomy for stroke, the concern will be how to provide universal access to high-tech treatment in a country with such high disparities. The RESILIENT investigators themselves recognize that most of the treating hospitals had only one or two angiography suites for multiple specialties. Besides, different centers contributed different numbers of patients; this demonstrates heterogeneity, even in a controlled setting.

It took 17 years from the National Institute of Neurological Disorders and Stroke rt-PA Stroke Study Group (NINDS) (10) trial publication to the Brazil government's approval of alteplase in the SUS. Based on this, one can imagine the length of time it may take for the Brazilian government to approve thrombectomy, even after a national powerful trial. Nevertheless, it is important to highlight that the Brazilian Ministry of Health supported the trial, and despite the high costs of thrombectomy, its efficacy and cost-effectiveness are proven for a limited resource setting.

Future political and research initiatives should explore ways to expand the accessibility to thrombectomy and reduce its costs. A possible way to accelerate the time from clinical onset of stroke to the endovascular thrombectomy would be exploring the safety and efficacy of treatment under local anesthesia. In low- and middle-income countries, this would allow for wider availability without the constraint related to the routine use of general anesthesia in both adult (11) and pediatric population (12). Other initiatives, such as task sharing in neurosurgery (that is, delegating certain neurosurgical tasks to non-neurosurgical specialists) and partnerships between developing countries for international training programs, could be useful to increase neurosurgical capacities in regions where workforce deficit remains substantial (13, 14).

In summary, the RESILIENT trial opens the door for a promising future for stroke care in low- and middle-income countries. However, this future will depend on the translation of scientific evidence to public policies. The scientific community did its part.

AUTHOR CONTRIBUTIONS

PH, CM, and RB: conception. GM, MZ, and RB: analysis of data. PH: draft. GM, CM, MZ, and RB: critical review. All authors have final approval of the manuscript and agreement to be accountable for all aspects of the work.

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ORIGINAL RESEARCH
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Training the Next Generation of Academic Global Neurosurgeons: Experience of the Association of Future African Neurosurgeons

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Introduction: Although the past decade has seen a substantial increase in African neurosurgeons' academic productivity, productivity remains low compared to their colleagues from other regions. Aspiring neurosurgeons can contribute to the academic neurosurgery workforce by taking care of less technical and time-consuming research tasks. Fortunately, global neurosurgery institutions have also made efforts to increase research exposure and scholarly output in academic global neurosurgery. The Association of Future African Neurosurgeons (AFAN) created a research incubator for aspiring academic global neurosurgeons in Africa to provide enrollees with mentorship, skills, and experience. This study assesses and reports the activities and results of the research incubator.

Methods: Aspiring academic global neurosurgeons were enrolled in the AFAN Research Incubator Program (ARIP), whose primary objective was to provide enrollees with foundational skills in all aspects of the research cycle. ARIP enrollees participated in didactic and practical activities with the aim of publishing $\geq$1 article and presenting $\geq$1 abstracts at international conferences in one year.

Results: Fifteen AFAN members aged 25.0 $\pm$ 3.0 years enrolled in ARIP: 7 (46.7%) medical students, 4 (26.7%) general practitioners, and 4 (26.7%) residents. Eleven (73.3%) were male, 6 (40.0%) were from Cameroon and 6 (40.0%) had no previous research experience. Two (13.3%) enrollees dropped out. ARIP enrollees published a total of 28 articles, and enrollees published a median of 1.0 (IQR = 2) first-author articles on neurosurgical system strengthening. Additionally, ARIP enrollees presented 20 abstracts with a median of one abstract (IQR = 3.0).

Conclusion: South-South research collaborations like ARIP can contribute to improving global neurosurgery research capacity and output. These collaborations can set up the foundations for robust research in low- and middle-income countries.

Keywords: Africa, capacity building, global neurosurgery, neurosurgery, research

INTRODUCTION

Despite substantial increases over the past decade, African neurosurgeons' academic productivity remains low compared to their colleagues from other regions. More than one-third of African countries have no peer-reviewed neurosurgery articles, and the median number of articles for African countries with peer-reviewed articles is six publications (1). The low academic output is primarily due to a workforce shortage, and for the few neurosurgeons available, the patient workload is an impediment to research (2–4). Other barriers include a lack of exposure, lack of protected research time, limited access to articles, and lack of mentorship (5, 6). For example, more than 60% of aspiring African neurosurgeons do not have a mentor and have never presented an abstract at a conference, participated in a journal club, or contributed to a manuscript (7). One reason for the lack of exposure is that academic neurosurgeons do not have time for research activities (3, 4). Aspiring neurosurgeons can contribute to the academic neurosurgery workforce by taking care of less technical and time-consuming research tasks, creating time for academic neurosurgeons to do more research. The early involvement of aspiring neurosurgeons in research activities equally benefits them because it increases their exposure and skills.

Global neurosurgery institutions have made efforts to increase research exposure and scholarly output in academic global neurosurgery. For example, the World Federation of Neurosurgical Societies' Global Neurosurgery Committee has set-up a mentorship program and funding mechanisms (8). to promote research in low- and middle-income countries, no study, to our knowledge, has described a formal capacity-building initiative aiming to increase academic global neurosurgery exposure among aspiring neurosurgeons (5, 6).

The Association of Future African Neurosurgeons (AFAN), a 460-member neurosurgery interest group, created a research incubator for aspiring academic global neurosurgeons in Africa to provide enrollees mentorship, skills, and experience. This study aimed to assess and report the activities and results of the research incubator.

METHODS

On August 29, 2019, aspiring academic global neurosurgeons (medical students and general practitioners) were enrolled in the AFAN Research Incubator Program (ARIP) (**Figure 1**). ARIP was organized and led by the first author (USK), an experienced global neurosurgery researcher. Monthly lectures and journal clubs were organized on the first and second Saturday of each month at 5 p.m. GMT on Zoom (Zoom Inc., California, USA). The videos were recorded and shared with the enrollees for offline viewing. The authors obtained institutional review board approval before starting the project.

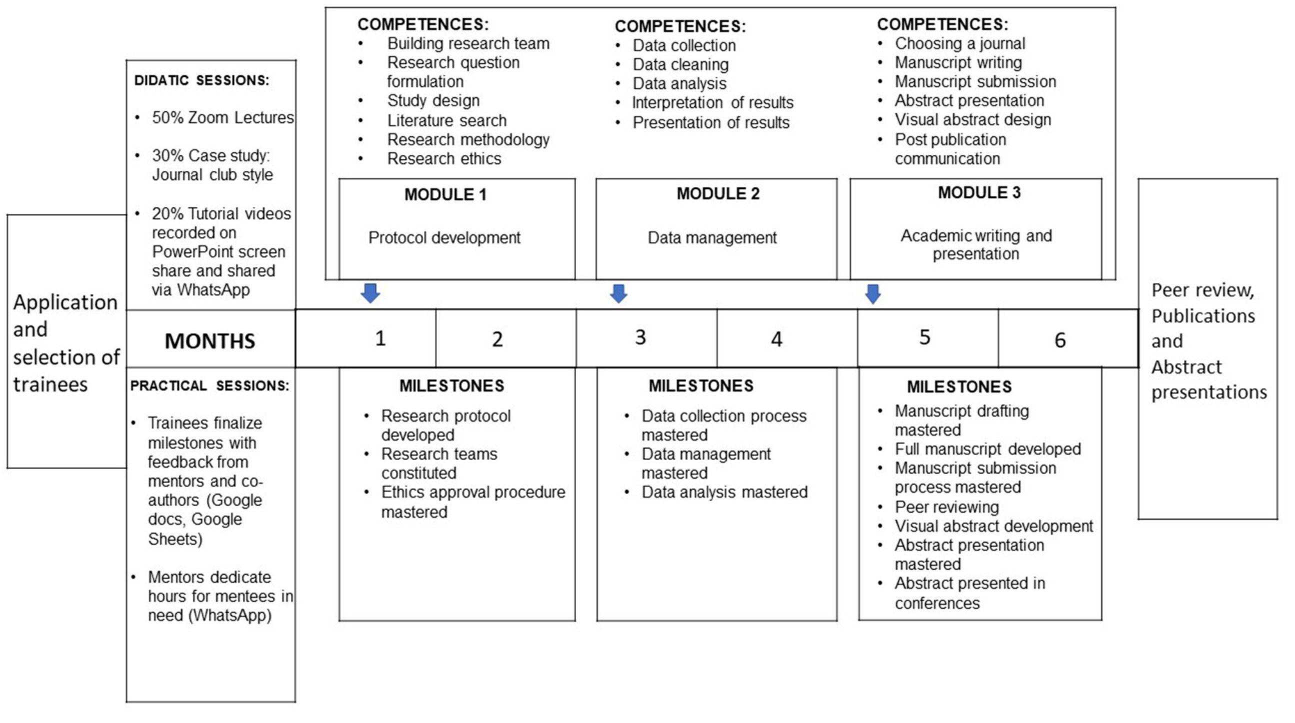
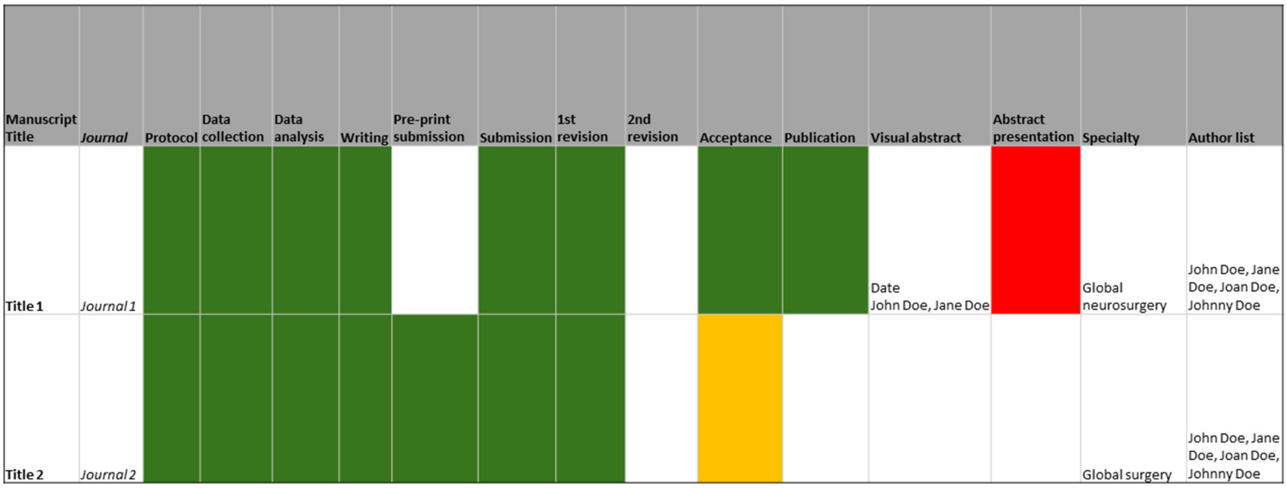


FIGURE 1 | The Association of Future African Neurosurgeons Research Incubator Program structure.



Manuscript Title	*Journal*	Protocol	Data collection	Data analysis	Writing	Pre-print submission	Submission	1st revision	2nd revision	Acceptance	Publication	Visual abstract	Abstract presentation	Specialty	Author list
Title 1	*Journal 1*											Date John Doe, Jane Doe		Global neurosurgery	John Doe, Jane Doe, Joan Doe, Johnny Doe
Title 2	*Journal 2*													Global surgery	John Doe, Jane Doe, Joan Doe, Johnny Doe

FIGURE 2 | Research track sheet showing checkpoints of the research cycle with completion and deadlines. Completion is color coded: green (completed task), orange (uncompleted task and deadline past), red (major setback), and white (previous task has not been completed).

ARIP Description

The primary objective of ARIP was to provide enrollees with foundational skills in all aspects of the research cycle: from study design to post-publication communication. The didactic courses were followed by practical exercises during which enrollees had to contribute significantly to a study.

Enrollees had to contribute significantly to five manuscripts, submit at least one article as a first-author, present at least one abstract at an international conference, design more than two visual abstracts, create an ORCiD account, create a ResearchGate account, and curate their social media accounts over 1-year.

The first author taught 28 90-min-lectures (60-min presentations and 30-min discussions). At the end of the lectures, each enrollee developed and proposed an idea for their first-author paper. Priority for first-author papers was given to studies involving human subjects if the first author was in their final year of medical school or residency and reviews (systematic, scoping, and narrative) if the first-author was not in their final year. This choice was made to avoid delays and costs related to institutional review board approvals, given that participants in their final year could get ethical approval easily.

All research projects were logged in Google Sheets (Google Inc., California, USA) using a traffic light coding system along with target journals, target conferences, deadlines, and co-author lists (**Figure 2**). Priority was given to open-access journals without article processing charges and virtual conferences to maximize visibility and decrease expenses. The manuscripts were written on Google Docs (Google Inc., California, USA) and co-authors contributed using the suggestion mode. The online document history function was used to quantify the contributions of co-authors and to determine authorship positions. This was chosen to ensure transparency and accountability. Each research team held a monthly meeting with the first author during the study period. Day-to-day communications were done on WhatsApp (WhatsApp Inc., California, USA).

All abstracts accepted at conferences were first presented internally and reviewed by other ARIP enrollees before being presented at international conferences. Also, English and French visual abstracts were designed for all published articles and disseminated on AFAN and via the co-authors' social media handles.

Statistical Analysis

Summary descriptive statistics were generated (gender, age, number of peer-reviewed articles pre-ARIP, number of peer-reviewed articles post-ARIP, and number of abstracts post-ARIP). A Wilcoxon signed-rank test was used to evaluate the difference in scholarly output before and after ARIP, and the P-value was considered statistically significant when <0.05.

RESULTS

Fifteen AFAN members aged 25.0 ± 3.0 years enrolled in ARIP: 7 (46.7%) medical students, 4 (26.7%) general practitioners, and 4 (26.7%) residents. Eleven (73.3%) were male, 6 (40.0%) were from Cameroon and 6 (40.0%) had no previous research experience (**Table 1**). Two (13.3%) enrollees dropped out (ID: 1 and 13).

ARIP enrollees published a total of 28 articles and a median of 1.0 (IQR = 2) first-author articles. The increase in peer-reviewed publications was statistically significant (post-ARIP median = 8.0, IQR = 8.0 articles vs. pre-ARIP median = 0.0 articles; $P = 0.01$). Of note, the article titled *Barriers to the management of non-traumatic neurosurgical diseases at 2 Cameroonian neurosurgical centers: A cross-sectional study* was selected as an editor's choice in *World Neurosurgery* (9). The publications covered all the aspects of a neurosurgical system: workforce and infrastructure (10), finance, governance, information management (11), and service delivery (12).

TABLE 1 | Socio-demographic data of the AFAN research incubator project.

ID	Sex	Age	Total articles	First author articles	Abstracts	Profession	Country	Previous research experience
1	M	25	8	0	3	GP	Cameroon	Thesis
2	F	27	15	2	2	Resident	Côte d'Ivoire	Thesis
3	M	26	15	5	3	GP	Cameroon	Thesis
4	M	26	22	3	5	GP	Cameroon	Thesis
5	M	24	18	3	5	Student	Cameroon	None
6	M	26	10	2	1	Resident	Côte d'Ivoire	Thesis
7	M	24	3	2	1	GP	DR Congo	Thesis
8	M	24	6	0	0	Student	DR Congo	None
9	M	33	8	1	0	Resident	Zimbabwe	Thesis and 4 articles
10	M	28	6	0	1	Resident	Morocco	Thesis and 5 articles
11	F	22	9	0	0	Student	Cameroon	None
12	M	23	10	2	3	Student	Zambia	1 article
13	F	20	3	0	0	Student	Zambia	None
14	M	24	4	0	0	Student	Cameroon	None
15	F	23	6	1	3	Student	Botswana	None

GP, general practitioner.

ARIP enrollees presented 20 abstracts, of which 5 were presented at the *World Federation of Neurosurgical Societies Global Neurosurgery 2020 Conference,* and 3 were presented at *The Neurology and Neurosurgery Interest Group - Society of British Neurological Surgeons Conference* (**Table 2**). The enrollees presented a median of one abstract (IQR = 3.0).

All enrollees had designed ≥2 visual abstracts, created ORCiD and ResearchGate accounts and curated their Twitter and Facebook accounts. Eight (53.3%) enrollees had met the target set initially (≥five peer-reviewed articles, ≥one first-author article, ≥one abstract, ≥two visual abstracts, and curation of ORCiD, ResearchGate, and other social media accounts) at the time of publication.

The enrollees were asked about their experience, and the majority (86.7%) had positive feedback. Direct quotes from the enrollees are below:

- "[ARIP] is the best research experience I have had. The course director and my peers are very helpful and always available."
- "I love that [ARIP] is goal-oriented and transparent. It motivates me to do my best."
- "Publishing in respectable specialty journals and being awarded the Editor's choice is the consecration of our individual and team efforts."

Participants identified project administration as the most challenging aspect of their research experience.

- "I find it hard to keep my co-authors motivated. I often have to do more work than was initially planned."
- "I struggle to organize meetings and set deadlines."

DISCUSSION

This global neurosurgery research capacity-building initiative is the first of its kind in Africa. We enrolled aspiring academic global neurosurgeons from all career levels. This program provides a framework for global neurosurgery research projects in low-resource settings and contributes to the attainment of research objectives set by the World Federation of Neurosurgical Societies' Global Neurosurgery Committee (8).

Impact

ARIP has significantly increased the scholarly output of enrollees, and its publications and abstracts were featured in prestigious journals and conferences.

Locally-driven research is critical for the attainment of universal neurosurgical care. For this to happen, there must be a critical mass of experienced researchers within local academic institutions, locally-driven research agendas, stakeholder buy-in, and integration of research findings into high-level decision-making (13). ARIP is working to grow the local academic neurosurgeon workforce and map out research gaps through literature reviews. ARIP offers hands-on experience, provides medical students and physicians opportunities from multiple African countries, and is output-oriented. In addition, ARIP is a South-South partnership focused on research that is mindful of local realities - lack of funding, difficulties obtaining ethical clearance, and limited mentorship (6, 14). All these characteristics make ARIP a sustainable model for research capacity-building in Africa.

Rosenberg et al. (15) developed a similar research capacity-building project for emergency medicine physicians in Rwanda. At the end of the training, they presented six abstracts, published six manuscripts, and offered advanced-degree scholarships to 11 participants (15). While ARIP presented many more abstracts and published more articles, none of our participants were awarded an advanced degree scholarship. Advanced degrees further contribute to research capacity building and are correlated with increased scholarly output (16). Unfortunately, the cost of these degrees can be prohibitive even in low-

TABLE 2 | Scholarly output of the AFAN research incubator program.

Title	Journal or conference
Manuscripts	
1. Exploring the knowledge and attitudes of Cameroonian medical students toward global surgery: a web-based survey	PLoS ONE
2. Global neurosurgery: implications for low- and middle-income countries. The case of Cameroon	Iranian Journal of Neurosurgery
3. The role of young and future neurosurgeons in global neurosurgery: perspectives from the Association of Future African Neurosurgeons	Journal of Neurosciences in Rural Practice
4. Systemic disorders and the prognosis of stroke in Congolese patients	Ghana Medical Journal
5. Prehospital conditions and outcomes following craniotomy for traumatic brain injury performed within 72 h in Central Cameroon Cameroon: a cross-sectional study	World Neurosurgery
6. Qu'est-ce que la chirurgie globale et quel est le rôle des pays francophones dans la chirurgie globale ?	Pan African Medical Journal Clinical Medicine
7. Planning to succeed: career development resources for future African neurosurgeons	ECAJS Journal
8. Barriers to the management of non-traumatic neurosurgical diseases at two Cameroonian neurosurgical Centers: a cross sectional study	World Neurosurgery
9. Systematic review of patient attitudes toward neurosurgery in low- and middle-income countries	Neurology India
10. Hierarchy of scientific evidence and thematic analysis of African neurosurgery research – A scoping review and bibliometric analysis	Interdisciplinary Neurosurgery
11. African neurosurgery research: a scientometric analysis of the top 115 most cited articles	Interdisciplinary Neurosurgery
12. COVID-19 and neurosurgical education in Africa: making lemonade from lemons	World Neurosurgery
13. Advancing medical research in sub-Saharan Africa: barriers, facilitators, and proposed solutions	Pan African Medical Journal Clinical Medicine
14. How can African medical researchers use social media to their advantage? – Pearls and pitfalls	Pan African Medical Journal Clinical Medicine
15. Systematic review and bibliometric analysis of African anesthesia and critical care medicine research Part I: contributions and hierarchy of evidence	BMC Anesthesiology
16. Systematic review and bibliometric analysis of African anesthesia and critical care medicine research Part II: a scientometric analysis of the 116 most cited articles	BMC Anesthesiology
17. Understanding the motivations, needs, and challenges faced by aspiring neurosurgeons in Africa: an E-survey	British Journal of Neurosurgery
18. Bibliometric analysis of the 200 most cited articles in World Neurosurgery	World Neurosurgery
19. Spontaneous subdural hematoma in a third-trimester gravid patient: a case report	Interdisciplinary Neurosurgery: Advanced Techniques and Case Management
20. Pediatric TBI in Zimbabwe: a Prospective Cohort Study	Romanian Journal of Neurology
21. Increasing neurosurgery interest in Africa: an analysis of the Association of Future African Neurosurgeons' social media handles	International Journal of Medical Students
22. Mapping global neurosurgery research collaboratives: a social network analysis of the 50 most cited articles	Neurosurgery Open
23. Schizencephaly associated with blindness and deafness in a 10-month old infant: a case report and literature review	Ghana Medical Journal
24. Barriers and Facilitators of Research in Cameroon (Part I) - An e-survey of physicians	Pan African Medical Journal Clinical Medicine
25. Barriers and Facilitators of Research in Cameroon (Part II) - An e-survey of medical students	Pan African Medical Journal Clinical Medicine
26. Comorbidities associated with pediatric epilepsy at a Cameroonian tertiary teaching hospital: a cross-sectional study	Pan African Medical Journal Clinical Medicine
27. Factors associated with adverse outcomes in Cameroonian patients with traumatic brain Injury: a Cross-Sectional Study	Emergency Medicine International
28. Management of Skull Base Fractures in Cameroon: a multi-institutional cross-sectional study	Emergency Medicine International
Abstracts	
1. Global neurosurgery in Sub-Saharan Africa: estimating the neurosurgical workforce and infrastructural capacities in Cameroon	InciSioN Global Surgery Symposium 2020
2. Global surgery in Cameroon: evaluating the knowledge and attitudes of medical students toward global surgery	InciSioN Global Surgery Symposium 2020
3. Epidemiology of neurosurgical tumors at two reference centers in Cameroon	Multinational Association of Supportive Care in Cancer 2020
4. The burden of direct medical expenditures for epilepsy care among Congolese patients: a single-center study	World Federation of Neurosurgical Societies Global Neurosurgery 2020 Conference
5. African neurosurgery research (Part I): hierarchy of scientific evidence and thematic analysis	World Federation of Neurosurgical Societies Global Neurosurgery 2020 Conference
6. African neurosurgery research (Part II): a scientometric analysis of the top 115 most cited articles	World Federation of Neurosurgical Societies Global Neurosurgery 2020 Conference

(Continued)

TABLE 2 | Continued

Title	Journal or conference
7. Understanding the motivations, needs, and challenges faced by aspiring neurosurgeons in Africa: AN e-survey	World Federation of Neurosurgical Societies Global Neurosurgery 2020 Conference
8. Mapping Global Neurosurgery Research Collaboratives: a Social Network Analysis of the 50 Most Cited Articles	World Federation of Neurosurgical Societies Global Neurosurgery 2020 Conference
9. Paroxysmal sympathetic storm and the role of Beta-Blockers in moderate/severe head trauma: a scoping review.	National Research Collaborative Meeting 2020
10. Management and outcomes of pediatric intracranial suppurations in low- and middle-income countries: a scoping review	National Research Collaborative Meeting 2020
11. Trends in the indications and outcomes of cesarean section in Bukavu - A single-center cross-sectional study	National Research Collaborative Meeting 2020
12. Cerebral aneurysms in Africa: a scoping review	National Research Collaborative Meeting 2020
13. Systematic Review of Patient Attitudes Toward Neurosurgery in Low- and Middle-Income Countries	Bethune Round Table 2020
14. Acute myelopathy as a complication of schistosomiasis - A narrative review	Pan-African Organization for Health, Education and Research: Medical research and mentorship symposium
15. Developing Neurosurgical Research Interest Amongst Aspiring African Neurosurgeons during COVID19 Pandemic	Stanford Center for Innovation in Global Health: The 7th Annual Global Health Research Convening
16. Fostering neurosurgery interest among medical students and general practitioners in low- and middle-income countries: the Association of Future African Neurosurgeons Experience	The Neurology and Neurosurgery Interest
17. Cerebral Aneurysms in Africa: a literature review	Group - Society of British Neurological Surgeons Conference
18. Management of Basilar Skull Fractures in Cameroon: a multi-institutional cross-sectional study	The Neurology and Neurosurgery Interest Group - Society of British Neurological Surgeons Conference
19. Outcomes of Traumatic Brain Injury in Cameroon: a Cross Sectional Study	The Neurology and Neurosurgery Interest Group - Society of British Neurological Surgeons Conference
20. Decompressive craniectomy for severe traumatic brain injury in low- and middle-income countries: a retrospective cohort study.	The Young Continental Association of African Neurosurgical Societies Traumatic Brain Injury Symposium

and middle-income countries (17). Unlike ARIP, the Rwandan group had access to a substantial funding source i.e., a National Institutes of Health R21 grant, and could afford such an initiative. ARIP and organizations that do not have access to funding can still accompany their enrollees in their application to graduate schools and for full scholarships (Ex. Chevening, Fulbright, or Mastercard Africa).

AFAN has a strong presence across the continent (>7,000 likes and >15,000 weekly impressions on Facebook), enabling widespread dissemination of research findings, surveys, and opportunities. This has raised the profile of AFAN as an academic institution and has increased interest among prospective partners. Since starting ARIP, we have received invitations to collaborate from the Young African Neurosurgeons Committee, Global Neurosurgery Committee, Walter E. Dandy Neurosurgical Society, Neurology and Neurosurgery Interest Group. Also, interest in ARIP has increased significantly. Currently, we have enrolled 32 new fellows and recruited previous enrollees as trainers.

Challenges and Limitations

We faced some challenges during ARIP. First, we lacked the resources to run more granular research. For example, we chose to avoid research involving human subjects to minimize the cost of institutional review board applications. Clinical research is an indispensable aspect of academic neurosurgery that evaluates the impact of systems-level changes on individual patients. Mindful of this, we intend to expand our research portfolio by collaborating with African neurosurgery centers. Next, our choice of open-access journals was restricted because we could not afford article processing charges. Often, one or more of our members was from a lower-middle or middle-income country, which meant that we were ineligible for a full waiver of article processing charges. Similarly, our choice of conferences for abstract submissions was limited because we could not afford registration fees. The transition of conferences to an online format due to COVID-19 from mid-2020 was a windfall for ARIP because most conferences waived registration fees. While we were able to accomplish a lot with limited resources, we acknowledge that some financial resources will be necessary to expand ARIP (15). To achieve this goal, AFAN has set up a grant development unit within the research department.

ARIP enrollees had to work on a tight schedule because the program was not integrated into their formal education. This meant that most projects took more time than necessary, especially during the exam period.

Despite the challenges faced, ARIP enrollees were satisfied with the program's quality and were willing to give back by training the new cohort of enrollees.

CONCLUSION

In summary, ARIP aims to build skills and increase the exposure of aspiring academic global surgeons to increase the scholarly output in Africa. ARIP enrollees showed dedication, passion, and tremendous potential, suggesting that greater gains will be noted if this program is implemented in a more resourceful setting. We intend to expand this program and report on the progress of the first and subsequent cohorts (H-index, recruitment in academic institutions, successful grant applications, peer-review journal positions, and postgraduate education).

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

UK: conceptualization, methodology, investigation, visualization, and writing – original draft. YZ, SN, FT, LS, GE, DS, RT, and NG: writing - review and editing. DJ: supervision, methodology, validation, and writing - review and editing. All authors contributed to the article and approved the submitted version.

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Needs of Young African Neurosurgeons and Residents: A Cross-Sectional Study

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Introduction: Africa has many untreated neurosurgical cases due to limited access to safe, affordable, and timely care. In this study, we surveyed young African neurosurgeons and trainees to identify challenges to training and practice.

Methods: African trainees and residents were surveyed online by the Young Neurosurgeons Forum from April 25th to November 30th, 2018. The survey link was distributed via social media platforms and through professional society mailing lists. Univariate and bivariate data analyses were run and a *P*-value < 0.05 was considered to be statistically significant.

Results: 112 respondents from 20 countries participated in this study. 98 (87.5%) were male, 63 (56.3%) were from sub-Saharan Africa, and 52 (46.4%) were residents. 39 (34.8%) had regular journal club sessions at their hospital, 100 (89.3%) did not have access to cadaver dissection labs, and 62 (55.4%) had never attended a WFNS-endorsed conference. 67.0% of respondents reported limited research opportunities and 58.9% reported limited education opportunities. Lack of mentorship ($P = 0.023$, Phi $= 0.26$), lack of access to journals ($P = 0.002$, Phi $= 0.332$), and limited access to conferences ($P = 0.019$, Phi $= 0.369$) were associated with the country income category.

Conclusion: This survey identified barriers to education, research, and practice among African trainees and young neurosurgeons. The findings of this study should inform future initiatives aimed at reducing the barriers faced by this group.

Keywords: Africa, education, global neurosurgery, neurosurgery, research

INTRODUCTION

Although low- and middle-income countries (LMICs) have the greatest burden of neurosurgical diseases, their access to resources is limited (1). Neurosurgeons in these regions, especially in Africa, face unique challenges (2). African countries have some of the highest cases per neurosurgeon, but few patients live within 2-h of a neurosurgical center (3–5). Moreover, most African patients, do not have access to comprehensive health insurance (6). The resulting out-of-pocket expenditures expose them to catastrophic and impoverishing expenditures and limit their access to surgical care (7).

Professional societies are supporting initiatives aimed at improving access to neurosurgical care in Africa. For example, The World Federation of Neurosurgical Societies (WFNS) sponsors the training of African neurosurgeons in accredited reference training centers (8) and the Continental Association of African Neurosurgical Societies (CAANS) recently created an *ad-hoc* committee to assist residents and young neurosurgeons. The Young African Neurosurgeons Committee has been tasked with facilitating education and research among future and young African neurosurgeons.

To understand the barriers and facilitators of research and education in African neurosurgery, the Young African Neurosurgeons Committee and the Young Neurosurgeons Forum of the WFNS (YNF-WFNS) surveyed residents, fellows, and consultants who are within 10 years of completing residency (9, 10). In this paper, we aimed to assess the needs and challenges faced by young African neurosurgeons and residents in their daily clinical and research activities.

METHODS

This was a cross-sectional study consisting of a self-administered survey composed of 28 multiple-choice and two free-text questions (**Appendix 1**) on the respondents' demographics, the type of neurosurgical center they worked in, access to infrastructures, facilitators, and barriers of research and education in daily practice, and suggested solutions (9, 10). The e-survey was developed and piloted by members of the YNF-WFNS. It respected the Checklist for Reporting Results of Internet E-Surveys (CHERRIES) guidelines and its face validity was established by WFNS officials.

A cover letter was annexed to the survey and data were collected from April 25th to November 30th, 2018. The survey link (Qualtrics, USA) was distributed to the electronic mailing lists of the YNF-WFNS and Young CAANS and to personal contacts via email and instant messages on social media platforms (Twitter, Facebook, and WhatsApp).

Respondents were a convenience sample of neurosurgeons and residents, and their responses to the survey were limited to one. The participation and dropout rates were not computed. Chi-Squared test, Pearson's Phi coefficient measure, and non-parametric multivariable tests were used to analyze the data, and the threshold of significance was set at 0.05. Data analysis was done using SPSS v. 26 (IBM, USA).

RESULTS

Demographics and Resources

Out of the 280 Young CAANS members, 112 neurosurgeons and residents from 20 African countries responded to the survey i.e., a response rate of 40% (**Figure 1**). There were no partially completed survey responses.

Sixty-six (58.9%) were from lower-middle-income countries, and 63 (56.3%) were from Sub-Saharan Africa. Ninety-eight (87.5%) respondents were male, 79 (70.5%) were aged between 30 and 40 years, and 52 (46.4%) were neurosurgery residents. Although 76 respondents (67.9%) worked in a university teaching hospital, only 33 (29.5%) declared being paid to do clinical work and research. Most respondents (71.4%) worked in cities of more than 1.5 million inhabitants (**Table 1**).

The majority of the respondents' hospitals had a capacity of 500 or fewer beds (55.4%) and 80 respondents (71.4%) reported they had dedicated neurosurgical wards. Most respondents reported having operating microscopes (68.8%) and intensive care units equipped with ventilators (91.1%). One hundred and nine (97.3%) had access to CT scans, and 88 individuals (78.6%)

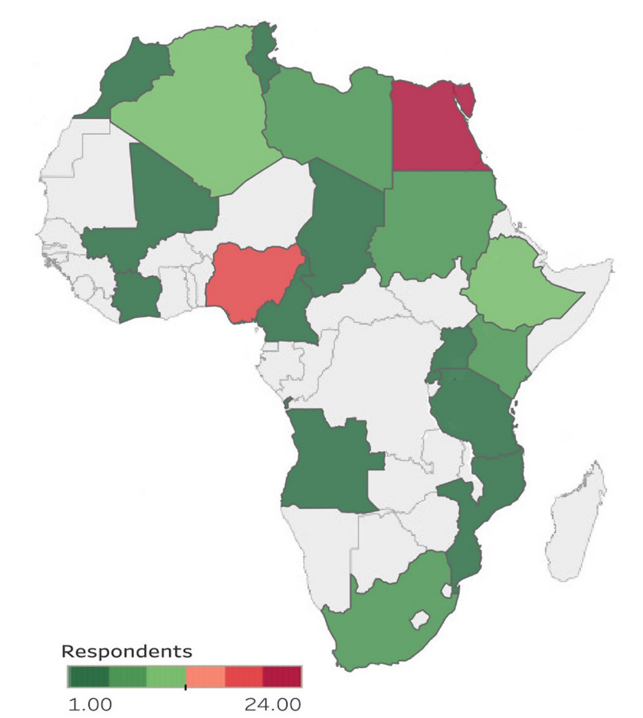

FIGURE 1 | Countries represented in the e-survey and the number of respondents per country.

TABLE 1 | Descriptive characteristics of the survey respondents and their activities.

Characteristic	Number of respondents [*n* (%)] *N* = 112
Sex	
Female	14 (12.5)
Male	98 (87.5)
Age (Years)	
<30	19 (17.0)
30-35	51 (45.5)
36–40	28 (25.0)
≥41	14 (12.5)
Region	
North Africa	49 (43.8)
Sub-Saharan Africa	63 (56.3)
World Bank income category	
Low-income	20 (17.9)
Lower-middle-income	66 (58.9)
Upper-middle-income	26 (23.2)
Profession	
Resident (< 5 years after graduating from medical school)	20 (17.9)
Resident (5 years or more after graduating from medical school)	32 (28.6)
Fellow	27 (24.1)
Consultant <5 years after finishing residency	12 (10.7)
Consultant 5 years or more after finishing residency	17 (15.2)
Other	4 (3.6)
Population of the city respondents work in	
<50,000	2 (1.8)
200,000–500,000	8 (7.1)
500,000–1,500,000	22 (19.6)
>1,500,000	80 (71.4)
Paid activities	
Clinical	79 (70.5)
Clinical and research	33 (29.5)

had access to MRIs. Only 31 (27.7%) respondents had access to catheter angiography. A summary of these data can be found in **Table 2**.

The most popular subspecialties where spine (50%; 95% CI: 40.4–59.6%), skull base (42.9%; 95% CI: 33.5–52.6%), and cerebrovascular surgery (38.4% 95% CI: 29.4–48.1%) (**Figure 2**). Spine surgery was more popular among residents than fellows or consultants (61.5 vs. 47.6 vs. 35.9%, respectively, $P = 0.05$). In contrast, cerebrovascular surgery was more popular among fellows than residents and consultants (52.4 vs. 46.2 vs. 20.5%, respectively, $P = 0.02$). The other subspecialty popularity differences did not show statistical significance.

Challenges to Education and Research

Only 39 (34.8%) respondents had journal clubs at their institutions, and 100 (89.3%) did not have access to hands-on cadaver dissection. Sixty two participants (55.4%) had never attended a WFNS conference or WFNS sponsored meeting,

Perceived Barriers

Almost every respondent (94.6%) felt that the neurosurgical needs of their local population were not adequately covered. The limited number of ICU beds (72.3%), lack of access to microsurgical equipment (59.8%) and inadequate/no insurance coverage (56.3%) were identified as major barriers to a suitable neurosurgical coverage of the patient population. Two out of three respondents reported limited opportunity to do research (67.0%), 66 reported limited access to organized teaching and training sessions (58.9%) (**Table 3**). Most participants reported hands-on courses as their preferred method of training (91.1%), 80 respondents preferred personal attendance (71.4%), and less than half (44.6%) chose web-based lectures.

The following hurdles in daily neurosurgical practice and the personal needs of our participants were found to be associated with the World Bank Income Class classification: inadequate or lack of insurance coverage ($P < 0.001$, Phi $= 0.498$), limited number of trained neurosurgeons ($P < 0.001$, Phi $= 0.375$), limited number of neurosurgical beds ($P = 0.003$, Phi $= 3.24$), lack of access to equipment ($P = 0.004$, Phi $= 0.314$), lack of organized prehospital care ($P = 0.005$, Phi $= 0.309$), lack of regular access to the advice of senior colleagues ($P = 0.002$, Phi $= 0.335$), lack of a mentor ($P = 0.023$, Phi $= 0.26$), lack of access to journals ($P = 0.002$, Phi $= 0.332$) and limited attendance at a neurosurgical conference ($P = 0.019$, Phi $= 0.369$).

TABLE 2 | Availability of material and human resources.

Resource	Number (Percentage)
Hospital	
Mixed activity (public and private)	15 (13.4)
Non-teaching public hospital	20 (17.9)
Private hospital	1 (0.9)
University teaching hospital	76 (67.9)
Bed capacity	
≤500	62 (52.4)
500–1,000	32 (28.6)
>1,000	18 (16.1)
Units that share their ward with other specialties	80 (71.4)
Number of ward beds dedicated to neurosurgery	
<25	31 (27.7)
25–50	47 (42.0)
50–75	19 (17.0)
75–100	8 (7.1)
>100	7 (6.3)
ICUs without mechanical ventilators	10 (8.9)
Equipment	
Catheter angiography	31 (27.7)
CT Scan	109 (97.3)
High-speed drill	65 (58.0)
Image guidance	27 (24.1)
MRI	88 (78.6)
Operating microscope	77 (68.8)
Rehabilitation specialists	57 (50.9)

More West African respondents reported bullying and harassment than their counterparts from South, East, North, and Central Africa (43.5 vs. 14.3 vs. 13.3 vs. 6.1 vs. 0%, respectively, $P = 0.002$). However, more Central African respondents experienced difficulties accessing journals than respondents from West, East, North, and South Africa (100 vs. 56.5 vs. 53.3 vs. 36.7 vs. 0%, respectively, $P = 0.01$). Also, more fellows reported limited research opportunities than consultants and residents (85.7 vs. 76.9 vs. 51.9%, respectively, $P = 0.01$).

DISCUSSION

This is the first study to examine the needs of African neurosurgery specialists and trainees. African residents and consultant neurosurgeons felt the neurosurgical needs of their patients were not met entirely. Respondents faced numerous barriers to neurosurgical practice, education, and research.

Practice and Education

African neurosurgery residents and practitioners had relatively high access to basic neuroimaging. 97.3% had access to a CT scan, and 78.6% had access to an MRI. In a survey of African neurosurgical residents regarding the adequacy of their training, Sader et al. found similar numbers - 95% for CT-scans and 80% for MRIs (11). In contrast, access to neurorehabilitation and operative equipment was limited. Only 58.0% of respondents had access to high-speed drills, 50.9% had access to neurorehabilitation services, and 24.1% had access to neuronavigation. It is concerning that only 27.7% of respondents had access to catheter angiography, given the enormous and rapidly increasing burden of cerebrovascular diseases in Africa (12–14). The scarcity of neurorehabilitation services and operative equipment concerns because 57.2% of participants were either residents or consultant neurosurgeons with <5 years of experience, and 67.9% worked at university teaching hospitals. With 91.0% of respondents working in cities with at least 500,000 inhabitants, African residents and early career neurosurgeons are therefore working in under-resourced high-volume centers. This limits their training and professional development. Neurorehabilitation and operative equipment have previously been identified as limiting factors to the development of neurosurgical practice in low-resource settings (11, 15–17). It is therefore crucial that strategies aimed at increasing the neurosurgical workforce in Africa are accompanied by investments in equipment and neurorehabilitation.

The benefits of neurosurgical dissection are undeniable. Participation in dissection labs increases the understanding of neuroanatomical relationships and improves operative skills (18, 19). For these reasons, hands-on dissections have become an integral part of postgraduate neurosurgical training (20).

Residency programs and professional societies in high-income countries offer dissection labs to their residents and young neurosurgeons but 89.3% of African residents and neurosurgeons did not have dissection labs at their home institutions. The cost of dissection labs can be prohibitive for LMIC neurosurgical centers and, in effect, constitutes a barrier to the training of neurosurgeons. Moreover, 55.4% of respondents had never been to an international neurosurgical event and were, therefore, less likely to have participated in a cadaver dissection abroad.

African neurosurgeons are aware of these difficulties and are working locally and internationally to improve service delivery and practice. Locally, South African training centers like the University of Cape Town offer sponsored pediatric neurosurgery fellowships to African neurosurgeons (21). Internationally, African training centers partner with non-governmental and academic organizations from high-income countries. For example, the Foundation for International Education in Neurological Surgery (FIENS) provides funded fellowships in American high volume academic centers to young African neurosurgeons (22). Also, East African training centers have collaborated with the Neurosurgery Education and Development (NED) foundation to provided endoscopic treatment and training using a mobile endoscopy unit (23). In Tanzania and Uganda, Weill Cornell and Duke University are running global neurosurgery fellowships in partnership with local training programs (24). Furthermore, in West Africa, Nigerian and Swedish centers have expanded the local neurosurgical capacity following the successful implementation of a twinning program (25).

While these collaborations provide valuable experience, few provide exposure to cadaver dissections. A solution around this is the use of low-cost, high-fidelity solutions for dissection.

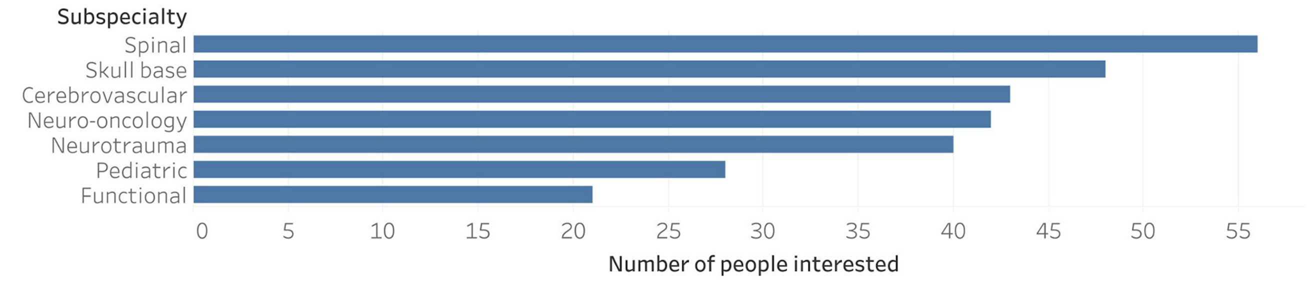

FIGURE 2 | Subspecialty interests.

TABLE 3 | Perceived barriers to day-to-day practice.

Barrier	Frequency (Percentage)
Inadequate or no insurance coverage	63 (56.3)
Limited number of trained neurosurgeons	57 (50.9)
Limited number of neurosurgical beds	52 (46.4)
Limited number of ICU beds	81 (72.3)
Lack of access to equipment necessary for microsurgery	67 (59.8)
Lack of regular/consistent access to CT	19 (17.0)
Lack of regular access to MRI	45 (40.2)
Lack of organized primary care	46 (41.1)
Lack of organized pre-hospital/emergency hospital care	60 (53.6)
Lack of organized rehabilitation care	61 (54.5)
Lack of access to organized teaching/training sessions	66 (58.9)
Limited number of opportunities for hands-on operating	58 (51.8)
Long hours of work	48 (42.9)
Poor work/life balance	63 (56.3)
Bullying and harassment issues	18 (16.1)
Lack of regular access to the advice of experienced/senior colleagues	38 (33.9)
Lack of a mentor	34 (30.4)
Lack of access to neurosurgical journals	50 (44.6)
Lack of access to neurosurgical textbooks	25 (22.3)
Limited opportunities to do research	75 (67.0)

These include the use of veterinary cadavers for spinal dissection, use of gelatin and silicone to simulate cerebrovascular surgery dissection, and the use of phone cameras as operative microscopes (26–28). These cheaper and innovative solutions can bridge the training gap in African neurosurgery programs.

The ongoing COVID pandemic has changed the landscape of neurosurgical education on the African continent, limiting physical interactions and in-person conferences. Educators have developed online solutions to meet the educational needs of African trainees and residents. These online events have the advantage of being less expensive because they eliminate travel and visa costs but they present a unique set of challenges. Online sessions offer less face-to-face and hands-on time in comparison with physical conferences and symposia. As such, they cannot be a substitute to in-person and hands-on experiences but they are and should be complements.

Research

African residents and young neurosurgeons equally face significant challenges in research. While it is true that the contribution of Africa to global neurosurgical research has increased over the past two decades, it still has a long way to go (29). One of the barriers to African neurosurgical research is protected time. Protected time is indispensable for the development of neurosurgeon-scientists (30). Most American residency programs encourage their residents to pursue research activities. Most American residents have a year or more of protected research time (31). Similarly, 45.0% of residents in Latin America are enrolled in a program with protected research time (32). These figures contrast starkly with 29.5% of residents in Africa who have protected research time.

In addition, 65.2% of participants did not have journal clubs at their institutions. In contrast, 85% of American residents have journal clubs at their training programs (33). Journal clubs expose participants to recent literature, enhance critical appraisal skills, and facilitate the practice of evidence-based neurosurgery (34). Given the high volume of neurosurgical literature and the heavy workload of neurosurgeons and residents, journal clubs are an opportunity for participants to keep up with the literature. Journal clubs should be organized on a monthly basis, and articles should be selected based on their impact on everyday practice (35).

Proposed Solutions

Seminar courses and workshops are crucial to the training of young African neurosurgeons (2). The Young African Neurosurgeons Committee has been organizing research courses at regional meetings to build research capacity among residents and young neurosurgeons (36, 37). Digital education modules, operative videos, and telesimulation are effective in tackling the current research and education barriers in low resource settings (38). The YNF-WFNS organizes live webinars for all young neurosurgeons (39). Moreover, as a result of the COVID-19 pandemic, most academic institutions have switched to online education solutions and have opened their webinars to non-members (40). These webinars facilitate education, peer mentorship, and collaboration among participants. Telesimulation is a good complement to hands-on courses. It reduces geographical barriers but cannot substitute hands-on lab courses.

It is unlikely that every African neurosurgical center will have all the necessary resources in the near future. In the meantime, these centers must leverage inter-African partnerships and collaborations with non-African institutions to tackle the challenges to research and education that we have identified. The partnerships between LMIC and high-income institutions must be based on equity and have frequent monitoring and evaluation (41, 42). Additionally, it is equally important to coordinate efforts so as to avoid redundancy.

Limitations

Young neurosurgeons and trainees without reliable internet, electronic devices, and email are less likely to be captured. Moreover, our use of non-randomized sampling methods reduces the external validity of our survey findings. Notwithstanding, our survey is the first to assess the needs and barriers faced by Young African researchers and with representatives of 20 African countries, we believe our findings are close to the truth. Also, our survey predated the COVID-19 pandemic and as such did not capture the pandemic-related needs of African residents and young neurosurgeons. This is a limitation considering that the pandemic led to cancellation of rotations, fellowships, and physical conferences. By presenting a pre-pandemic overview of the needs and barriers faced by African trainees and neurosurgeons, our study provides data to better appreciate the impact of the pandemic. We believe this data will be informative for the WFNS, CAANS, and their partners as they determine solutions to mitigate the impact of the pandemic on African neurosurgery.

CONCLUSION

There has been evolution in neurosurgical practice in Africa over the past two decades however neurosurgeons and residents face a myriad of difficulties in their day-to-day practice and education. Current efforts by the WFNS, CAANS, Young CAANS and YNF should be encouraged and the efforts of these organizations should prioritize actions that tackle the problems identified by young African neurosurgeons, namely the dearth of access to research, skills labs, literature and mentorship.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by World Federation of Neurosurgical Societies. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

UK and FR: methodology, investigation, data curation, and writing - original draft. AD, NB, NT, PG, SO, JB, IO, LJ, TM, ZS, BC, CK, SS, AM, JN, PS, SB, NE, MM, NE-G, FS, GF, and MQ: conceptualization and writing - review & editing. AMA, AS, FH, NM, and TL: conceptualization, investigation, and writing - review & editing. AA-H, AK, and IE: conceptualization, methodology, investigation, and writing - review & editing. IE: conceptualization, methodology, investigation, data curation, and writing - review & editing. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsurg.2021.647279/full#supplementary-material

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Racial and Ethnic Inequities in Mortality During Hospitalization for Traumatic Brain Injury: A Call to Action

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The health disparities which drive inequities in health outcomes have long plagued our already worn healthcare system and are often dismissed as being a result of social determinants of health. Herein, we explore the nature of these inequities by comparing outcomes for racial and ethnic minorities patients suffering from traumatic brain injury (TBI). We retrospectively reviewed all patients enrolled in the Trauma One Database at the Oregon Health & Science University Hospital from 2006 to October 2017 with an abbreviated injury scale (AIS) for the head or neck >2. Racial and ethnic minority patients were defined as non-White or Hispanic. A total of 6,352 patients were included in our analysis with 1,504 in the racial and ethnic minority cohort vs. 4,848 in the non-minority cohort. A propensity score (PS) model was generated to account for differences in baseline characteristics between these cohorts to generate 1,500 matched pairs. The adjusted hazard ratio for in-hospital mortality for minority patients was 2.21 [95% Confidence Interval (CI) 1.43–3.41, $p < 0.001$] using injury type, probability of survival, and operative status as covariates. Overall, this study is the first to specifically look at racial and ethnic disparities in the field of neurosurgical trauma. This research has demonstrated significant inequities in the mortality of TBI patients based on race and ethnicity and indicates a substantive need to reshape the current healthcare system and advocate for safer and more supportive pre-hospital social systems to prevent these life-threatening sequelae.

Keywords: mortality, disparities, inequities, TBI, neurotrauma, race

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INTRODUCTION

Structural disparities propagated against racial and ethnic minorities have long been known to drive inequities in health outcomes in the US yet are often dismissed as an unfortunate yet unavoidable consequences of what has been disguised as the social determinants of health. However, many of these inequities are formed long before our patients ever step foot into a healthcare facility and stem not from individual poor health decisions but from decades of structural racism and systematic oppression which leave minority patients at a disadvantage for health outcomes even from before birth (1–3). [It is important to state clearly at this point that we will discuss race and ethnicity not as biologically-based separations of persons but as socially-formed systematic manners of categorizing persons based on culture, geographic origin, language, etc. so as to provide financial, social, and political advantage over specific groups of persons with a long and evidence-based history of such action (3–8)]. These systemic factors have been extensively researched in the fields of public health, sociology, psychology, and more to demonstrate significant negative impacts on a minority persons lifelong risk for medical and psychological trauma (1–3, 9).

Specifically in the field of trauma, these inequities are then exacerbated by ongoing external factors such as insurance, access to level I trauma centers, mechanism of injury, time to surgical intervention, staffing of skilled providers, access to post-acute care and rehabilitation, and community or financial support (1, 10–14). In neurosurgical trauma, the crux of disease burden lies in traumatic brain injury (TBI) which is increasingly becoming a more prevalent global medical issue with devastating effects on both personal and healthcare sequelae (15–20). As with other healthcare fields, neurosurgery and neuro-trauma are not immune to the adverse effects of structural racism on racial and ethnic inequities (10, 21–24). Past research in this field has failed to identify or call out the specific role of sociological and systemic factors that influence these pervasive, persistent, and problematic disparities of health outcomes for our minority patients. In this study, we explore the racial and ethnic inequities in mortality during hospitalization following traumatic brain injury and will engage both a sociological and medical perspective to call to action a change in practice toward a more expansive and sympathetic understanding of the factors involved in minority health outcomes in neuro-trauma.

MATERIALS AND METHODS

Study Design and Setting

This study is a retrospective review of all patients entered into the Trauma One Database established in 2006 at the Oregon Health & Science University Hospital (OHSU), one of the two Level I Trauma centers in the state of Oregon. For our research, we included all patients ≥16 years-old entered into the system from 2006 to October of 2017. The dataset used for analysis contained all patient demographic and insurance characteristics, details regarding the mechanism of injury (MOI), treatments provided in the pre-hospital setting and throughout the hospital stay, comorbidities at the time of presentation, discharge disposition, and overall complications. This study follows the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guidelines, and was approved by the OHSU Institutional Review Board (25).

Measurements and Outcomes

TBI severity was classified according to the patient's Glasgow Coma Scale (GCS) score on arrival with the following classifications: severe as GCS <8, moderate as 8–12, and mild as ≥13. Minor trauma was defined by an Injury Severity Score (ISS) of ≤15. Racial and ethnic minority patients were defined as identifying as any non-White race or as being of Hispanic ethnicity. Mechanism of injury categories were assigned based on the Abbreviated Injury Scale (AIS), ISS, and ICD-9-CM, or ICD-10-CM codes (26). Probability of survival is calculated at our institution using the Trauma Injury Severity Score methodology with a weighted formula comprising of ISS, age, and Revised Trauma Score.

The primary outcome of interest was in-hospital mortality stratified by racial and ethnic minority status. The secondary outcome was the trend in mortality classified by arrival year, injury type, and the presence of work-related injuries.

Statistical Analysis

Continuous variables were described using means and standard deviations (SD), and compared between groups using a two-sample Student's t-test. When appropriate for skewed variables, the geometric mean and geometric standard deviation were calculated and used for comparisons. Dichotomous and categorical variables were reported using counts and percentages and compared using Fisher's exact-test.

Due to the inherent potential for selection bias in this observational retrospective study, and to account for differences in baseline socioeconomic and demographic characteristics, a propensity-score (PS) matching model was employed. Age, sex, injury mechanism, and primary payor were included as the covariates in this final model, consistent with what has been done in the literature previously when examining racial and ethnic disparities (27, 28). Matching with a 1:1 ratio using nearest neighbor methodology was then performed using MatchIt Package in R, version 4.1.0 (29). Balance of baseline covariates and region of common support was then assessed using absolute standardized mean differences, jitter plots and histograms, provided in the **Supplementary Materials**.

A multivariate Cox Proportional Hazards regression model was then created using an iterative combined forward and backward stepwise selection procedure from the candidate covariates for the propensity-matched cohorts. Assumptions required for proportional hazards regression were assessed numerically for each covariate, and graphically by the plotting of scaled Schoenfeld residuals. The final model included injury type, probability of survival, and operative status as covariates. Since the AIS score covariate was found to violate the assumption of proportional hazards, the final model was stratified by this covariate. Goodness of fit of each model was then assessed using Cox-Snell residuals.

A p-value < 0.05 was considered to be statistically significant. All analyses were performed using R software, version 4.0.4 (R Foundation for Statistical Computing, Vienna, Austria). The final analysis was confirmed using Stata, version 16.1 (StataCorp, College Station, Texas).

RESULTS

Patient Demographics

There was a total of 6,352 patients included in the Trauma One database with 1,504 included in the racial/ethnic minority cohort and 4,848 patients in the White/non-Hispanic cohort. The clinical characteristics of the patients and propensity-matched patients are shown in **Tables 1A**, **1B**, respectively. Following statistical PS matching, the maximum number of participants

TABLE 1A | Baseline patient characteristics stratified by minority status.

		Total	Non-minority	Minority	*p*-value	Absolute standardized difference
n		6,352	4,848	1,504		
Age (years)*		47.89 (1.63)	49.66 (1.61)	42.61 (1.65)	<0.001	0.313
Categorical age	15–24	908 (14.3)	613 (12.6)	295 (19.6)	NA	0.341
	25–34	813 (12.8)	567 (11.7)	246 (16.4)		
	35–44	700 (11.0)	491 (10.1)	209 (13.9)		
	45–54	868 (13.7)	672 (13.9)	196 (13.0)		
	55–64	946 (14.9)	766 (15.8)	180 (12.0)		
	65–74	792 (12.5)	656 (13.5)	136 (9.0)		
	75–84	743 (11.7)	589 (12.1)	154 (10.2)		
	85+	582 (9.2)	494 (10.2)	88 (5.9)		
Sex	Male	4,353 (68.5)	3,264 (67.3)	1,089 (72.4)	<0.001	0.111
	Female	1,999 (31.5)	1,584 (32.7)	415 (27.6)		
Race	White	4,866 (86.9)	4,848 (100.0)	18 (2.4)	NA	9.012
	Black or African American	100 (1.8)	0 (0.0)	100 (13.4)		
	American Indian or Alaskan Native	59 (1.1)	0 (0.0)	59 (7.9)		
	Asian	142 (2.5)	0 (0.0)	142 (19.0)		
	Hispanic or Latino	346 (6.2)	0 (0.0)	346 (46.2)		
	Pacific Islander or Native Hawaiian	15 (0.3)	0 (0.0)	15 (2.0)		
	Other	69 (1.2)	0 (0.0)	69 (9.2)		
Ethnicity	Not Hispanic or Latino	5,976 (94.1)	4,848 (100.0)	773 (51.4)	<0.001	1.375
	Hispanic or Latino	375 (5.9)	0 (0.0)	731 (48.6)		
BMI*		26.64 (1.23)	26.74 (1.23)	26.3 (1.23)	0.097	0.080
Injury type	Blunt	6130 (96.5)	4706 (97.1)	1424 (94.7)	<0.001	0.122
	Penetrating	221 (3.5)	141 (2.9)	80 (5.3)		
Mechanism of injury	Fall	3006 (47.5)	2416 (50.0)	590 (39.3)	NA	0.322
	Firearm	146 (2.3)	94 (1.9)	52 (3.5)		
	Motor vehicle traffic—Motorcyclist	272 (4.3)	227 (4.7)	45 (3.0)		
	Motor vehicle traffic—Occupant	1,079 (17.0)	765 (15.8)	314 (20.9)		
	Motor vehicle traffic—Pedestrian	397 (6.3)	272 (5.6)	125 (8.3)		
	Pedal cyclist, other	287 (4.5)	240 (5.0)	47 (3.1)		
	Struck by, against	511 (8.1)	345 (7.1)	166 (11.1)		
	Transport, other	248 (3.9)	201 (4.2)	47 (3.1)		
	Other	386 (6.1)	270 (5.6)	116 (7.7)		
Work relatedness of injury	Work related	226 (3.6)	156 (3.2)	70 (4.7)	0.011	0.074
	Not work related	6,125 (96.4)	4,691 (96.8)	1,434 (95.3)		
GCS on ED presentation*		11.12 (1.75)	11.33 (1.72)	10.44 (1.83)	<0.001	0.142
ISS*		19.36 (1.58)	19.14 (1.58)	20.07 (1.6)	<0.001	0.102
AIS H&N	3	2,721 (42.8)	2,102 (43.4)	619 (41.2)	0.001	0.112
	4	2,374 (37.4)	1,836 (37.9)	538 (35.8)		
	5	1,238 (19.5)	899 (18.5)	339 (22.5)		
	6	19 (0.3)	11 (0.2)	8 (0.5)		
TBI severity	Mild	4,010 (76.2)	3,139 (77.8)	871 (71.1)	<0.001	0.155
	Moderate	323 (6.1)	235 (5.8)	88 (7.2)		
	Severe	927 (17.6)	661 (16.4)	266 (21.7)		

(Continued)

TABLE 1A | Continued

		Total	Non-minority	Minority	*p*-value	Absolute standardized difference
Transport mode	Ambulance	4,880 (77.0)	3,713 (76.9)	1,167 (77.6)	0.516	0.081
	Privately owned vehicle	88 (1.4)	68 (1.4)	20 (1.3)		
	Walk in	7 (0.1)	7 (0.1)	0 (0.0)		
	Helicopter	891 (14.1)	684 (14.2)	207 (13.8)		
	Police or law enforcement	1 (0.0)	1 (0.0)	0 (0.0)		
	Auto launch helicopter	0 (0.0)	0 (0.0)	0 (0.0)		
	Other	40 (0.6)	35 (0.7)	5 (0.3)		
	Fixed wing aircraft	427 (6.7)	323 (6.7)	104 (6.9)		
Advanced directives	Advance directive, directive to physicians, or living will	174 (2.8)	145 (3.0)	29 (2.0)	0.081	0.080
	Both advance directive AND POLST prior to injury	41 (0.7)	32 (0.7)	9 (0.6)		
	No, neither advance directive nor POLST prior to injury	5,863 (93.0)	4,470 (92.5)	1,393 (94.4)		
	POLST in effect prior to injury	229 (3.6)	184 (3.8)	45 (3.0)		
Operative status	Operative patient	2,012 (31.7)	1,493 (30.8)	519 (34.5)	0.008	0.079
	Non-operative patient	4,337 (68.3)	3,352 (69.2)	985 (65.5)		
Time to first OR visit (min)*		963.07 (5.49)	1048.08 (5.21)	735.71 (6.27)	<0.001	0.203
Length of hospital stay (days)*		3.85 (3.53)	4.01 (3.3)	3.37 (4.27)	<0.001	0.131
Length of ICU stay (days)*		2.12 (2.92)	2.16 (2.82)	1.98 (3.24)	0.007	0.082
Total hospital charges*		44,689.2 (2.66)	44,613.48 (2.63)	44,934.16 (2.75)	0.804	0.007
Primary payor	Vehicle insurance	1,382 (21.8)	988 (20.4)	394 (26.2)	NA	0.341
	Charity	1 (0.0)	0 (0.0)	1 (0.1)		
	Commercial insurance	1,832 (28.8)	1,529 (31.5)	303 (20.2)		
	Medicaid	798 (12.6)	559 (11.5)	239 (15.9)		
	Medicare	1,290 (20.3)	1,038 (21.4)	252 (16.8)		
	Other health insurance (VA)	290 (4.6)	216 (4.5)	74 (4.9)		
	Self pay	521 (8.2)	354 (7.3)	167 (11.1)		
	Ward of federal government	29 (0.5)	21 (0.4)	8 (0.5)		
	Workman's compensation	208 (3.3)	143 (2.9)	65 (4.3)		
Secondary payor	Vehicle insurance	412 (14.4)	299 (13.7)	113 (16.4)	NA	0.225
	Charity	0 (0.0)	0 (0.0)	0 (0.0)		
	Commercial insurance	1,417 (49.4)	1,119 (51.3)	298 (43.3)		
	Medicaid	642 (22.4)	467 (21.4)	175 (25.4)		
	Medicare	195 (6.8)	160 (7.3)	35 (5.1)		
	Other health insurance (VA)	198 (6.9)	133 (6.1)	65 (9.4)		
	Self pay	2 (0.1)	1 (0.0)	1 (0.1)		
	Ward of federal government	3 (0.1)	2 (0.1)	1 (0.1)		
	Workman's compensation	1 (0.0)	1 (0.0)	0 (0.0)		

(Continued)

TABLE 1A | Continued

		Total	Non-minority	Minority	*p*-value	Absolute standardized difference
Discharge disposition	Home	3,737 (58.8)	2,834 (58.5)	903 (60.0)	NA	0.256
	Expired	630 (9.9)	411 (8.5)	219 (14.6)		
	Skilled nursing facility	1,050 (16.5)	866 (17.9)	184 (12.2)		
	Acute care facility-hospital	91 (1.4)	79 (1.6)	12 (0.8)		
	Rehabilitation facility	321 (5.1)	251 (5.2)	70 (4.7)		
	Home health	179 (2.8)	139 (2.9)	40 (2.7)		
	Hospice	42 (0.7)	36 (0.7)	6 (0.4)		
	Court/law enforcement	8 (0.1)	5 (0.1)	3 (0.2)		
	Against medical advice	71 (1.1)	55 (1.1)	16 (1.1)		
	Psychiatric hospital or unit	7 (0.1)	6 (0.1)	1 (0.1)		
	Long term acute care	44 (0.7)	34 (0.7)	10 (0.7)		
	Institution not defined elsewhere	162 (2.6)	126 (2.6)	36 (2.4)		
	Intermediate care facility	10 (0.2)	6 (0.1)	4 (0.3)		
	Other	0 (0.0)	0 (0.0)	0 (0.0)		
Probability of survival		0.92 (0.12)	0.92 (0.12)	0.92 (0.14)	0.203	0.043
Deaths	Live	5,722 (90.1)	4,437 (91.5)	1,285 (85.4)	<0.001	0.191
	Die	630 (9.9)	411 (8.5)	219 (14.6)		

The values displayed are computed from the geometric mean and geometric standard deviation.

BMI, Body Mass Index; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; AIS H&N, Abbreviated Injury Score of the Head & Neck; TBI, Traumatic Brain Injury; POLST, Physicians Orders For Life-Sustaining Treatment; ICU, Intensive Care Unit; VA, Veterans Affairs.

in each group was 1,500 (approximately equivalent to the total number of patients in the minority group).

Overall, the patients were 68.5% male and 31.5% female. There was a statistically significant difference in sex between the White/non-Hispanic and the minority cohorts with males making up 67.3% of the White/non-Hispanic group vs. 72.4% of the minority cohort ($p < 0.001$). The average age of all patients was 47.89 years old. There was a statically significant difference in the average ages based on cohorts with that of the White/non-Hispanic group as 49.66 years old and of the minority group as 42.61 years old ($p < 0.001$). By age group, the highest incidence of TBI overall and in the White/non-Hispanic cohort occurred in the 55–64 year old group (14.9% of overall patients, 15.8% of White/non-Hispanic patients) while the highest incidence for the minority cohort occurred in the 15–24 year old group (19.6% of minority patients).

Overall, there were 7 different categories for race/ethnicity included in the demographics of the database: White (86.9%), Black/African American (1.8%), American Indian or Alaskan Native (1.1%), Asian (2.5%), Hispanic/Latino (6.2%), Pacific Islander or Native Hawaiian (0.3%), and Other (1.2%). Of the minority sub-group, the patients were 13.4% Black, 7.9% American Indian/Alaskan Native, 19% Asian, 46.2% Hispanic/Latino, 2.0% Pacific Islander/Native Hawaiian, and 9.2% Other.

Mortality and Adverse Outcomes

The overall in-hospital mortality rate was 9.9% with a statistically significant difference between in-hospital mortality rate of White/non-Hispanic patients (8.5%) and the in-hospital mortality rate of minority patients (14.6%) ($p < 0.001$). The adjusted hazard ratio for in-hospital mortality for minority patients in the propensity-matched cohort was 2.21 [95% Confidence Interval (CI) 1.43, 3.41] with $p < 0.001$ (**Table 2**). Examination of the absolute standardized mean differences, and of the region of common support indicated effective propensity-score matching (**Supplementary Figures 1, 2**). There was no statistically significant difference in the overall probability of survival prior to propensity matching, however the Kaplan-Meier curve of both the non-propensity matched and propensity matched patients (**Figures 1A,B**) demonstrates a visibly lower survival probability in the minority group. The overall length of hospital stay was 3.85 days with a larger standard deviation in the minority group (4.27 days) vs. the White/non-Hispanic group (3.30 days) ($p < 0.001$). The length of ICU stay in all groups was an average of 2.12 days ($p = 0.007$). There was no statistically significant difference in discharge disposition, with 58.5% overall discharged to home, 58.5% of White/non-Hispanic patients discharged home, and 60.0% of minority patients discharged home. There were slight differences in discharges to Skilled Nursing Facilities (SNFs) (17.9% of White/non-Hispanic patients

TABLE 1B | Patient characteristics stratified by minority status following propensity matching.

		Total	Non-minority	Minority	p-value	Absolute standardized difference
n		3,000	1,500	1,500		
Age (years)*		43.1 (1.65)	43.54 (1.65)	42.66 (1.65)	0.265	0.041
Categorical age	15-24	568 (18.9)	275 (18.3)	293 (19.5)	NA	0.120
	25-34	494 (16.5)	249 (16.6)	245 (16.3)		
	35-44	383 (12.8)	174 (11.6)	209 (13.9)		
	45-54	396 (13.2)	201 (13.4)	195 (13.0)		
	55-64	390 (13.0)	210 (14.0)	180 (12.0)		
	65-74	293 (9.8)	157 (10.5)	136 (9.1)		
	75-84	285 (9.5)	131 (8.7)	154 (10.3)		
	85+	191 (6.4)	103 (6.9)	88 (5.9)		
Sex	Male	2,172 (72.4)	1,087 (72.5)	1,085 (72.3)	0.967	0.003
	Female	828 (27.6)	413 (27.5)	415 (27.7)		
Race	White	1,518 (67.6)	1,500 (100.0)	18 (2.4)	NA	9.000
	Black or African American	99 (4.4)	0 (0.0)	99 (13.3)		
	American Indian or Alaskan Native	59 (2.6)	0 (0.0)	59 (7.9)		
	Asian	142 (6.3)	0 (0.0)	142 (19.0)		
	Hispanic or Latino	346 (15.4)	0 (0.0)	346 (46.3)		
	Pacific Islander or Native Hawaiian	15 (0.7)	0 (0.0)	15 (2.0)		
	Other	68 (3.0)	0 (0.0)	68 (9.1)		
Ethnicity	Not Hispanic or Latino	2,624 (87.5)	1,500 (100.0)	771 (51.4)	<0.001	1.375
	Hispanic or Latino	375 (12.5)	0 (0.0)	729 (48.6)		
BMI*		26.57 (1.23)	26.87 (1.23)	26.31 (1.24)	0.108	0.099
Injury type	Blunt	2,853 (95.1)	1,432 (95.5)	1,421 (94.7)	0.398	0.034
	Penetrating	147 (4.9)	68 (4.5)	79 (5.3)		
Mechanism of injury	Fall	1,198 (39.9)	608 (40.5)	590 (39.3)	NA	0.051
	Firearm	104 (3.5)	52 (3.5)	52 (3.5)		
	Motor vehicle traffic - Motorcyclist	87 (2.9)	42 (2.8)	45 (3.0)		
	Motor vehicle traffic - occupant	616 (20.5)	303 (20.2)	313 (20.9)		
	Motor vehicle traffic - pedestrian	253 (8.4)	128 (8.5)	125 (8.3)		
	Pedal cyclist, other	91 (3.0)	44 (2.9)	47 (3.1)		
	Struck by, against	341 (11.4)	175 (11.7)	166 (11.1)		
	Transport, other	85 (2.8)	38 (2.5)	47 (3.1)		
	Other	225 (7.5)	110 (7.3)	115 (7.7)		
Work relatedness of injury	Work related	129 (4.3)	59 (3.9)	70 (4.7)	0.368	0.036
	Not work related	2,870 (95.7)	1,440 (96.1)	1,430 (95.3)		
GCS on ED presentation*		10.62 (1.81)	10.81 (1.8)	10.43 (1.83)	0.142	0.059
ISS*		19.8 (1.6)	19.52 (1.6)	20.08 (1.6)	0.101	0.060
AIS H&N	3	1,239 (41.3)	623 (41.5)	616 (41.1)	0.220	0.077
	4	1,104 (36.8)	566 (37.7)	538 (35.9)		
	5	646 (21.5)	308 (20.5)	338 (22.5)		
	6	11 (0.4)	3 (0.2)	8 (0.5)		
TBI severity	Mild	1,780 (72.6)	912 (74.1)	868 (71.0)	0.219	0.070
	Moderate	169 (6.9)	81 (6.6)	88 (7.2)		
	Severe	503 (20.5)	237 (19.3)	266 (21.8)		
Transport mode	Ambulance	2,312 (77.2)	1,147 (76.7)	1,165 (77.7)	0.796	0.073
	Privately owned vehicle	37 (1.2)	17 (1.1)	20 (1.3)		

(Continued)

TABLE 1B | Continued

		Total	Non-minority	Minority	p-value	Absolute standardized difference
	Walk in	2 (0.1)	2 (0.1)	0 (0.0)		
	Helicopter	419 (14.0)	213 (14.2)	206 (13.7)		
	Police or law enforcement	1 (0.0)	1 (0.1)	0 (0.0)		
	Auto launch helicopter	0 (0.0)	0 (0.0)	0 (0.0)		
	Other	12 (0.4)	7 (0.5)	5 (0.3)		
	Fixed wing Aircraft	211 (7.0)	108 (7.2)	103 (6.9)		
Advanced directives	Advance directive, directive to physicians, or living will	62 (2.1)	33 (2.2)	29 (2.0)	0.492	0.058
	Both advance directive and polst prior to injury	13 (0.4)	4 (0.3)	9 (0.6)		
	No, neither advance directive nor polst prior to injury	2,805 (94.6)	1,416 (94.8)	1,389 (94.4)		
	POLST in effect prior to injury	86 (2.9)	41 (2.7)	45 (3.1)		
Operative status	Operative patient	1,039 (34.6)	522 (34.8)	517 (34.5)	0.848	0.007
	Non-operative patient	1,960 (65.4)	977 (65.2)	983 (65.5)		
Time to first or visit (min)*		871.31 (5.81)	1,012.32 (5.37)	735.10 (6.23)	0.005	0.183
Length of hospital stay (days)*		3.8 (3.83)	4.26 (3.4)	3.38 (4.24)	<0.001	0.172
Length of ICU stay (days)*		2.15 (3.08)	2.34 (2.92)	1.98 (3.24)	<0.001	0.150
Total Hospital charges*		46,051.76 (2.73)	47,165.17 (2.71)	44,964.63 (2.75)	0.193	0.048
Primary payor	Vehicle insurance	792 (26.4)	398 (26.5)	394 (26.3)	NA	0.090
	Charity	0 (0.0)	0 (0.0)	0 (0.0)		
	Commercial Insurance	589 (19.6)	287 (19.1)	302 (20.1)		
	Medicaid	489 (16.3)	251 (16.7)	238 (15.9)		
	Medicare	530 (17.7)	278 (18.5)	252 (16.8)		
	Other health insurance (VA)	127 (4.2)	53 (3.5)	74 (4.9)		
	Self pay	334 (11.1)	167 (11.1)	167 (11.1)		
	Ward of federal government	17 (0.6)	9 (0.6)	8 (0.5)		
	Workman's compensation	122 (4.1)	57 (3.8)	65 (4.3)		
Secondary payor	Vehicle insurance	230 (16.3)	117 (16.1)	113 (16.4)	NA	0.118
	Charity	0 (0.0)	0 (0.0)	0 (0.0)		
	Commercial Insurance	647 (45.7)	349 (48.0)	298 (43.3)		
	Medicaid	340 (24.0)	165 (22.7)	175 (25.4)		
	Medicare	74 (5.2)	39 (5.4)	35 (5.1)		
	Other health insurance (VA)	119 (8.4)	54 (7.4)	65 (9.4)		
	Self pay	2 (0.1)	1 (0.1)	1 (0.1)		
	Ward of federal government	3 (0.2)	2 (0.3)	1 (0.1)		
	Workman's compensation	0 (0.0)	0 (0.0)	0 (0.0)		
Discharge disposition	Home	1,793 (59.8)	893 (59.5)	900 (60.0)	NA	0.235
	Expired	346 (11.5)	128 (8.5)	218 (14.5)		
	Skilled nursing facility	402 (13.4)	218 (14.5)	184 (12.3)		
	Acute care facility-hospital	33 (1.1)	21 (1.4)	12 (0.8)		
	Rehabilitation facility	165 (5.5)	95 (6.3)	70 (4.7)		
	Home health	82 (2.7)	42 (2.8)	40 (2.7)		
	Hospice	15 (0.5)	9 (0.6)	6 (0.4)		
	Court/law enforcement	6 (0.2)	3 (0.2)	3 (0.2)		
	Against medical advice	38 (1.3)	22 (1.5)	16 (1.1)		
	Psychiatric hospital or unit	5 (0.2)	4 (0.3)	1 (0.1)		

(Continued)

TABLE 1B | Continued

		Total	Non-minority	Minority	p-value	Absolute standardized difference
	Long term acute care	23 (0.8)	13 (0.9)	10 (0.7)		
	Institution not defined elsewhere	87 (2.9)	51 (3.4)	36 (2.4)		
	Intermediate care facility	5 (0.2)	1 (0.1)	4 (0.3)		
	Other	0 (0.0)	0 (0.0)	0 (0.0)		
Probability of survival		0.92 (0.13)	0.93 (0.12)	0.92 (0.14)	0.040	0.092
Deaths	Live	2,654 (88.5)	1,372 (91.5)	1,282 (85.5)	<0.001	0.189
	Die	346 (11.5)	128 (8.5)	218 (14.5)		

The values displayed are computed from the geometric mean geometric standard deviation.
BMI, Body mass index; GCS, Glasgow coma scale; ISS, Injury severity score; AIS H&N, Abbreviated injury score of the head & neck; TBI, Traumatic brain injury; POLST, Physicians orders for life-sustaining treatment; ICU, Intensive care unit; VA, Veterans affairs.

TABLE 2 | Final cox proportional hazard regression models for overall survival using propensity-matched cohorts and robust standard error.

Mortality		*n* (%)	Univariate HR (95% CI)	Multivariate HR (95% CI)
Minority status	Non-minority	1,500 (50.0)	Reference	Reference
	Minority	1,500 (50.0)	1.83 (1.47–2.29, $p < 0.001$)	2.21 (1.43–3.41, $p < 0.001$)
Injury type	Blunt	2,853 (95.1)	Reference	Reference
	Penetrating	147 (4.9)	3.50 (2.52–4.89, $p < 0.001$)	1.51 (0.64–3.59, $p = 0.350$)
Probability of survival	Mean (SD)	0.9 (0.1)	0.02 (0.01–0.04, $p < 0.001$)	0.04 (0.02–0.08, $p < 0.001$)
Operative status	Operative patient	1,039 (34.6)	Reference	Reference
	Non-operative patient	1,960 (65.4)	2.11 (1.66–2.69, $p < 0.001$)	2.60 (1.55–4.35, $p < 0.001$)

HR, Hazard Ratio; SD, Standard Deviation.

vs. 12.2% of minority patients), Acute Care Facility-Hospitals (1.6% of White/non-Hispanic patients vs. 0.8% of minority patients), and Rehabilitation Facilities (5.2% of White/non-Hispanic patients vs. 4.7% of minority patients).

Severity and Type of Disease at Presentation

Out of all TBI admissions, 96.5% were due to blunt trauma and 3.5% were due to penetrating trauma. There was a statistically significant difference between percentage of blunt vs. penetrating trauma with only 2.9% of trauma being penetrating in the White/non-Hispanic group while 5.3% of trauma was penetrating in the minority group ($p < 0.001$). In all patients, the most common mechanism of injury was fall (47.5%), followed by occupant in a motor vehicle crash (MVC) (17.0%). In the White/non-Hispanic group, this trend was similar with 50% of trauma being due to fall and 15.8% being due to MVC; however, in the minority group, although the trend was similar, the percentage of fall (39.3%) was lower and the percentage of MVC trauma (20.9%) was higher than the White/non-Hispanic group. There was a statistically significant difference in work-relatedness of injury with 4.7% of the minority group's injuries being due to work vs. only 3.2% of the White/non-Hispanic group ($p = 0.011$).

There were many statistically significant differences in severity of presenting injury between the White/non-Hispanic group and the minority group. The presenting GCS in the White/non-Hispanic group was 11.33 while that in the minority group was 10.44 ($p < 0.001$). The ISS in the White/non-Hispanic group was 19.14 vs. 20.07 in the minority group ($p < 0.001$). The percentage of patients with AIS > 3 and 4 was similar between groups, however the percentage of patients with AIS > 5 was 18.5% in the White/non-Hispanic group vs. 22.5% in the minority group. The percentage of TBI severity (mild, moderate, and severe) was statistically significant with 5.8% moderate and 16.4% severe TBI in the White/non-Hispanic group vs. 7.2% moderate and 21.7% severe in the minority group ($p < 0.001$).

Types of Medical Interventions

There was no statistically significant difference between groups regarding mode of transport to the hospital with each group arriving *via* ambulance around 77% of the time and a privately owned vehicle 1.3–1.4% of the time. Advanced directives were in place for 3.0% of White/non-Hispanic patients vs. 2.0% of minority patients. There were 92.5% of patients in the White/non-Hispanic group with neither an Advanced Directive nor POLST in place prior to injury vs. 94.4% of patients in the minority group with neither document in place. In the White/non-Hispanic group, 30.8% of the patients were operative vs. 34.5% of the patients in the minority group ($p = 0.008$).

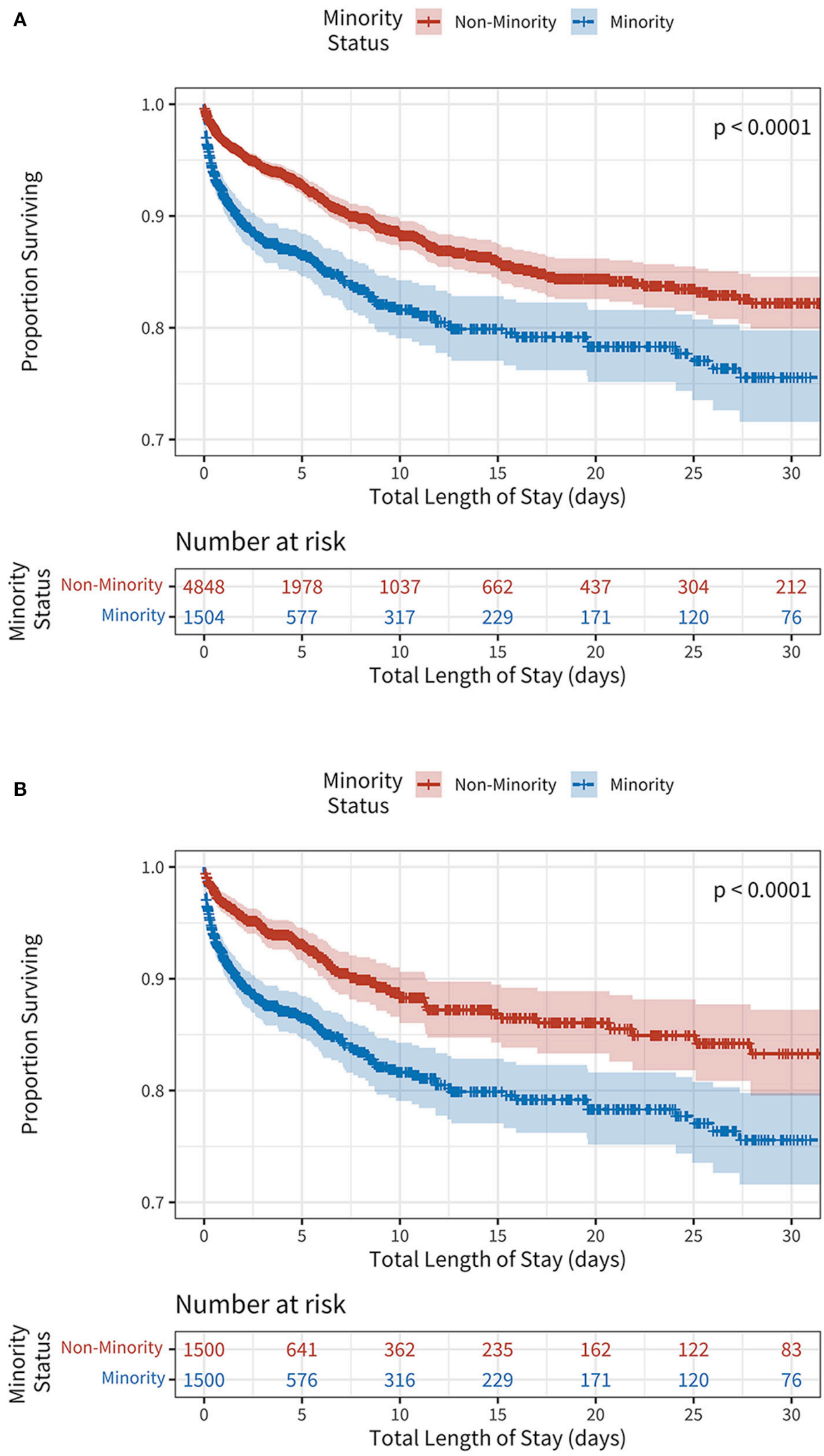

FIGURE 1 | (A) Unadjusted Kaplan-Meier survival curves stratified by minority status. **(B)** Propensity-score weighted Kaplan-Meier survival curves stratified by minority status.

The time from presentation to OR for White/non-Hispanic patients was 1048.08 min vs. 735.71 for minority patients ($p < 0.001$).

Insurance and Financial Factors

The average total hospital charges for all patients was $44.689.2 vs. $44,613.48 for White/non-Hispanic patients and $44,934.16 for minority patients ($p = 0.804$). For the White/non-Hispanic group, commercial insurance was the most common primary payor at 31.5% of patients while for the minority group, the most common primary payor was vehicle insurance at 26.2% of patients. The second most common primary payor for White/non-Hispanic patients was Medicare at 21.4% while the second most common for minority patients was commercial insurance at 20.2%. Workman's compensation paid as the primary payor for 2.9% of White/non-Hispanic patients vs. 4.3% of minority patients. White/non-Hispanic patients utilized self-pay methods 7.3% of the time vs. 11.1% of the time for minority patients.

DISCUSSION

In this study, we explored the disparities between white/non-Hispanic and minority patients in mortality and adverse outcomes in traumatic brain injury patients presenting to a Level I trauma center in Portland, OR. Our results suggest that there are significant differences in mortality and adverse outcomes even given similar severity of injury, presenting factors, and financial factors. In our primary outcome, mortality, there was a large statistically significant difference between in-hospital death and hospital length of stay between groups. Accounting for potentially confounding factors such as severity of presenting injury, primary payor insurance mechanisms, hospital charges, and mechanism of injury, minority patients were at double the risk of in-hospital mortality than White/non-Hispanic patients. Regarding disparities in other aspects of care, there was no statistically significant difference in discharge disposition, though there was a trend toward higher rates of discharge to SNFs, Acute Care Facility-Hospitals, and Rehabilitation Facilities in the White/non-Hispanic group compared to the minority group. This could potentially demonstrate differences in access to such facilities, differences in insurance or payment methods, or even access to social work facilitation of these types of discharges.

Although there was no statistically significant difference in total hospital charges, our analyses did in fact show a trend regarding types of primary payors between the White/non-Hispanic patients and the minority patients in that the most common primary payor for White/non-Hispanic patients was commercial insurance vs. vehicle insurance for minority patients. This correlates well to our finding that there was a higher percentage of MVC-related injury in the minority group compared to the White/non-Hispanic group and may also help to explain their greater severity of injury at presentation. However, the additional increase in percentage of both Workman's compensation as well as self-pay seen in the minority group raises the concern that through these payor routes, minority patients may not have had similar access to discharge options such as SNFs or rehab facilities as did patients in the White/non-Hispanic group. Previous research has suggested that the influence of insurance is so strong that differences in coverage can increase the likelihood of availability to post-hospitalization care in less vulnerable populations (30). Yet later research has explored the extent of influence insurance has on discharge location and has found that despite similar insurance, minority patients were found to be discharged more frequently to home without care than to SNF or acute-care facility post-hospitalization. Similarly, these studies found that white patients with lower vulnerable group membership (VGM) were discharged quicker to SNF or acute-rehab facility, which has been shown to provide higher rates of functional recovery than home care, than patients of color with higher VGM scores (31–33).

There was a statistically significant difference in types of trauma between White/non-Hispanic patients and minority patients with minority patients presenting more often with penetrating trauma than their White/non-Hispanic counterparts. Minority patients also tended to have a higher rate of MVC as primary MOI and a higher rate of injury related to their work compared to the White/non-Hispanic patients. Minority patients tended to present with more severe injuries as demonstrated by both pure ISS as well as their tendency toward higher rates of more severe AIS at presentation. This may correlate to our findings that a higher number of minority patients were judged as operative patients compared to the White/non-Hispanic patients and similarly that minority patients had quicker times to OR than White/non-Hispanic patients. Although all of these findings as secondary outcomes are disparities in and of themselves, they do not explain the significant difference in our primary outcome of overall mortality between minority and White/non-Hispanic patients given that our primary analysis accounted for these severity factors.

It is well-studied in many other aspects of medicine and epidemiology that patients receive differing quality of healthcare and therefore have significantly different outcomes as a result of these health disparities. Not only do minority patients face persistent unconscious bias in the healthcare field and have differential access to baseline healthcare, it has also been shown that the healthcare that they do end up receiving likely is less adequate to handle surgically or medically complex issues due to shortages of necessary specialists, technology gaps, or timely access to services (24, 34). Previous research in neurosurgery and other surgically complex fields have demonstrated marked disparities in the procedural outcomes between minority and White/non-Hispanic patients (13, 22, 23, 35), however the current research regarding disparities in trauma management of minority patients still has yet to show the true inequality of care.

Among reasons that can be documented for these healthcare disparities in traumatic brain injury, one of the most likely explanations in our patient population was the sheer severity of injury at presentation and the likelihood of operation in our minority patients. This, alongside greater numbers of penetrative traumas and traumas related to MVC rather than fall, produced a much more severe clinical picture for our minority group than our White/non-Hispanic group. To explain these presenting findings, it is important to look at the history of trauma in regions and neighborhoods of predominantly minority persons. Through decades of housing red-lining, tax adjustments, and inequitable educational progress, neighborhoods primarily composed of minority persons in America have trended toward more dangerous, violent regions by no fault of the persons living in those regions (36–40). It is logical to assume that areas of increased risk of violence would have higher rates of violent trauma than those with better protections in place. Additionally, persons of minority status often live further from healthcare facilities adequately equipped to manage the complexity of the trauma with which the patient presents. Many studies have recently shown the extent of the disparities in both number and quality of providers but also the number and quality of the technology available at local or regional hospitals compared to the wealthier and often more academic hospitals placed in centers of higher economic advantage (12, 24, 34, 41).

However, there are many factors that could potentially influence a patient's mortality or secondary outcomes following a traumatic brain injury. The limitations of this paper lie in the fact that many of these factors are simply not recorded in our typical point of care healthcare system for trauma and therefore are much more difficult to study. Additionally, the retrospective nature of this study is a limitation. However, most epidemiological and sociological research looking at cultural and community-oriented factors related to healthcare can only be studied in a retrospective manner. In this paper, we were not able to examine all the pre-hospital factors influencing our patients outcomes and thus could only analyze the data points associated with the seemingly extensive Trauma One database for one of the two level 1 trauma centers in the state of Oregon, yet even with these data, there are numerous sociological, epidemiological, financial, psychological, and political factors at play that go unreported and therefore are under-researched (21). These factors typically thought of to be non-medical have consistently demonstrated pervasive, persistent, and poignant disparities between minority patients and White/non-Hispanic patients that have plagued our healthcare system in the United States (1, 3, 8, 10, 38, 42–44). These health disparities have been demonstrated to be independent of individual health choices; these inequalities are not biologically determined yet they plague only certain sects of our populations, permeating beyond healthcare. Not only do our minority patients have generations of well-documented medical trauma that prohibits a full trusting relationship of the American healthcare system but there are clearly also disparities in patient's lives pre-hospital such as access to routine healthcare, leniency in the workplace for regular healthcare maintenance, financial freedom for healthcare maintenance, safe working environments, housing opportunities in neighborhoods free of violence, full of healthy foods, and access to clear air/water, and many more that are simply not documented when our patients present with neuro-trauma (3, 8, 38, 42, 44). The health equity framework with which we claim to utilize to progress our medical care demands that we recognize these extraneous but highly influential aspects of our patients' lives. We must make ourselves aware of the macro-social factors which perpetuate this disproportionate suffering among our patients of color and act with the responsibility and privilege we carry in our communities to make these disparities known. We must not only care for our patients when we encounter them within our clinics, emergency departments (EDs), and operating rooms, but in the healthcare disparities that exist outside of the concrete confines of the traditional healthcare system. Thus, we have a responsibility to engage with the upstream factors in our patients' lives that put them at increased risk even prior to entering our facility's doors. The traumas of structural racism do not start the moment of impact from a fall or an MVC; our patients' traumas begin when they are raised in a discriminatory society and robbed of certain medical, social, political, and financial privileges accustomed by our White/non-Hispanic patients.

Our study is but one current research set to analyze the disparities in yet another aspect of medical care in the United States and certainly not the only one to find inequalities in management of trauma. It is imperative that we as a medical community target not only healthcare improvements to properly regulate and treat neurosurgical trauma, but focus our progress toward equitable community environments, living situations, financial and insurance-based payment plans, and trauma prevention efforts in order to better care for our patients of color both pre-hospital and once they arrive into our ED. Now with an ever-growing accumulation of research shining light to these racial and ethnic disparities in every corner of medical research, it is simply insufficient to produce more research, but it is ever more pertinent to call all medical providers to greater action.

CONCLUSION

In this study, we explored the in-hospital mortality outcomes and characteristics of adult patients who were admitted with traumatic brain injury to one of the two Level I trauma centers in Portland, OR between 2006 to October of 2017. Our data demonstrate a significant disparity in overall in-hospital mortality in minority patients, greater severity of presenting injury, higher incidence of MVC- or work-related injury, and higher operative rate than White/non-Hispanic patients given insignificant differences in insurance, hospital charges, and other accounting factors. Although these are novel findings for the field of neurosurgical trauma related to traumatic brain injury, they are repeated in other specialties and other medically complex patient populations in the American healthcare system. Research has been keen to identify these marked inequalities over the past couple of decades yet still there has not been a clear path to dismantling these disparities within the medical community. Treating patients under our care is our greatest privilege and responsibility as physicians. As such, we have a societal and professional duty to recognize and accept that the effects of structural racism have taken hold of our patients' health long before they arrive in our trauma bays, ICU beds, and operating tables. These disparities permeate our society and contribute to inequitable health outcomes, and we must take action to identify the factors which perpetuate this disproportionate suffering. Simply treating the minority of patients who require surgical intervention or clinical consultation is not enough. Our roles demand that we recognize these larger social factors acting upstream on our patients before they enter our fractioned healthcare system which often fosters the very mistrust that hides them from our otherwise watchful eyes in the first place. The necessary first step in providing an equitable healthcare system for all patients regardless of socioeconomic, racial, or ethnic status, is continued awareness of the pervasiveness and consistency of these medical disparities and emphasized efforts to improve the sociological factors that perpetuate them.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by OHSU Institutional Review Board. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

ER was the primary author on this manuscript and also assisted in methodology, concept design, and coordination. JN was the primary statistician of the project, designed the statistical methodology, and performed all necessary coordination tasks for data analysis. AR was the supervising physician on this project and was responsible for overseeing all aspects of its creation. All authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsurg.2021.690971/full#supplementary-material

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Corrigendum: Racial and Ethnic Inequities in Mortality During Hospitalization for Traumatic Brain Injury: A Call to Action

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A Corrigendum on

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There was an error in **Table 1B** as published in the original article. Secondary payor, discharge disposition, probability of survival, and deaths were overwritten for the propensity-matched cohort with instead a repetition of the demographic characteristics. The corrected and complete version of **Table 1B** appears below.

The authors apologize for this error and state that this does not change the scientific conclusions of the article in any way. The original article has been updated.

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TABLE 1B | Patient characteristics stratified by minority status following propensity matching.

		Total	Non-minority	Minority	p-value	Absolute standardized difference
n		3,000	1,500	1,500		
Age (years)*		43.1 (1.65)	43.54 (1.65)	42.66 (1.65)	0.265	0.041
Categorical age	15-24	568 (18.9)	275 (18.3)	293 (19.5)	NA	0.120
	25-34	494 (16.5)	249 (16.6)	245 (16.3)		
	35-44	383 (12.8)	174 (11.6)	209 (13.9)		
	45-54	396 (13.2)	201 (13.4)	195 (13.0)		
	55-64	390 (13.0)	210 (14.0)	180 (12.0)		
	65-74	293 (9.8)	157 (10.5)	136 (9.1)		
	75-84	285 (9.5)	131 (8.7)	154 (10.3)		
	85+	191 (6.4)	103 (6.9)	88 (5.9)		
Sex	Male	2,172 (72.4)	1,087 (72.5)	1,085 (72.3)	0.967	0.003
	Female	828 (27.6)	413 (27.5)	415 (27.7)		
Race	White	1,518 (67.6)	1,500 (100.0)	18 (2.4)	NA	9.000
	Black or African American	99 (4.4)	0 (0.0)	99 (13.3)		
	American Indian or Alaskan Native	59 (2.6)	0 (0.0)	59 (7.9)		
	Asian	142 (6.3)	0 (0.0)	142 (19.0)		
	Hispanic or Latino	346 (15.4)	0 (0.0)	346 (46.3)		
	Pacific Islander or Native Hawaiian	15 (0.7)	0 (0.0)	15 (2.0)		
	Other	68 (3.0)	0 (0.0)	68 (9.1)		
Ethnicity	Not Hispanic or Latino	2,624 (87.5)	1,500 (100.0)	771 (51.4)	<0.001	1.375
	Hispanic or Latino	375 (12.5)	0 (0.0)	729 (48.6)		
BMI*		26.57 (1.23)	26.87 (1.23)	26.31 (1.24)	0.108	0.099
Injury type	Blunt	2,853 (95.1)	1,432 (95.5)	1,421 (94.7)	0.398	0.034
	Penetrating	147 (4.9)	68 (4.5)	79 (5.3)		
Mechanism of injury	Fall	1,198 (39.9)	608 (40.5)	590 (39.3)	NA	0.051
	Firearm	104 (3.5)	52 (3.5)	52 (3.5)		
	Motor vehicle traffic - Motorcyclist	87 (2.9)	42 (2.8)	45 (3.0)		
	Motor vehicle traffic - occupant	616 (20.5)	303 (20.2)	313 (20.9)		
	Motor vehicle traffic - pedestrian	253 (8.4)	128 (8.5)	125 (8.3)		
	Pedal cyclist, other	91 (3.0)	44 (2.9)	47 (3.1)		
	Struck by, against	341 (11.4)	175 (11.7)	166 (11.1)		
	Transport, other	85 (2.8)	38 (2.5)	47 (3.1)		
	Other	225 (7.5)	110 (7.3)	115 (7.7)		
Work relatedness of injury	Work related	129 (4.3)	59 (3.9)	70 (4.7)	0.368	0.036
	Not work related	2,870 (95.7)	1,440 (96.1)	1,430 (95.3)		
GCS on ED presentation*		10.62 (1.81)	10.81 (1.8)	10.43 (1.83)	0.142	0.059
ISS*		19.8 (1.6)	19.52 (1.6)	20.08 (1.6)	0.101	0.060
AIS H&N	3	1,239 (41.3)	623 (41.5)	616 (41.1)	0.220	0.077
	4	1,104 (36.8)	566 (37.7)	538 (35.9)		
	5	646 (21.5)	308 (20.5)	338 (22.5)		
	6	11 (0.4)	3 (0.2)	8 (0.5)		
TBI severity	Mild	1,780 (72.6)	912 (74.1)	868 (71.0)	0.219	0.070
	Moderate	169 (6.9)	81 (6.6)	88 (7.2)		
	Severe	503 (20.5)	237 (19.3)	266 (21.8)		
Transport mode	Ambulance	2,312 (77.2)	1,147 (76.7)	1,165 (77.7)	0.796	0.073
	Privately owned vehicle	37 (1.2)	17 (1.1)	20 (1.3)		

(Continued)

TABLE 1B | Continued

		Total	Non-minority	Minority	p-value	Absolute standardized difference
	Walk in	2 (0.1)	2 (0.1)	0 (0.0)		
	Helicopter	419 (14.0)	213 (14.2)	206 (13.7)		
	Police or law enforcement	1 (0.0)	1 (0.1)	0 (0.0)		
	Auto launch helicopter	0 (0.0)	0 (0.0)	0 (0.0)		
	Other	12 (0.4)	7 (0.5)	5 (0.3)		
	Fixed wing Aircraft	211 (7.0)	108 (7.2)	103 (6.9)		
Advanced directives	Advance directive, directive to physicians, or living will	62 (2.1)	33 (2.2)	29 (2.0)	0.492	0.058
	Both advance directive and polst prior to injury	13 (0.4)	4 (0.3)	9 (0.6)		
	No, neither advance directive nor polst prior to injury	2,805 (94.6)	1,416 (94.8)	1,389 (94.4)		
	POLST in effect prior to injury	86 (2.9)	41 (2.7)	45 (3.1)		
Operative status	Operative patient	1,039 (34.6)	522 (34.8)	517 (34.5)	0.848	0.007
	Non-operative patient	1,960 (65.4)	977 (65.2)	983 (65.5)		
Time to first or visit (min)*		871.31 (5.81)	1,012.32 (5.37)	735.10 (6.23)	0.005	0.183
Length of hospital stay (days)*		3.8 (3.83)	4.26 (3.4)	3.38 (4.24)	<0.001	0.172
Length of ICU stay (days)*		2.15 (3.08)	2.34 (2.92)	1.98 (3.24)	<0.001	0.150
Total Hospital charges*		46,051.76 (2.73)	47,165.17 (2.71)	44,964.63 (2.75)	0.193	0.048
Primary payor	Vehicle insurance	792 (26.4)	398 (26.5)	394 (26.3)	NA	0.090
	Charity	0 (0.0)	0 (0.0)	0 (0.0)		
	Commercial Insurance	589 (19.6)	287 (19.1)	302 (20.1)		
	Medicaid	489 (16.3)	251 (16.7)	238 (15.9)		
	Medicare	530 (17.7)	278 (18.5)	252 (16.8)		
	Other health insurance (VA)	127 (4.2)	53 (3.5)	74 (4.9)		
	Self pay	334 (11.1)	167 (11.1)	167 (11.1)		
	Ward of federal government	17 (0.6)	9 (0.6)	8 (0.5)		
	Workman's compensation	122 (4.1)	57 (3.8)	65 (4.3)		
Secondary payor	Vehicle insurance	230 (16.3)	117 (16.1)	113 (16.4)	NA	0.118
	Charity	0 (0.0)	0 (0.0)	0 (0.0)		
	Commercial Insurance	647 (45.7)	349 (48.0)	298 (43.3)		
	Medicaid	340 (24.0)	165 (22.7)	175 (25.4)		
	Medicare	74 (5.2)	39 (5.4)	35 (5.1)		
	Other health insurance (VA)	119 (8.4)	54 (7.4)	65 (9.4)		
	Self pay	2 (0.1)	1 (0.1)	1 (0.1)		
	Ward of federal government	3 (0.2)	2 (0.3)	1 (0.1)		
	Workman's compensation	0 (0.0)	0 (0.0)	0 (0.0)		
Discharge disposition	Home	1,793 (59.8)	893 (59.5)	900 (60.0)	NA	0.235
	Expired	346 (11.5)	128 (8.5)	218 (14.5)		
	Skilled nursing facility	402 (13.4)	218 (14.5)	184 (12.3)		
	Acute care facility-hospital	33 (1.1)	21 (1.4)	12 (0.8)		
	Rehabilitation facility	165 (5.5)	95 (6.3)	70 (4.7)		
	Home health	82 (2.7)	42 (2.8)	40 (2.7)		
	Hospice	15 (0.5)	9 (0.6)	6 (0.4)		
	Court/law enforcement	6 (0.2)	3 (0.2)	3 (0.2)		
	Against medical advice	38 (1.3)	22 (1.5)	16 (1.1)		
	Psychiatric hospital or unit	5 (0.2)	4 (0.3)	1 (0.1)		

(Continued)

TABLE 1B | Continued

		Total	Non-minority	Minority	p-value	Absolute standardized difference
	Long term acute care	23 (0.8)	13 (0.9)	10 (0.7)		
	Institution not defined elsewhere	87 (2.9)	51 (3.4)	36 (2.4)		
	Intermediate care facility	5 (0.2)	1 (0.1)	4 (0.3)		
	Other	0 (0.0)	0 (0.0)	0 (0.0)		
Probability of survival		0.92 (0.13)	0.93 (0.12)	0.92 (0.14)	0.040	0.092
Deaths	Live	2,654 (88.5)	1,372 (91.5)	1,282 (85.5)	<0.001	0.189
	Die	346 (11.5)	128 (8.5)	218 (14.5)		

The values displayed are computed from the geometric mean geometric standard deviation.
BMI, Body mass index; GCS, Glasgow coma scale; ISS, Injury severity score; AIS H&N, Abbreviated injury score of the head & neck; TBI, Traumatic brain injury; POLST, Physicians orders for life-sustaining treatment; ICU, Intensive care unit; VA, Veterans affairs.

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Continental Survey of Access to Diagnostic Tools and Endovascular Management of Aneurysmal Subarachnoid Hemorrhage in Africa

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Rationale: Interventional neurovascular procedures are effective in lowering the burden of mortality and complications resulting from aneurysmal subarachnoid hemorrhage (aSAH). Despite the wide uptake of interventional neurovascular procedures in high-income countries, access to care in low- and middle-income countries remains limited, and little is known about accessibility in Africa. In this survey, we decided to assess access to diagnostic tools and treatment of aSAH in Africa.

Methodology: A Google form e-survey was distributed to African neurosurgery centers accepting responses from January 4th to March 21st 2021. Data on accessibility to diagnostic tools, treatment methodologies, and interventional neuroradiology personnel in African centers were collected. Ninety five percent confidence intervals were computed for each variable.

Results: Data was received from 36 neurosurgical centers in 16 African countries (16/54, 30%). Most centers were public institutions. Ninety four percent of the centers had the necessary resources for a lumbar puncture (LP) and a laboratory for the diagnosis of aSAH. Most centers had at least one computed tomography (CT) scanner, 81% of the centers had access to CT angiography and some had access to conventional angiography. Forty seven percent of the centers could obtain a head CT within 2 h of presentation in an emergency. Sixty one percent of centers provided clipping of intracranial aneurysms whilst only 22% of centers could perform the endovascular treatment. Sixty four percent of centers did not have an endovascular specialist.

Conclusion: This survey highlights health inequity in access to endovascular treatment for aSAH. Lack of diagnostic tools to identify an aneurysm and a shortfall of qualified endovascular specialists are prime reasons for this. Our findings can inform health system strengthening policies including the acquisition of equipment and capacity building in Africa.

Keywords: aneurysmal subarachnoid hemorrhage, diagnostic tools, management, survey, Africa

INTRODUCTION

Subarachnoid hemorrhage (SAH) accounts for up to 8.9% of the total global stroke burden (1). Although SAH typically results from traumatic brain injury, it can also present subsequent to spontaneous rupture of an intracranial aneurysm where it is termed aneurysmal subarachnoid hemorrhage (aSAH). Timely access to computed tomography (CT), CT angiography (CTA), lumbar puncture, and/or conventional angiography is required to make a diagnosis of aSAH. Also, timely access to treatment is essential. Endovascular procedures have become the preferred treatment for most areas due to their less invasive nature, the reduced risk of postoperative complications, and favorable outcomes when compared to clipping (2).

Mortality resulting from aSAH remains high across Africa in comparison to high-income countries. The 1-month mortality rate from aSAH in Kenya is reported to be 26.6% whilst it is 44.4% in Nigeria with an incidence of 4.1 per 100,000 person-years. (3–5). Autopsy studies in Africa revealed up to 15.7% of cardiovascular causes of death in Kenya could be as a result of SAH, highlighting the large number of undiagnosed SAH cases in Africa (6). Hence the true incidence of SAH and aSAH is unknown and this may be due to delayed presentation and lack of access to neuroimaging and angiography as well as poor medical record keeping (4). In comparison, high-income countries (HICs) report in-hospital mortality rates ranging from 11.3 to 18% (7, 8). However, it should be noted that HICs report a 6 month mortality rate that is considerably higher than the in-hospital mortality rate and many more patients have unfavorable outcomes at follow-up (7, 8). Many HIC neurosurgical centers are able to provide timely access to neurosurgical treatment for aSAH, however; it is unclear if the same is true for neurosurgical centers across the African continent (9). It is reported that neurosurgical centers specializing in the treatment of intracranial aneurysms and aSAH are scarce in some African countries, and those that do exist only offer open vascular aSAH treatment (10). Indeed some African centers report needing to transfer patients to departments that can provide treatment for aSAH and this is particularly true for endovascular treatment (3, 11). This can sometimes result in patients being transferred to other countries or even another continent for appropriate treatment; albeit the literature does not mention the mode of transportation (12). Due to these factors and the delay in presentation, aSAH patients experience limited access to and significant delays in receiving endovascular treatment but also surgical clipping, and this is particularly true for public hospitals compared to private hospitals (4). The higher cost of endovascular procedures compared to clipping may impact the ability of low- and middle-income countries (LMICs) to provide such treatment (10, 13). Scarcity of safe and suitable medical equipment is another commonly cited barrier to the provision of endovascular treatment options (10). Furthermore, the lack of interventional neuroradiology (INR) training across Africa has resulted in a deficit of INR specialists across the continent (14). In fact, it is reported that patients with aSAH are often treated medically instead of procedurally in some African countries (15).

The tools required to diagnose aSAH such as neuroimaging, lumbar puncture, and angiography may be accessible in some African countries (16, 17). However, accessibility and availability of CT and MRI is highly variable across the African continent and can be significantly short of the recommended standard set by the World Health Organization (WHO) (18, 19). Neuroimaging is particularly scarce in rural African hospitals (20, 21). It is promising that some African hospitals do have access to CTA, though its availability remains limited and the cost of CTA remains unaffordable to many patients (22). aSAH mandates timely diagnosis in order for adequate treatment to be provided and to reduce the risk of further complications. As a result, African neurosurgical centers must have prompt access to diagnostic tools for aSAH.

The availability of endovascular treatment options and equally diagnostic tools for aSAH across Africa is unknown. There is a paucity of data as many African countries do not have published literature relating to these topics (15). It is hypothesized that many African countries face challenges in providing timely diagnosis and suitable treatment of aSAH. Knowledge of the presently available treatment modalities and diagnostic tools across Africa would allow for efficient resource allocation, workforce planning and to identify those centers that are in particular need of neurosurgical equipment donation. We aimed to address this knowledge gap and to create a map of the availability of endovascular treatments and diagnostic tools for aSAH across the African continent.

METHODS

A Google form e-survey questionnaire was distributed to African neurosurgical centers *via* social media platforms (WhatsApp, Telegram, LinkedIn, and Twitter). The survey was validated independently by two African professors of neurosurgery. The participants were identified through neurosurgical societies such as Association of Future African Neurosurgeons (AFAN) and Young African Neurosurgeons Forum (Young CAANS). The data collected included the submitter's role within the center, details about the healthcare setting, the methods of diagnosis, treatment of aSAH used locally, and the accessibility of said methods. Reminders to fill in the survey were sent every week. The survey was active from January 4, 2021 to March 21, 2021. Forty-nine responses were received in total. Thirteen responses (27%) were duplicate responses from the same centers. Duplicate data was removed via a standardized process by considering the seniority of the respondent, time in current role and the amount of data fields completed in the survey. Results were analyzed by calculating percentage data and by calculation of the mean, median and interquartile range where appropriate.

Ethics approval for this study was not needed as no personal information was being collected, but objective information about institutions.

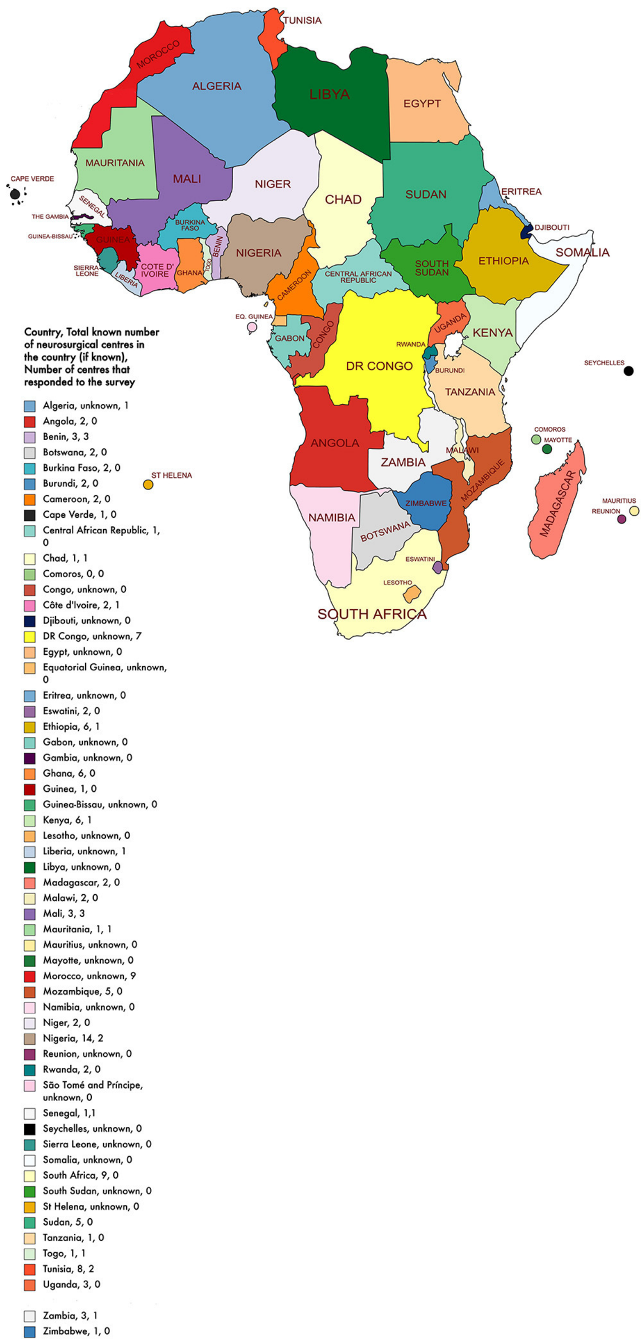

FIGURE 1 | African map with country, total known number of neurosurgical centers in the country, and number of centers that responded to the survey.

TABLE 1 | Location (country) of surveyed neurosurgical centers, type of hospital, the total number of hospital beds at surveyed neurosurgical centers, total number of intensive care beds at surveyed neurosurgical centers.

Country	Percentage of centers (actual)
Algeria	3% (1)
Benin	8% (3)
Chad	3% (1)
Côte d'Ivoire	3% (1)
Democratic republic of the Congo	19% (7)
Ethiopia	3% (1)
Kenya	3% (1)
Liberia	3% (1)
Mali	8% (3)
Mauritania	3% (1)
Morocco	25% (9)
Nigeria	6% (2)
Senegal	3% (1)
Togo	3% (1)
Tunisia	6% (2)
Zambia	3% (1)
Type of hospital	**Percentage of centers (actual)**
Public	67% (24)
Private	8% (3)
Both public/private	19% (7)
Military	3% (1)
Unknown	3% (1)
Total number of hospital beds (range)	**Percentage of centers (actual)**
1–50	28% (10)
51–200	11% (4)
201–400	17% (6)
401–700	17% (6)
701–1000	11% (4)
1,001+	3% (1)
Unknown	14% (5)
Total number of ICU/ITU beds (range)	**Percentage of centers (actual)**
1–5	19% (7)
6–10	33% (12)
11–20	8% (2)
21–30	14% (5)
31–40	6% (2)
41+	3% (1)
Unknown	19% (7)

RESULTS

After the removal of the duplicate responses, we received 36 responses. Data were received from 36 different neurosurgical centers in 16 of the 54 African countries (16/54, 30%) (**Figure 1**). Most institutions were public healthcare centers (24/36, 67%) whilst the remaining were either a private, military, or a mixed (public and private) center (**Table 1**). The median number of total beds at a center was 385 beds and the median number of intensive care unit beds at a center was 14 beds.

The majority of centers had easy access to resources necessary for a lumbar puncture (LP) and an on-site laboratory for the diagnosis of aSAH (34/36, 94%). Most centers (30/36, 83%) had at least one CT scanner.

Most centers investigated aSAH using computed tomography (CT) angiography (29/36, 81%) and some had access to conventional angiography (17/36, 47%) of centers had access to formal/traditional angiography. Reasons commonly cited for lack of access to formal/traditional angiography were lack of equipment and lack of trained personnel (**Table 2**). Almost every center had access to a CT scan in their radiology department or

TABLE 2 | Comments provided by respondents for reasons why formal/traditional cerebral angiography was not available at their center.

Comments provided by respondents
Unavailable in my hospital
Equipment and expertise not available
Technical platform not available
No available technical materials or human resources
Lack of resources by the government
Not available in our hospital so we refer the patient to a private clinic or another hospital for investigation
Not trained

TABLE 3 | Clinical parameters and investigations that are typically used by the surveyed neurosurgical centers to diagnose subarachnoid hemorrhage (SAH), typical investigations utilized to investigate for an aneurysm in patients with SAH at the surveyed neurosurgical centers, time is taken to perform a CT head scan in an emergency, number of CT scanners at the surveyed neurosurgical centers, number of qualified interventional neuroradiology (INR) doctors at the surveyed neurosurgical centers.

Typical investigations used to diagnose SAH	Percentage of centers (actual)
Clinical evidence	72% (26)
CT head	97% (35)
CT intracranial angiogram	39% (14)
Lumbar puncture	28% (10)
Typical investigations used to investigate for an intracranial aneurysm following diagnosis of SAH	**Percentage of centers (actual)**
CT intracranial angiogram	81% (29)
Conventional cerebral angiography	25% (9)
No available imaging modality	17% (6)
Time to CT head in an emergency	**Percentage of centers (actual)**
<1 h	3% (1)
1–2 h	44% (16)
2–6 h	22% (8)
6–12 h	17% (6)
12–24 h	6% (2)
24+ h	8% (3)
1 week	0% (0)
1 month	0% (0)
Number of CT scanners	**Percentage of centers (actual)**
0	17% (6)
1	50% (18)
2	25% (9)
3	8% (3)
4+	0% (0)
Number of qualified INR doctors	**Percentage of centers (actual)**
0	64% (23)
1	8% (3)
2	8% (3)
3	11% (4)
4+	8% (3)

at an external site in their city (35/36, 97%). Some of the centers could obtain a head CT within 2 h (17/36, 47%). A minority of centers lacked a CT scanner (6/36, 17%) in their radiology department, but all had access to a CT scanner in their city. Two of these centers (2/6, 33%) were able to perform an emergency CT head scan in 2–6 h, another two centers (2/6, 33%) could get a scan in 6–12 h, one (1/6) could do so in 12–24 h and the last center (1/6) needed more than 24 h to get a scan (**Table 3**). The majority of centers had access to magnetic resonance imaging (MRI) (33/36, 92%), whilst 67% (24/36) of centers had access to magnetic resonance angiography (MRA).

Twenty-two centers performed clipping (22/36, 61%) whereas only 22% (8/36) of centers offered endovascular treatment. Almost two-thirds of centers did not have an endovascular specialist in their center (23/36, 64%). Centers that provided endovascular treatment were teaching or university-affiliated hospitals. All of these centers had at least 1 on-site CT scanner, access to MRI, MRA, and formal angiography. Six of these centers reported taking a maximum of 2 h to obtain a CT head whilst the remaining 2 centers reported taking 2–6 h and 6–12 h, respectively. The number of beds at these centers ranges from 14 to 2,535 (median = 240, IQR = 600–29) with the number of ITU beds ranging from 4 to 20 (median = 8, IQR = 22.5–5.5).

Of the 22 centers providing open vascular aneurysmal treatment, 45% (10/22) provided service on weekends and 41% (9/22) provided service out of regular working hours. Of the eight centers providing endovascular treatment for aSAH, 63% (5/8) performed endovascular treatment on weekends and out of regular working hours.

DISCUSSION

To our knowledge, this is the first continental survey to inventory the diagnostic tools and endovascular treatment of aSAH across Africa. We found that almost every neurosurgical center had access to a CT scan in their radiology department or at an external site in their city and nearly half of the centers diagnosed SAH via a CT scan within 1–2 h of presentation. Clipping was the more common method of securing intracranial aneurysms. Notably, only 22% of centers could provide endovascular treatment. The majority of centers did not have an endovascular specialist at their center. Overall the duplicate responses received from the neurosurgical centers were very similar in their responses though neurosurgical trainees tended to be slightly more optimistic than a consultant/attending neurosurgeon from the same center when considering the time taken to obtain a CT head in an emergency. Our study highlights the lack of endovascular treatment options available to treat aSAH across the African continent.

The disparity of neurosurgical outcomes can be a result of a lack of accessibility to the innovative neuroimaging modalities which aid operative accuracy and postoperative outcomes (23). Our continental survey reported similar findings to Sader et al. (24) as the authors reported 95 and 81% of neurosurgical centers in Sub-Saharan Africa had access to CT scanners and MRI, respectively, compared to 97 and 92% in our survey, respectively. Furthermore, from the 33 (33/36, 92%) centers that can carry out MRI, 11 (11/33, 33%) centers reported not having access to magnetic resonance angiography (MRA) without providing the reason for this. It is known that there is a shortage of MRI scanners across Africa and the majority of MRI units have low-field scanners (25). Reasons for lack of access to MRA may include lack of MRA software and lack of radiologists trained in interpreting MRA images. Furthermore, some neurosurgical centers may transfer patients to an external MRI unit for imaging but these units may not be able to provide advanced imaging such as MRA. Current global guidelines recommend non-contrast CT head as the cornerstone for diagnosing aSAH with a sensitivity of almost 100% within the first 3 days (26). This matches the majority of our survey responses as the timing of the emergency CT head was reported to be within 2 h of presentation in 47% (17/36) compared to 45% (16/36) within 2–24 h and 8% (3/36) in more than 24 h. However, it is important to consider travel times to neurosurgical centers since the time of ictus, as longer travel times are associated with poorer outcomes (27).

Around 10 countries did not have more than one neurosurgical center (28–30). Only 22% of the neurosurgical centers were able to perform the endovascular procedures recommended for aSAH. Thus, the majority of the patients will experience time delays in the form of (a) waiting for an ambulance to be transferred to a neurointerventional center; (b) long travel distance to a neurointerventional center; (c) reassessment by the neurointerventional center's team. Although our continental survey did not aim to provide a comparative analysis of post-procedure outcomes between the endovascular treatment and surgical intervention for aSAH, the endovascular approach is less invasive in nature and has reduced risk of postoperative complications compared to clipping (2).

Additional factors may play a vital role in increasing the time from diagnosis to treatment. Germans et al. conducted a multivariate analysis showing that presentation at a referring hospital and admission to the treatment center later in the day were independently related to a longer time interval between diagnosis and treatment (31). Our survey showed that 45% of neurosurgery centers provided service on weekends and 41% provided service out of regular working hours. Moreover, only five (13.9%) of the 36 surveyed units provided endovascular treatment on the weekends. Therefore, the majority of the patients admitted with aSAH across Africa over the weekend are at high risk of experiencing treatment delays. Patients with severe aSAH (poor neurological grade) who are left untreated over a weekend are associated with an independent risk of mortality within 12 weeks of the onset of symptoms (32). Interestingly of the five centers providing weekend endovascular treatment, four (80%) were based in Morocco; this was 44.4% (4/9) of the neurosurgical units that we surveyed in Morocco. The disparity in the accessibility and availability of endovascular services within Africa further compounds the issue for patients residing outside Morocco.

The underlying factors to the shortage of endovascular services could be due to reasons such as the cost of materials, lack of INR specialists, inadequate INR training, and insufficient infrastructure. It is known that the cost of endovascular coiling is higher than clipping in LMICs, largely due to the cost of the materials needed for coiling (33). As a result, patients in LMICs may not be able to afford endovascular treatment. Furthermore, our study revealed that almost two-thirds of neurosurgery centers did not have an endovascular specialist at their center. Thus, an increased number of qualified INRs is needed to reduce the time to treatment. As INR is a newly developing field in neurosurgery requiring highly specialized training and access to advanced technology, it will be beneficial for Africa to further develop capacity-building efforts, gain training mentorship from global neurosurgeons and obtain funding support from global health actors and policymakers to promote upskilling of African neurosurgeons. Given the prevalence and the high mortality rate of aSAH in Africa, it is imperative that the growing neurosurgical workforce is equipped with the skills they need to meet the unmet burden of the disease. Compared to HICs, a lack of equipment and trained personnel in LMICs puts many neurosurgeons and neurosurgery centers at a disadvantage when it comes to efficiently treat aSAH using endovascular procedures. A lack of endovascular treatment options may also hinder the performance of neurosurgeons, increasing risk of burnout due to working more than their expected capacity. These barriers should be prioritized in future guidelines to address the inequalities of the healthcare standards provided across the continent.

The lack of INR specialists is not a problem that is limited to Africa and LMICs. HICs such as the United Kingdom (UK) face similar problems. Unlike many countries which produce hybrid neurosurgeons that perform both endovascular and open neurosurgical techniques, INR in the UK is rather considered as a subspecialty for those training in clinical radiology (34). It has been reported that there were only 90 trained INRs working in 28 neuroscience centers in the UK in 2017; this sparsity in the workforce may not provide comprehensive endovascular service nationally (35). This, too, has led to a shortfall in the delivery of endovascular treatment on weekends compared to weekdays, thus consequently leading to significantly longer mean waiting times from admission or scan to treatment time (both $p < 0.0001$) and higher in-hospital mortality rates ($p = 0.08$) (36). Interestingly, Kotecha et al. surveyed the attitudes of neurosurgical trainees in pursuing INR training and found that trainees have the interest and the insight to develop skills and knowledge in INR. Therefore, there is potential to improve the service provision of INR in HICs such as the UK, provided trainees are given the opportunity to pursue it (37). Future research could make use of a similar survey to assess the appetite of African neurosurgical trainees toward endovascular training. Such research could kindle a learning opportunity to develop between African neurosurgeons and global INR mentors, thereby upskilling the continental workforce.

We collected data from 16 African countries; less than half of the total number of African countries. Major neurosurgical hubs like, Egypt, South Africa, Tunisia, and Zimbabwe were not represented in this study. The precise locations and the number of all active neurosurgical units across Africa is not known and so we were unable to calculate the proportion of African neurosurgical centers that responded to the survey. However, data on the spread of neurosurgeons across Africa exists and we received responses from the majority of African countries with more than four practicing neurosurgeons (38). Furthermore, 1 in 4 of our responses was from Morocco

(25%, $n = 9$). This could have skewed the results as Morocco had better access to endovascular treatment services compared to the rest of the countries surveyed. Moreover, the small sample size means the results of the study are not entirely representative of the African continent. The small sample size equally limited our ability to compute disaggregated data and we could not calculate comparative differences at the regional level. To minimize the effect of non-response bias we increased the data collection period and the number of survey dissemination modes.

CONCLUSION

The diagnosis and treatment of aSAH are well-established. The findings of this study demonstrate a lack of availability and accessibility of diagnostic and management tools for aSAH in the surveyed African neurosurgical centers. This is a detrimental factor not only to the health of Africans requiring intervention but also to the World Health Organisation's (WHO) initiative in achieving universal health coverage. This study highlights the disparity of endovascular care uptake in comparison to high-income countries as well as within African countries. This study also finds that neurosurgical clipping is unavailable in many African neurosurgical centers. We urge local governments and stakeholders to review their specialty training curricula and to invest in expanding the infrastructure of the neurosurgical units in their countries, to ensure that all patients with aSAH can access quality and timely intervention, regardless of their location or time of bleed. Initially this can be achieved by expanding the availability of neurosurgical clipping across Africa whilst an endovascular treatment infrastructure is developed.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found in the article/supplementary material.

AUTHOR CONTRIBUTIONS

YD: Conceptualization, Data curation, Writing the original draft, Reviewing, editing, and Project administration. JK: Conceptualization, Writing the original draft, Data analysis, Reviewing, editing, and Project administration. AE, SO, and JE: Writing the original draft. SB: Conceptualization, Reviewing, editing, and Supervision. DD and DS: Visualisation. MB and MT: Visualisation and Validation. GH: Conceptualisation. NB: Conceptualisation, Data curation, and Supervision. UK: Conceptualisation, Data analysis, Writing draft, Visualisation, and Supervision. All authors contributed to the article and approved the submitted version.

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International Neurotrauma Training Based on North-South Collaborations: Results of an Inter-institutional Program in the Era of Global Neurosurgery

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Objective: Shortage of general neurosurgery and specialized neurotrauma care in low resource settings is a critical setback in the national surgical plans of low and middle-income countries (LMIC). Neurotrauma fellowship programs typically exist in high-income countries (HIC), where surgeons who fulfill the requirements for positions regularly stay to practice. Due to this issue, neurosurgery residents and medical students from LMICs do not have regular access to this kind of specialized training and knowledge-hubs. The objective of this paper is to present the results of a recently established neurotrauma fellowship program for neurosurgeons of LMICs in the framework of global neurosurgery collaborations, including the involvement of specialized parallel education for neurosurgery residents and medical students.

Methods: The Global Neurotrauma Fellowship (GNTF) program was inaugurated in 2015 by a multi-institutional collaboration between a HIC and an LMIC. The course organizers designed it to be a 12-month program based on adapted neurotrauma international competencies with the academic support of the Barrow Neurological Institute at Phoenix Children's Hospital and Meditech Foundation in Colombia. Since 2018, additional support from the UK, National Institute of Health Research (NIHR) Global Health Research in Neurotrauma Project from the University of Cambridge enhanced the infrastructure of the program, adding a research component in global neurosurgery and system science.

Results: Eight fellows from Brazil, Venezuela, Cuba, Pakistan, and Colombia have been trained and certified *via* the fellowship program. The integration of international competencies and exposure to different systems of care in high-income and low-income environments creates a unique environment for training within a global neurosurgery framework. Additionally, 18 residents (Venezuela, Colombia, Ecuador, Peru, Cuba, Germany, Spain, and the USA), and ten medical students (the United Kingdom, USA, Australia, and Colombia) have also participated in elective rotations of neurotrauma and critical care during the time of the fellowship program, as well as in research projects as part of an established global surgery initiative.

Conclusion: We have shown that it is possible to establish a neurotrauma fellowship program in an LMIC based on the structure of HIC formal training programs. Adaptation of the international competencies focusing on neurotrauma care in low resource settings and maintaining international mentoring and academic support will allow the participants to return to practice in their home-based countries.

Keywords: neurosurgery, neurotrauma, fellowship, global neurosurgery, education

INTRODUCTION

According to a recent analysis of global neurosurgery academic groups, more than two-thirds of the world's population has gaps in the provision of appropriate surgical and anesthetic care (1). There are an estimated 13,8 million potential neurosurgical cases every year worldwide, with more than 80% occurring in low- and middle-income countries (LMIC) (1). It has also been calculated that nearly 45% of the total neurosurgical cases are related to traumatic brain injury (TBI) care, including burr holes, craniotomies, and craniectomies (1, 2).

Unfortunately, neurosurgical care availability is limited in the most needed regions of the world. Even if neurosurgical care is available, sub-specialized care is often lacking according to global neurosurgery research audits (3–6). In general, neurotrauma surgical procedures are considered first-line macro-neurosurgical interventions according to the World Federation of Neurosurgical Societies (WFNS) classification for the level of provided neurosurgical care in different cities of the world (4).

As simple as it may seem, the success in survival and decreased disability for TBI patients is linked more with a sophisticated approach rather than the surgical procedure *per se* (7, 8). Decision-making for optimal surgical technique, selection of medical therapies, interpretation of basic and advanced neuromonitoring, and how to triage and select patients according to evidence-based outcomes in the different types of context is something that only comes with appropriate sub-specialized training in neurotrauma care (9, 10). Despite these elements, it has been recognized that formal neurotrauma fellowship programs are concentrated in HICs. Regularly, these programs are fully funded by universities or industry sponsors, and to apply, candidates need to fulfill requirements and obtain credentialing for practice under the rules of each country. As has been experienced by many, once LMIC applicants obtain credentialing for practice as sub-specialists in these countries, they seldom return to their natal countries, looking for a better way of life in high resource environments (11, 12). The objective of this paper is to present the results of a recently established model for a neurotrauma fellowship program, created for LMIC neurosurgeons within the framework of global neurosurgery collaborations.

MATERIALS AND METHODS

The Global Neurotrauma Fellowship (GNTF) program was developed in 2015 as a capacity-building effort by a multi-institutional collaboration between the Barrow Neurological Institute at Phoenix Children's Hospital in the United States and Meditech Foundation, a research center and educational non-government organization in Colombia. The original idea was established because of different discussions and clinical interactions of a mentor-mentee relationship in the framework of a capacity-building trauma grant for LMICs, sponsored by the United States (US) National Institute of Health (NIH) Fogarty International Center (D43 TW007560).

This U.S.-Colombia collaboration established the Trauma and Injury Excellence in Education on Research (TrainEER) Program, devoted to advancing the training of health care professionals in trauma research across Colombia. Through a combination of short- and long-term training, the TrainEER Program was able to provide individuals with extensive trauma and injury research training between 2007 and 2012, all while developing sustainable research partnerships with US investigators. The principal investigators were an American trauma surgeon and a Colombian trauma surgeon, Drs. Timothy Billiar and Juan C. Puyana, based at the University of Pittsburgh Medical Center in Pittsburgh (PA).

During this program, a mentor-mentee collaboration was established between Dr. David Adelson, who was the director of the Center for Injury Research and Control (CIRCL) at the University of Pittsburgh, and Dr. Andres M. Rubiano, who was a TrainEER Program fellow at the time. The collaboration was initiated during the TrainEER Program and was maintained throughout its course and beyond.

The fellowship's initial concept was established in 2012 after Dr. Adelson visited Colombia where he and Dr. Rubiano identified an opportunity to adapt the curriculum

TABLE 1 | Global Neurotrauma International Fellowship Program academic sections, rotation sites, and modules.

Program sections	Neurotrauma general principles*	Research basic training**	General principles for global health***
Module 1	General Trauma Care/Clinical Skills and Surgery of Neurotrauma Care. Topics: Trauma systems, Prehospital care, Trauma resuscitation, airway management, abdominal and thoracic trauma assessment, FAST technique, orthopedic trauma assessment, imaging lecture in general trauma, pediatric and elderly trauma assessment. (Months 1-3) (Valle Salud Clinic, Cali, Colombia)	Clinical Research and Basic Science Research. Topics: best practices in clinical research, methodological approaches, basic epidemiology, basic statistical analysis, funding opportunities, ethics principles in clinical research, observational studies, clinical studies. (Months 1-3) (Meditech Foundation, Research Center, Cali, Colombia)	Leadership and Teamwork. Topics: leadership skills, phenomenological and ontological models of leadership, global health principles, humanitarian medicine, basic public health principles, teamwork. (Month 4) (Meditech Foundation, Research Center, Cali, Colombia)
Module 2	Special Procedures in Neurotrauma. Topics: Basic and advanced ICP monitoring, transcranial doppler, Infrascanner in neurotrauma, optic nerve ultrasound, neurotrauma surgical management (cranial and spinal), brain oxygenation monitoring, external ventricular drains, scalp injuries management, CSF leaks management, CNS infection management. (Months 5-6) (Valle Salud Clinic, Cali, Colombia/Addenbrooke Hospital, Cambridge, UK)	Presentation Skills at Scientific Meetings. Topics: design and development of slides and lectures, principles of health education and teaching skills. (Months 5-6) (Meditech Foundation, Research Center, Cali, Colombia)	Global Health and Global Neurosurgery. Topics: principles of global neurosurgery, neurosurgery capacity building, burden of neurosurgical diseases in LMICS, technical documents supporting global neurosurgery initiatives, task shifting and task sharing in LMICs, dealing with neurosurgical procedures in low resources environments. (Months 7-8) (UROS Clinic, Neiva, Colombia/Hospital Santa Casa Sao Joao del Rei, Brasil/Hospital Miguel Couto, Rio do Janeiro, Brasil)
Module 3	Advanced Monitoring and Neurointensive Care in Special Populations. Topics: neuromonitoring in children, EEG evaluation, evoked potentials, NIRS principles in neurointensive care, advanced imaging interpretation in neurotrauma: Special MRI sequences, angiography, tractography, biomarkers evaluation. (Months 9-10) (Barrow Neurological Institute at St Joseph and Phoenix Children Hospitals/Las Americas Clinic, Medellín, Colombia)	Skills for Scientific Writing in Biomedical Publications. Topics: general principles of narrative revies, scoping reviews, systematic reviews, meta-analysis, how to write scientific papers, reference managers, ethics in medical writing. (Months 11-12) (Meditech Foundation, Research Center, Cali, Colombia)	Neurotrauma Quality Improvement and Patient Safety. Topics: guidelines and protocol development and adherence in Neurotrauma, trauma QI methodologies, best clinical practices in neurotrauma, indicators of quality and performance in neurotrauma, morbidity and mortality panels and meetings, neurotrauma registries development and management. (Months 11-12) (Vallesalud Clinic, Cali, Colombia)

**The neurotrauma general principles section, include a permanent rotation in surgical theater and Intensive Care Units (ICU) in different centers, from low to high level of resources for the care of neurotrauma patients.*

***The basic research program include a mentorship program with senior academic instructors of the program, including participation in seminars, webinars and symposiums. Periodical meetings with the research group of MEDITECH and direct participation as co-investigators in active research projects in different centers are included.*

****The general principles for Global Health section include a mentorship program with senior academic instructors of the program, including participation in seminars, webinars, and symposiums. Periodical meetings with the research group of MEDITECH and direct participation in global surgery activities are included.*

for neurotrauma fellows from the accredited Committee on Advanced Subspecialty Training (CAST) of the Society of Neurological Surgeons in the United States for implementation in low-resource environments. With private donor support from the US, MEDITECH Foundation in Colombia and Barrow Neurological Institute at Phoenix Children's Hospital in the US adopted a competency-based curriculum, ensuring trainees fulfilled requirements for basic and advanced neurotrauma care in low, medium, and high resource scenarios. A 12-month modular program (**Table 1**) was instituted, which included multiple clinical and surgical rotations in Colombia, Brazil, and the US.

Instructors were selected by highly experienced senior neurosurgeons and critical care physicians from these countries, all of whom were committed to an academic career in neurotrauma and neurocritical subspecialties. The clinical and surgical practices were established mainly in Cali and Neiva (Colombia), at two busy private hospitals devoted to trauma care (6 months) with complementary observational rotations for advanced neuromonitoring and advanced surgical techniques as defined by those corresponding techniques carried out in the US. Direct participation in research activities, including interaction with research methodology mentors from the US, was also part of the program.

In 2018, additional support for the continuation of the fellowship program was received from the NIHR Global Health Research in Neurotrauma Project from the University of Cambridge in the United Kingdom (UK) as part of a global neurosurgery collaboration for capacity building in neurotrauma care for LMICs. This collaboration between Colombia, the US, and the UK enhanced the infrastructure and learning opportunities of the program, adding a research component in global neurosurgery and system science. A senior expert in neurotrauma care, Prof. Peter Hutchinson, and a junior expert in clinical research, Dr. Angelos Kolias, from the University of Cambridge were added to the board of directors of the program,

TABLE 2 | Characteristics of past and current fellows.

Name	Country	Institution	Specialty	Duration of residency program in years	Age range	Time of working experience before the fellowship (in years)
Raul Augusto Echeverri MD	Venezuela	Institute of Neurology and Neurosurgery, La Havana, Cuba	Neurosurgery	5	30-40	5
Ahsan Ali Khan MD	Pakistan	Southeast University, Nanjing, China	Neurosurgery	4	20-30	1
Santiago Morales MD	Colombia	El Bosque University, Colombia	Neurosurgery	5	40-50	15
Diana Marcela Sánchez Parra MD	Colombia	Centro Internacional de Restauracion Neurologica, La Havana, Cuba	Neurosurgery	5	30-40	1
Jorge Luiz Da Rocha Paranhos MD	Brazil	Brazilian Medical Association	Neurosurgery/Critical Care	5	60-70	26
José Nel Carreño MD	Colombia	Juan N. Corpas School of Medicine	Neurosurgery/Critical Care	5	40-50	23
Wellingson Silva Paiva MD, PhD	Brazil	University of São Paulo	Neurosurgery	5	40-50	11
Robson Luis Oliveira de Amorim MD, PhD	Brazil	University of São Paulo	Neurosurgery	5	40-50	11

giving new insights into the development of the vision and mission of the fellowship moving forward.

The global neurosurgery concepts and system science were included as pivotal aspects of the future impact of this program. Within this frame, procedures can be learned in different scenarios, but the integration of public policy, global surgery, and system ecology will open a new door in knowledge and leadership projection for these fellows. The hope is that the fellows will then be prepared to create lasting changes in the health care infrastructure of their home countries equipped with leadership in knowledge and public policy skills.

Any neurosurgeon from any LMIC can apply to the fellow program, and the selection will include evaluation of the curriculum vitae and an interview with the fellowship directors. To start the process, an online application form needs to be filled including all the additional documents that are required, including curriculum vitae, personal statement, letters of recommendation, and certification of a neurological surgery program in the applicant's original country. There is no application deadline, and all the applications received during the previous year will enter the selection process for the next year. Applications are managed online at the fellowship website: https://www.globalneurotraumafellowship.com/.

RESULTS

Overall, eight fellows have taken part in the program. **Table 2** presents the characteristics of each fellow, including their name, age range during the fellowship, home country, home institution, specialty, length of neurosurgical training, and neurosurgical experience.

All fellows were funded, with a salary stipend, in addition to the provision for housing, food, and transportation while on international rotations. Additional financial support was provided for research training. This included funding for data collection, management, analysis, and support for academic writing.

Clinical Exposure

All fellows were exposed to basic and advanced training at several institutions with neurosurgery and critical care capabilities in Colombia (Vallesalud Clinic, Cali/UROS Clinic, Neiva/Las Americas Clinic, Medellin), in addition to lower-level facilities with solely base-level neurosurgical capabilities (**Figure 1**). Some of these rotations include the trauma centers in the cities of Bogota, Neiva, Cali, and Medellin. Fellows have also rotated in busy trauma centers in Brazil (Hospital Miguel Couto, Rio do Janeiro/Hospital Santa Casa, Sao Joao del Rei/Hospital Das Casas, São Paulo), and the US and UK (Barrow Neurological Institute at Phoenix Children Hospital and St Joseph Hospital in Phoenix/Addenbrookes Hospital, Cambridge, UK).

Continuous Medical Education

Fellows have taken part in clinical research training programs and continuing medical education (CME) programs such as the advanced trauma life support (ATLS) course of the American College of Surgeons, the advanced cardiac life support (ACLS) course of the American Heart Association, the Fundamental Critical Care Course (FCCS) course of the American Critical Care Society and the Trauma Ultrasound Training Program (USET) of the Pan-American Trauma Society.

FIGURE 1 | Dr. Laura Pastor, visiting neurosurgical resident from Spain, performing a spinal cord injury surgery with a mentor of the fellowship program in Colombia, Dr. Alvaro Soto.

Research

Fellows have contributed significantly to the global neurosurgery academic community, presenting their research at international conferences such as the International Conference for Recent Advances in Neurotraumatology (ICRAN) and publishing in highly reputable journals like NEUROSURGERY, Frontiers in Neurology, and World Neurosurgery (13–16). They perform most of the research activities while based in Colombia in different centers in a broad level of resource availability. Everything to apply similar principles when they return to their home countries. Quality improvement research activities are under planning to evaluate the impact of the fellow's training after finishing the program.

Post-fellowship

The fellows that have completed the program have gone on to create lasting change in their communities. One fellow created a program of sponsored rotations in neurotrauma and critical care for Venezuelan residents who return to their country to improve neurotrauma care practices in different regions throughout the country (**Figure 2**). We consider these actions as a means of measuring the program's overall impact. Other fellows have been strong advocates for the improvement of neurotrauma health-system strengthening in their home institutions, most notably in Brazil, where one of our fellows has been actively leading neurotrauma care research and systems improvements activities in the Amazonian region.

FIGURE 2 | Graduation ceremony of Dr. Raul Echeverri (Venezuela), who created an award for Venezuelan neurosurgical residents who traveled to Colombia for additional neurotrauma training within the fellowship program. From left to right, Dr. Ruy Monteiro (Brazil), Dr. Echeverri (Venezuela), Dr. David Adelson (US), Dr. Alvaro Soto (Colombia), and Dr. Andres M. Rubiano (Colombia).

DISCUSSION

Neurotrauma care in low-resource settings faces many challenges. This includes a lack of availability of subspecialty care for neurosurgeons, neuro-intensivist, and neuroscience nursing. There is a lack of staff, disparities in distribution, and access to adequate technologies for diagnosis and management, including the basics of CT scanning and ICU care. Furthermore, there is a lack of financial resources for the long-term care of patients following all levels of neurotrauma (17–19).

A large portion of this disparity of care could be mitigated by an increase in neurotrauma and neurocritical care staff. However, in HICs, there has been an overall lack of interest in these subspecialties. This general lack of interest from HIC's has been transferred to LMIC's despite neurotrauma being identified as one of the neurologic and neurosurgical conditions with the most substantial patient burden in LMIC's. This brings with it the most significant opportunities for advancement care. Nevertheless, young neurosurgeons seem to have more motivation for highly technological driven specialties like functional neurosurgery, endovascular, cerebrovascular, and skull-based neurosurgery (20–22). These, along with other highly reimbursing specialties like spine or tumor neurosurgery are incredibly lucrative and thus, highly sought after. The subspecialties tend to bring with them a more comfortable lifestyle, including less of a load of emergency procedures during nights and weekends and a more significant economic return for those pursuing private and elective practice.

Neurotrauma care has been traditionally offered in public and charity institutions in all countries. Many of these institutions regularly face economic and administrative problems when compared to their private hospital, practice, and institutional counterparts (23–25). In this way, neurotrauma care may be perceived as a second-class subspecialty, reserved for trainees in entry-level neurosurgery. Additionally, there is often a lack

FIGURE 3 | Trauma surgery during COVID-19 pandemic. Dr. Santiago Morales, neurotrauma fellow (Colombia), and Dr. Andres M. Rubiano, fellow instructor (Colombia) performing an emergency cranial decompression on a patient with severe TBI.

of primary focus for neurotrauma in neurocritical care at national and international meetings. This further extends the misperception that neurotrauma is a second-class subspecialty. This has led to separate organizations and specialties developing a framework to fill this gap, i.e., neurocritical care or trauma care general societies without the involvement of neurosurgery (26–28).

With the disproportionately high burden of neurotrauma disease in LMIC's, neurotrauma is a highly technical and complex subspecialty in these geographic areas where it is most needed (**Figure 3**). In the absence of formal neurotrauma subspecialty training programs in these areas, it is easy for this view to grow. It is not uncommon to see formal fellowship training programs in endovascular or spine neurosurgery in LMICs, with an absence of formal neurotrauma fellows (29, 30). In these countries, the national burden of neurotrauma has an incidence of 800-939 cases for every 100,000 people. This, in contrast to the incidence of aneurysms and cervical stenosis in these countries as 3.4-6.9 cases for every 100,000 and 2.3-3.4 cases for every 100,000, respectively (2, 31, 32).

The question that arises is whether the available short-term rotations or short-term programs or CME activities would provide enough expertise to fill this gap. A review of the existing curriculums for neurotrauma and neurocritical care does not fulfill the requirements of an appropriate training program that will allow fellows to achieve mastery in the triage/assessment of the neurotrauma patient, the decision making for medical and surgical care, the integration of care pathways, and the surgical skills in innovation for the future growth and improvement of inpatient care (33, 34). Many severe TBI patients are not appropriately managed because they are "too sick," or moderate TBI patients are not aggressively managed because they are considered "not sick enough." When a neurotrauma patient dies, the "fulfilled prophecy" is accomplished (35).

With a new area of global neurosurgery forged by discoveries in system science research, stakeholders can see more clearly the many moving parts and processes that both strengthen and weaken health systems and thus neurotrauma care. System science understands that neurotrauma care, like any other disease, is a function of the multitude of factors that go into providing optimal care. This includes healthcare personnel, technology, equipment, infrastructure, health guidelines, and processes, in addition to educational programming. The interaction of these components is what determines optimal vs. suboptimal care.

Of these factors, educational programming has both an immediate and a future-looking approach as fellows are involved in care in real-time and are the future not only of the field itself but also as the next generation of educators. A formal education program will allow fellows to learn the complexities of care, but also the moving parts revealed by system science research. When solely focusing on general neurosurgical aspects of care, essential elements for the proper care of neurotrauma patients can easily be overlooked (36, 37). Aspects like timely access to early surgery, appropriate interaction with prehospital and emergency providers, teamwork with trauma surgeons or other critical care physicians are essential aspects of the job, and thus education must not overlook these areas (38).

The fellowship program that we have developed exposes neurosurgeons from LMICs to a full range of contexts where they can become engaged as part of a broader community of peers within the same subspecialty and can share in the challenges and successes that come with practicing with different levels of resources and perspectives. Working in this environment allows them to participate in the global community of neurotrauma and neurocritical care providers. They participate in the same clinical and academic activities, and partner and collaborate on research projects, focusing on creating a difference in their home regions. Since the inception of the program, the mentoring process has fostered that transformational experience for LMIC neurosurgeons. Our next step is to add new competencies from the human aspect, including leadership training and communication skills that are critical when facing difficult situations like managing severe TBI patients in low resources settings.

Multinational and multi-institutional collaborations like the Global Health Research Group in Neurotrauma are creating new possibilities to enhance these types of programs to create the next generation of neurotrauma care leaders in LMICs. Initiatives include funding fellows in LMICs to undertake specific research projects and to collect data for extensive observational studies

TABLE 3 | National Institutes of Health Research—Global Health Research Group in Neurotrauma. University of Cambridge.

List of supported fellows 2018/2019, NIHR Global Health Research Group on Neurotrauma, University of Cambridge

Country	Gender (*n*)	Age range	Institution
Brazil	Male (1)	(20-40)	University of São Paulo
Colombia	Male (2) Female (1)	(20-40)	Meditech Foundation
Ethiopia	Female (2)	(20-40)	Addis Ababa University &Tikur Anbessa Hospital
India	Male (3)	(20-40)	National Institute of Mental Health & Neurosciences Christian Medical College
Indonesia	Male (1)	(20-40)	Soetomo General Hospital Airlangga University
Malaysia	Male (2)	(20-40)	University of Malaya Medical Centre
Myanmar	Male (1) Female (1)	(20-40)	Yangon, University of Medicine 1
Pakistan	Male (1)	(20-40)	North West General Hospital and Research Center
South Africa	Male (1)	(20-40)	Red Cross Children's Hospital and University of Cape Town
Tanzania	Male (1)	(20-40)	Muhimbili Orthopaedic Institute
United Kingdom	Male (3)	(20-40)	Cambridge University Hospitals NHS Trust
Zambia	Male (1)	(20-40)	University Teaching Hospital

List of sponsored GHRG Research Fellows in Neurotrauma Clinical Research (2018-2019).

(39). The current list of fellows and projects from the NIHR program covers a wide range of collaborations in and with LMICs (**Table 3**). Other examples of trainee engagement include participation in the World Health Assembly of United Nations, organized by the WHO and held annually in Geneva, to assist in raising the profile of neurological and surgical disorders with health ministers and ministries globally (40, 41). Many of the different aspects of the program can be measured by generating indicators of impact for this program, including the number of new collaborations created by fellows in their home countries, number, and quality of publications addressing global surgery and public health aspects from the neurotrauma perspective, or new funding obtained for support of research activities in their home countries.

The Fellowship Program has not been affected by the Covid pandemic, as most trauma cases have continuing arriving at most hospitals. Telemedicine initiatives have been involved to accomplish a better evaluation of patients under risk circumstances. There are recent publications produced by the fellowship group related to exploring what are the ideal conditions to keep safety measures during emergency neurotrauma surgery (42, 43).

CONCLUSION

It is possible to establish a neurotrauma fellowship program in an LMIC based on the established criteria for neurotrauma training in HIC programs. Adaptation of the international competencies focusing on neurotrauma care in low resource settings and maintaining international mentoring and academic support enhances the likelihood that the neurotrauma-trained fellow will return to clinical and academic practice in their home countries. Ongoing collaborative global community support will further enhance the growth of the advanced level of care in LMICs.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

AR, DG, PA, RE, AK, SM, AAK, and PH contributed to the design and implementation of the research, to the analysis of the results, and to the writing of the manuscript. All authors contributed to the article and approved the submitted version.

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Survey Fatigue During the COVID-19 Pandemic: An Analysis of Neurosurgery Survey Response Rates

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Background: The COVID-19 pandemic has caused a surge in research activity while restricting data collection methods, leading to a rise in survey-based studies. Anecdotal evidence suggests this increase in neurosurgical survey dissemination has led to a phenomenon of survey fatigue, characterized by decreased response rates and reducing the quality of data. This paper aims to analyze the effect of COVID-19 on neurosurgery surveys and their response rates, and suggest strategies for improving survey data collection.

Methods: A search was conducted on March 20, 2021, on Medline and EMBASE. This included the terms "neurosurgery," "cranial surgery," "spine surgery," and "survey" and identified surveys written in English, on a neurosurgical topic, distributed to neurosurgeons, trainees, and medical students. Results were screened by two authors according to these inclusion criteria, and included articles were used for data extraction, univariable, and bivariable analysis with Fisher's exact-test, Wilcoxon rank-sum test, and Spearman's correlation.

Results: We included 255 articles in our analysis, 32.3% of which were published during the COVID-19 pandemic. Surveys had an average of 25.6 (95% CI = 22.5–28.8) questions and were mostly multiple choice (78.8%). They were disseminated primarily by email (75.3%, 95% CI = 70.0–80.6%) and there was a significant increase in dissemination *via* social media during the pandemic (OR = 3.50, 95% CI = 1.30–12.0). COVID-19 surveys were distributed to more geographical regions than pre-pandemic surveys (2.1 vs. 1.5, $P = 0.01$) and had higher total responses (247.0 vs. 206.4, $P = 0.01$), but lower response rates (34.5 vs. 51.0%, $P < 0.001$) than pre-COVID-19 surveys.

Conclusion: The rise in neurosurgical survey distribution during the COVID-19 pandemic has led to survey fatigue, reduced response rates, and data collection quality.

We advocate for population targeting to avoid over-researching, collaboration between research teams to minimize duplicate surveys, and communication with respondents to convey study importance, and we suggest further strategies to improve response rates in neurosurgery survey data collection.

Keywords: COVID-19, neurosurgery, survey fatigue, survey, response rate, non-response, data collection

INTRODUCTION

During the Coronavirus Disease (COVID-19) pandemic, many global organizations have strived to conduct research to find solutions and mitigation strategies to the burdens of the pandemic (1). Indeed, the National Institute of Health estimates more than a fifth of the current biomedical community have pivoted their efforts to address COVID-19 related research questions - showing impressive adaptability of the research community (2, 3) - and overall publications have hit a record high (4). However, the pandemic has affected how research in and of itself is conducted, and the feasibility of conducting non-COVID-19 related studies. For instance, new subject enrollment for clinical trials across all specialties dropped by 79% between April 2019 and April 2020, and by 76% in neurological and neurosurgical studies (5). Social distancing and quarantine rules have delayed clinical trials and laboratory work so academics have been forced to embrace remote strategies for primary data collection (6). Therefore, online surveys have become a crucial tool during the COVID-19 pandemic, allowing for the collection of real-time data despite the global restrictions that have been put in place (7). Online surveys come with a host of advantages: ease of use for the respondent, ease of data analysis for the surveyor, low cost, wide range of options for dissemination, and flexibility of question design (8).

However, the authors' anecdotal experience in the neurosurgical field indicates that an increased propensity for survey fatigue has accompanied the recent surge in survey dissemination. Survey fatigue is a well-known phenomenon in academia, occurring when respondents tire of the survey they're completing and produce suboptimal responses or terminate participation pre-maturely (9). This leads to an overall lower quality of respondent data and reduces the power of studies conducted through this method of data collection. A number of factors are known to influence respondent fatigue, such as survey length, survey topic, question complexity, and question type (10), and literature has been published with advice on minimizing the chances of fatigue occurring (11, 12).

In this paper, we propose a second type of survey fatigue, characterized by lower response rates. This proposition is driven by the experiences from a recent unpublished collaborative between the Neurology and Neurosurgery Interest Group (NANSIG) and the Association of Future African Neurosurgeons (AFAN), where despite survey reminders, social media dissemination, and extension of data collection period, the survey was met with only 13 responses from across the continent of Africa (unpublished data). We believe that the surge in survey dissemination in the neurosurgical field since the beginning of the COVID-19 pandemic has led to potential survey respondents being approached more frequently within a short period, leading to a type of survey fatigue in which these respondents refuse to complete surveys at all. There is currently no data available in the neurosurgical literature quantifying the changes in survey dissemination and response in light of the COVID-19 pandemic, and understanding these changes and the drivers behind them is crucial to improve the quality of data collection in future studies.

This study aims to analyze the effects of the COVID-19 pandemic on neurosurgical survey production and responses. We will analyze the number, pattern of distribution, and response rates of surveys produced before the pandemic and since the pandemic to investigate changes between these two time periods, and understand how COVID-19 has impacted neurosurgical data collection through surveys. We will particularly be looking at the presence of survey fatigue. Finally, we will investigate what factors may have contributed to the development of survey fatigue within the neurosurgical community during the COVID-19 pandemic, to inform future survey design and improve the quality of data collected.

METHODS

A search strategy was developed to capture all surveys completed by neurosurgery attendings/consultants, residents/registrars, and medical students interested in the specialty. The databases MEDLINE and Embase were searched using key terms such as "neurosurgery," "spine surgery," "cranial surgery," and "survey" from inception to March 20, 2021. The results were screened by two authors (RdK and USK) according to our inclusion criteria, using the software Rayyan (13). For the article to be included for data extraction, the article had to be (i) written in English, (ii) detailing a survey administered to neurosurgeons, neurosurgical trainees, or students interested in neurosurgery, (iii) and the survey had to be based on a topic relevant to neurosurgery (i.e., surveys exploring general medical or surgical concepts relevant to other specialties were excluded).

The included articles were then used for data extraction, in which they were segregated into surveys conducted before the COVID-19 pandemic, and surveys conducted since the start of the COVID-19 pandemic. Numbers of surveys, respondents, and response rates were then analyzed for each of these groups. Summary descriptive statistics were calculated for qualitative (i.e., frequencies and percentages) and quantitative (i.e., mean and 95% confidence interval) data. Then, bivariable analysis was computed using: Fisher's exact-test, odds ratios and their 95% confidence intervals; Wilcoxon rank-sum test; and Spearman's correlation.

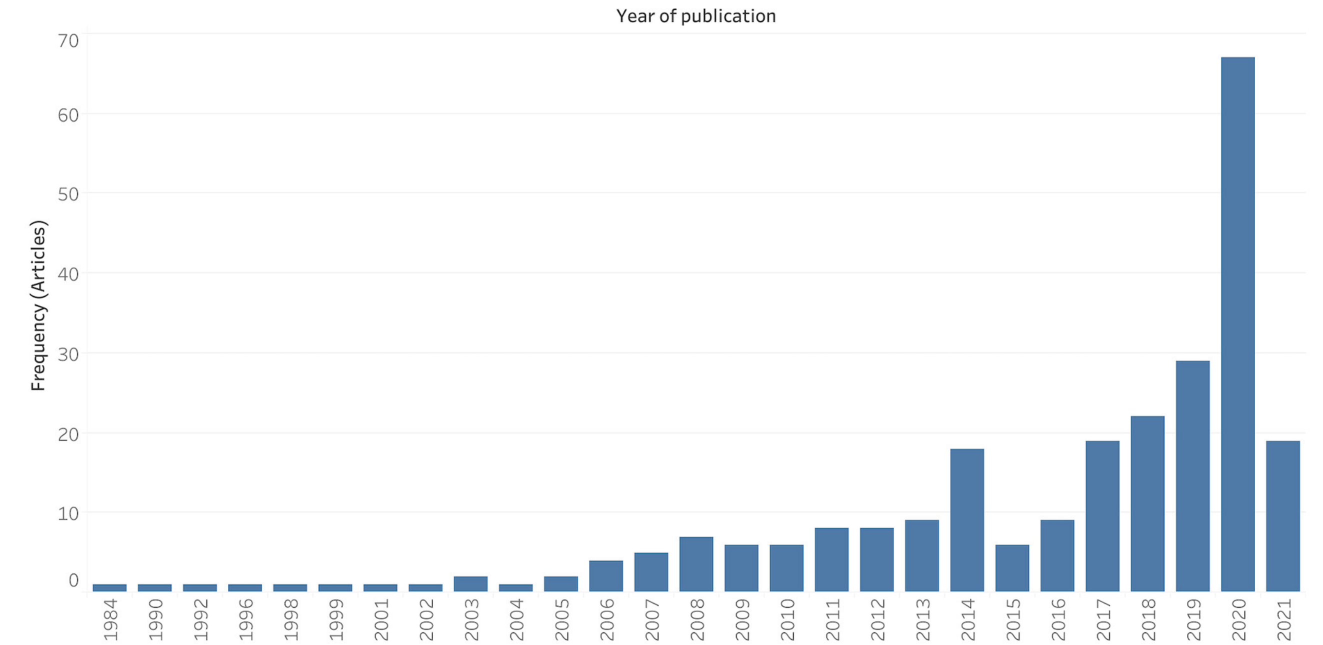

FIGURE 1 | Publication trend of neurosurgery survey research.

RESULTS

Two hundred and fifty-five studies met the inclusion criteria. They were published between 1984 and 2021, with 67.7% (n = 172) of papers published in the pre-COVID-19 era. The COVID-19 era was defined as beginning on the 1st of January 2020, as per the WHO report on December 31st, 2019 (14). There was a clear publication peak in 2020 (n = 67, 26.3%), corresponding to the year of the COVID-19 pandemic (**Figure 1**).

Each survey collected responses from an average of 1.7 (95% CI = 1.49–1.90) WHO regions and 1.2 (95% CI = 1.1–1.2) professional groups (i.e., medical students, residents/registrars, or neurosurgeon consultants/attendings). Overall, COVID-19 era surveys were distributed to more geographical regions than pre-COVID-19 era surveys (2.1 vs. 1.5, P = 0.01). We found that more neurosurgery surveys of Southeast Asian (OR = 3.22, 95% CI = 1.64–7.00, P = 0.001) and Eastern Mediterranean (OR = 2.39, 95% CI = 1.13–5.42, P = 0.03) respondents were published in the COVID-19 era than in the pre-COVID-19 era. There was no evidence to suggest differences in the number of surveys targeting medical students, residents, and attendings between the two timeframes (**Table 1**).

On average, the surveys were composed of 25.6 (95% CI = 22.5–28.8) questions. The majority of studies were made up of multiple-choice questions (n = 201, 78.8%) and 77 surveys (30.2%) contained free-text questions. Each survey had an average of 1.3 (95% CI = 1.2–1.4) question types (i.e., multiple choice, free text, Likert scale, and short answer) and was distributed by a single mode (95% CI = 1.0–1.1). The survey distribution modes included email (n = 192, 75.3%, 95% CI = 70.0–80.6%), post-mail (n = 26, 10.2%, 95% CI = 6.5–13.9%), social media (n = 20, 7.8%, 95% CI = 15.1–24.9%), and oral distribution (n = 12, 4.7%, 95% CI = 2.1–7.3%). There was a three-fold increase in dissemination *via* social media in the COVID-19 era in comparison to the pre-COVID-19 era (OR = 3.50, 95% CI = 1.30–12.0).

The surveys collected an average of 194.9 (95% CI = 157.3–232.5) total responses, and they had a mean response rate of 44.7% (95% CI = 40.3–48.9%). The greater the number of regions surveyed, the higher the number of responses (R = 0.26, P < 0.001). The response rate negatively correlated with the number of regions surveyed (R = −0.24, P = 0.001) and with the total number of responses (R = −0.40, P < 0.001) (**Table 2**).

Studies collecting data from America (−18.5%, P < 0.001), the Western Pacific (−15.8%, P = 0.03), Southeast Asia (−15.1%, P = 0.03), and the Eastern Mediterranean (−13.6%, P = 0.01) regions had lower response rates in the COVID-19 era (**Table 3**). Overall, COVID-19 era surveys had higher total responses (247.0 vs. 206.4, P = 0.01) but lower response rates (34.5 vs. 51%, P < 0.001) than pre-COVID-19 era surveys.

DISCUSSION

Key Findings

In this study, we analyzed the effects of the COVID-19 pandemic on the pattern of neurosurgical survey production and responses. There was a significant increase in the number of neurosurgical surveys published since the COVID-19 pandemic. There was a particular increase in surveys of Southeast Asian and Eastern Mediterranean respondents during the COVID-19 pandemic. The primary mode of survey dissemination was email, and there

TABLE 1 | Neurosurgery survey study characteristics in the pre-COVID-19 and COVID-19 eras.

Study population	Pre-COVID-19 era frequency (percentage) *n* = 172 (67.7)	COVID-19 era frequency (percentage) *n* = 83 (32.3)	Odds ratio (95% CI)	*P*-value Fisher's exact
Professional role				
Attendings	135 (52.9)	55 (21.6)	0.56 (0.31–1.00)	0.06
Residents	60 (23.5)	28 (11.0)	0.97 (0.56–1.68)	0.99
Medical students	9 (3.5)	7 (2.7)	1.69 (0.61–4.71)	0.41
Region				
Africa	33 (12.9)	22 (8.6)	1.53 (0.80–2.92)	0.24
America	88 (34.5)	43 (16.9)	0.98 (0.54–1.85)	0.99
Europe	39 (15.3)	26 (10.2)	1.58 (0.84–2.94)	0.15
Eastern Mediterranean	17 (6.7)	17 (6.7)	2.39 (1.13–5.42)	0.03*
South East Asia	18 (7.1)	22 (8.6)	3.22 (1.64–7.00)	0.001*
Western Pacific	19 (7.5)	16 (6.3)	1.94 (0.92–4.47)	0.11
Question types				
Multiple-choice	126 (49.4)	62 (24.3)	0.98 (0.28–4.10)	0.99
Free text	43 (16.9)	27 (10.6)	1.47 (0.80–2.73)	0.27
Mode of distribution				
Email	111 (43.5)	53 (20.8)	0.85 (0.42–1.89)	0.70
Social media	8 (3.1)	12 (4.7)	3.50 (1.30–12.0)	0.01*
Post mail	16 (6.3)	4 (1.6)	0.48 (0.11–1.20)	0.22
Oral	7 (2.7)	3 (1.2)	0.86 (0.22–3.65)	0.99

Percentage of each study characteristic relative to the total 255 articles are presented.
$^*P < 0.05$.

TABLE 2 | Correlation between total number of responses or response rates and quantitative independent variables.

Quantitative variables	Correlation coefficient	*P*-value Spearman's rho
Total number of responses		
Number of regions surveyed	0.26	< 0.001**
Number of study populations	0.01	0.92
Response rate	−0.40	< 0.001**
Total number of questions	0.04	0.56
Number of question types	−0.12	0.09
Number of survey distribution modes	−0.04	0.50
Response rate		
Number of regions surveyed	−0.24	0.001*
Number of study populations	−0.03	0.69
Total number of responses	−0.40	< 0.001**
Total number of questions	0.05	0.53
Number of question types	0.10	0.18
Number of survey distribution modes	0.001	0.99

$^*P < 0.01$, $^{**}P < 0.001$.

TABLE 3 | Response rates across various study populations.

Study populations	Mean response rate difference	*P*-value Wilcoxon rank-sum test
Professional role		
Attendings	−1.5%	0.78
Residents	−0.5%	0.69
Medical students	+3.5%	0.54
Region		
Africa	−2.3%	0.52
America	−18.5%	< 0.001**
Europe	+2.1%	0.88
Eastern Mediterranean	−13.6%	0.01*
South East Asia	−15.1%	0.003*
Western Pacific	−15.8%	0.003*

$^*P < 0.01$, $^{**}P < 0.001$.

has been a three-fold increase in survey dissemination through social media since the beginning of the pandemic. We found that COVID-19 era surveys were distributed to more regions, and while surveying more regions led to a greater number of responses, it was also associated with a lower response rate. Overall, surveys conducted during the COVID-19 pandemic were found to have a higher total number of responses but lower response rates.

Implications

These results support our hypothesis that the COVID-19 pandemic has led to survey fatigue characterized by non-response (respondents refusing to complete any part of a survey), as reflected by the lowered response rate during the pandemic. During the COVID-19 pandemic, the number of surveys created and disseminated has increased significantly, and on average, each survey has targeted more regions. Therefore, more neurosurgical attendings/consultants, residents/registrars, and interested medical students have been solicited for surveys now than ever before, and all within a very brief window of time. Thus, non-response survey fatigue may be a consequence of individuals feeling overwhelmed with the number of survey requests. This is of particular note if that individual is a member of a small sample population, such as members within the neurosurgical field. For example, there are approximately only 500 neurosurgeons across Sub-Saharan Africa (15), and so any studies which attempt to survey this population are limited to a small number of potential responders. Each surgeon may therefore receive multiple requests occurring simultaneously or in close succession, leading to a feeling of being "over-researched" (16). This feeling of being over-researched may be further exacerbated if the content of surveys overlaps (16). In order to prevent such repetition and duplication of efforts, researchers should consult repositories of protocols for ongoing studies and discuss new studies with those who are likely to be aware of potential overlaps or synergies. This may include professional organizations, research funders, and government agencies (17).

Furthermore, the three-fold increase in social media dissemination during the COVID-19 pandemic can contribute to this feeling by creating the illusion that survey requests are omnipresent. To tackle this, researchers could be encouraged to receive training on the use of social media for participant recruitment. This training should highlight how to utilize social media to reach a population of interest, whilst minimizing spread to individuals for whom the survey is irrelevant. Relevant users could be identified through previous activity and interests, for example (18). It should also be noted that although social media dissemination is effective at recruiting participants for studies across a range of specialties (19), its use also limits the pool of participants to those neurosurgeons with access to the internet and social media platforms. This is particularly relevant to our unpublished survey, which was disseminated across Africa. Prior literature has shown a reduced response rate to online surveys amongst healthcare professionals from low- and middle-income countries (LMICs). Proposed reasons for this included inconsistent internet connection, more expensive mobile data, and reduced time to respond to surveys due to increased patient care workload (10).

It may also be that respondents from LMICs do not feel confident in filling out surveys on topics they are unfamiliar with, which is more likely to occur in cases where surveys are distributed globally to both high-income countries and LMICs. Reduced understanding of the questionnaire has been shown to correlate with higher levels of non-response (20). If surveys distributed globally consistently present topics that are unfamiliar to LMIC clinicians, it could lead to LMIC clinicians believing that future surveys sent out to a global audience are likely to be irrelevant, and therefore should be ignored (21). This eventuality would hamper trans-national efforts centered around health equity and information sharing. Therefore, it is critical when designing research studies that the applicability of the content for an international audience is taken into consideration. This could even be mandated at the ethical approval stage or through the creation of gatekeepers for research conducted internationally. Possible gatekeepers are organizations that represent clinicians. Approval of a survey from local, state or national organizations has also been shown to improve physician response (22). Therefore, gatekeepers can improve trust amongst physicians and prompt a higher response rate (23). Gatekeepers are also likely to reduce dissemination of similar survey projects and can prevent survey fatigue in this way.

TABLE 4 | Interventions proven to increase response rates.

Intervention	Explanation
Keep the questionnaire brief	Shorter questionnaires require less time to complete, reducing respondent burden (25)
Use simple and precise language	Poor wording of questions and lack of clarity reduces respondent motivation (26)
Provide a personalized invitation	Personalization decreases the perception of anonymity and increases investment (27)
Translate the survey into relevant languages	Response rates increase when respondents can complete the survey in their mother tongue (28)
Set a deadline for responses	This creates an illusion of urgency that helps encourage responses (23)
Send regular reminders	Reminders increase survey visibility and likelihood of response (29)
Offer a financial incentive	Respondents are more likely to engage when something is promised in return (30)

In addition to over-researching and technological challenges, lack of communication with participants to convey the importance of their responses can also discourage engagement with surveys, as it is more difficult for participants to appreciate the relevance of their contributions and feel invested in the study (16). Lack of investment into the results of the survey has been shown to contribute to non-response (24, 25). Offering to share the survey results provides an opportunity to discuss the importance of the survey and creates a more trustful relationship between the surveyor, and participant and can stimulate the participant to take an active interest into the importance of the survey project. This also allows for a potential avenue for participant feedback once the results of the survey have been disseminated to each participant, which could help improve future projects (17).

Table 4 provides further evidence-based recommendations to improve response rates and reduce fatigue in surveyed populations. These interventions relate to both survey design and dissemination, and along with the above recommendations, increase the likelihood of potential respondent engagement with neurosurgery surveys, allowing for the collection of higher quality data.

Limitations

One limitation of our study is that we were unable to extract data about all variables that may contribute to survey fatigue and non-response, either because included papers did not provide the adequate information, or because analysis was not possible. For example, the length of the data collection period was too variable across studies to analyze its relationship with total responses and response rates, so we were unable to determine whether this has an effect. Survey quality may also affect response rate, but many papers included in this study did not provide a copy of the questionnaire, preventing us from formally appraising this potential contributing factor. Another limitation is that of the nature of publication: some surveys will inevitably not have been published, and others might still be in review or writing. However, we believe that this latter point would only support our results, as the surveys as yet unpublished will more likely have been conducted recently, since the beginning of the COVID-19 pandemic.

CONCLUSION

The COVID-19 pandemic has caused unprecedented challenges to primary data collection through clinical trials and laboratory research, leading to a significant rise in online strategies, such as neurosurgical survey distribution. The results from this study confirm our hypothesis that this surge in survey production has also led to the development of a phenomenon known as survey fatigue, characterized by reduced response rates. We've suggested a number of methods to tackle this problem, and thus improve the quality of data collected through surveys. Mindful population targeting prevents respondents from feeling over-researched, collaboration between research teams minimizes duplication of survey questions, and communication with respondents can convey study importance to incentivize potential respondents to participate in neurosurgical surveys.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

RdK: conception, methodology, data extraction, writing, and editing. AE, JK, and AC: data extraction, writing, and editing. SO, NB, JE, and MK: data extraction and writing. GH and SB: writing and editing. DD: writing. DS: visualization. UK: conception, methodology, data analysis, and editing. All authors contributed to the article and approved the submitted version.

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Management and Outcomes of Paediatric Intracranial Suppurations in Low- and Middle-Income Countries: A Scoping Review

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Introduction: Intracranial suppurations account for a significant proportion of intracranial masses in low- and middle-income countries (LMICs), particularly among children. The development of better imaging equipment, antibiotics, and surgical techniques has enabled significant progress in detecting and treating intracranial abscesses. However, it is unclear whether these advances are accessible and utilised by LMICs. In this review, we aimed to describe the landscape of paediatric intracranial suppurations in LMICs.

Methods: This scoping review was conducted using the Arksey and O'Malley framework. MEDLINE, EMBASE, WHO Global Index Medicus, AJOL and Google scholar were searched for relevant articles from database inception to January 18th, 2021. Publications in English and French were included.

Results: Of the 1,011 records identified, 75 were included. The studies, on average, included 18.8 (95% CI = 8.4–29.1) children (mean age: 8.2 years). Most children were male (62.2%, 95% CI = 28.7–95.7%). Intracranial suppurations were most commonly (46.5%) located in the supratentorial brain parenchyma. The most prevalent causative mechanism was otitis (37.4%) with streptococcus species being the most common causative organism (19.4%). CT scan (71.2%) was most commonly used as a diagnostic tool and antibiotics were given to all patients. Symptoms resolved in 23.7% and improved in 15.3% of patients. The morbidity rate was 6.9%, 18.8% of patients were readmitted, and the mortality rate was 11.0%.

Conclusion: Most intracranial suppurations were complications of preventable infections and despite MRI being the gold standard for detecting intracranial suppurations, CT scans were mostly used in LMICs. These differences are likely a consequence of inequities in healthcare and have resulted in a high mortality rate in LMICs.

Keywords: management, outcomes, intracranial, suppurations, paediatric, infection, low and middle income countries

INTRODUCTION

Intracranial suppurations are infections of the central nervous system (CNS) characterised by the production and the accumulation of pus within the brain parenchyma and meningeal spaces (1, 2). Intracranial suppurations commonly occur through infection of a neighbouring site spreading to the CNS, such as sinusitis, otitis, or mastoiditis (3). Other causes include direct trauma, surgery, or haematogenous spread (3). Intracranial suppurations are generally divided into three broad categories: brain abscesses, in which the infection is based within the brain parenchyma; subdural empyemas, where the pus sits between the dura and the arachnoid membrane; and extradural empyemas, where the pus accumulates between the dura and the skull (1, 3).

Intracranial suppurations can be common, with brain abscesses alone accounting for 8% of intracranial masses in low-and-middle-income countries (LMICs), compared to only 2% in high-income countries (HICs) (4). With a mortality rate of up to 25% (5), they represent a significant burden of disease in LMICs. One contributing factor to the higher incidence in LMICs is the rate of HIV infection in these countries, as immunosuppression is a significant risk factor for the development of intracranial suppurations (6). With an increasing number of HIV-positive patients presenting with intracranial suppurations in LMICs, elucidating the current ability of local healthcare systems to cope with these cases is key. One critical facet to tackling intracranial suppurations is identifying the causative organism. The causative organism behind intracranial suppurations vary, but are largely bacterial species; the most common causative organisms being streptococcus and staphylococcus species (7). The bacterial species causing the intracranial suppuration vary depending on the primary infection site, the patient's underlying health, geographical location, and the patient's age. Of note, children are particularly vulnerable to intracranial suppurations due to their susceptibility to the development of adjacent infections, such as otitis and sinusitis. In LMICs, children represent a large population demographic, accounting for nearly half the population in some countries (8). Additionally, the highest global incidence rate of otitis media has been reported in Sub-Saharan Africa and South Asia (9); the majority of cases occur in the paediatric age group (10).

While the development of better imaging equipment, antibiotics, and surgical techniques have enabled significant progress in our ability to detect and treat intracranial abscesses. These advances are not necessarily accessible in low-resource settings such as LMICs. For example, one paper suggests that only 27.3% of patients in Cameroon with intracranial abscesses have access to an MRI scan (11), despite this mode of imaging being recommended for diagnosis (12). Once intracranial suppuration is identified, medical treatment with antibiotics and surgical treatment aiming to evacuate the pus are recommended (13). However, it is still unclear to what extent LMICs have access to these recommended treatment methods.

Therefore, the research question of the present study is: how are paediatric intracranial suppurations managed in LMICs? Our review primarily aims to provide an overview of the epidemiology, management, and outcomes of this population of patients. We aim to detect heterogeneity in treatment and whether this treatment deviates from the gold standard across LMICs. Gaining an understanding of the current landscape in LMICs is a vital step toward ensuring efforts are being directed toward areas most in need, both geographically and in terms of aspect of care: diagnostics, pharmacological treatment, and surgical treatment.

METHODS

A scoping review on the epidemiology, management, and outcomes of paediatric intracranial suppurations in LMICs was conducted as per the published and registered protocol (14). The Arksey and O'Malley scoping review framework was used to guide the scoping review (15). The Preferred Reporting Items for Systematic Review and Meta-Analysis extension for Scoping Reviews (PRISMA-ScR) guidelines were used to report the findings (16).

Inclusion and Exclusion Criteria

We included studies that fulfilled the specific inclusion criteria discussed in our published protocol. Studies of interest included studies that discussed intracranial paediatric (defined as between 0 and 18 years of age) suppurations in LMIC populations. We also included journal articles, reviews, case reports, and letters. There were no restrictions to the period of the publications considered to ensure that all relevant articles published from database inception to date of search are captured. Publications in English and French languages were considered. We excluded studies that (a) did not include paediatric populations (or did not have disaggregated data about a paediatric population), (b) did not discuss intracranial suppurations, (c) were neither written in English nor French, and (d) were not related to LMICs (or did not have disaggregated data about an LMIC population), (e) did not have accessible full-text, and (f) are conference abstracts.

Search Strategy

The search protocol for this scoping review was executed in MEDLINE, EMBASE, WHO Global Index Medicus, and African Journals Online covering the period between database inception to January 18, 2021. The search strategy used variants and combinations of search terms related to children, intracranial suppurations, and LMICs. The Appendix in our published protocol shows the exact content and order of the search string queries (14). A hand search of Google Scholar was further conducted to identify additional articles that were not captured in the above process.

Study Selection

All the articles resulting from the search were exported into Rayyan (17), where duplicates were identified and deleted. Rayyan is a professional research software that is widely used by collaborators for ease of study selection decisions. The study selection process consisted of multiple steps. Firstly, an online training session was organised to ensure all authors understood the pre-defined inclusion and exclusion criteria of the study. Next, two reviewers of SZYO, DS, DUD, GH, BDT, BNDA, AE, JK, RdK, SN, YZ, DYCH, SC, SB and USK independently screened the titles and abstracts of the identified articles based on the criteria. Any disagreement between the two reviewers' decisions prompted further discussion. If a disagreement persisted, a senior author (SB or USK) was sought to resolve the disagreement. The full texts of the remaining articles were retrieved and screened by two reviewers (of SZYO, DS, DUD, GH, BDT, BNDA, AE, DYCH and USK) independently.

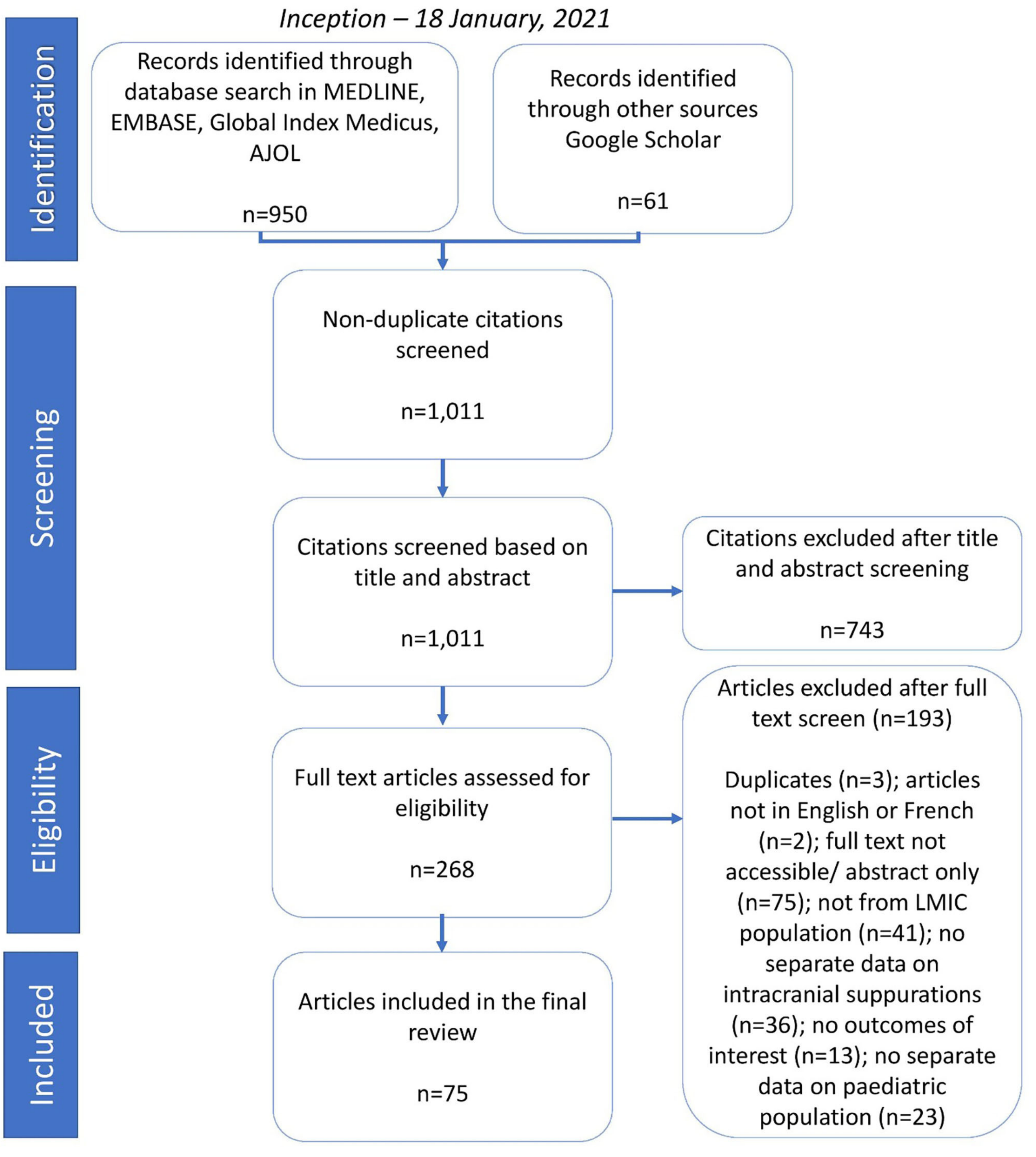

FIGURE 1 | PRISMA flow chart.

Data Extraction

Prior to data extraction, an Excel proforma sheet was used to ensure all participants in the data extraction step were extracting data homogeneously. The Excel sheet included columns of specific interest for data extraction such as study design, patient demographics/characteristics, type of intervention and outcomes of care. Data extraction was performed in two stages, a pilot stage followed by a proper stage. The pilot stage consisted of having multiple authors, each going through the same 10 selected articles to extract data. This was to ensure that all participant authors were able to extract data accurately for a swift data analysis stage. It was also important to pilot this stage to ensure the data collection sheet was reflective of the included studies.

Data Analysis

Extracted data was analysed by SPSS v.26 (IBM, USA). Pooled statistics were calculated using measures of central tendency and spread.

RESULTS

We identified 1,011 records: 950 (93.97%) via the database search and 61 (3.0%) *via* supplemental hand search. We excluded 743 articles (73.5%) at title and abstract screening, and 193 (19.1%) at full text screening. Seventy-five articles (7.4%) were eligible for inclusion (**Figure 1**).

Thirty-three studies (44.0%) reported on the management and outcomes of paediatric suppurations in India. The 2000–2009 decade saw the highest number of publications (n = 33, 44.0%) and the majority of studies were case reports (n = 40, 53.3%) (**Table 1**). The study populations consisted of 18.8 (95% CI = 8.4–29.1) children on average. The children were 8.2 (95% CI = 6.5–10.0) years old and most were male (mean = 11.7, 62.2%, 95% CI = 28.7–95.7%).

The majority of cases were intraparenchymal abscess. Intracranial suppurations were located in supratentorial intra-axial (46.5%, 95% CI = 43.7–49.3%), subdural (25.9%, 95% CI = 23.5–28.3%), infratentorial intra-axial (22.3%, 95% CI = 20.0–24.6%), and epidural (1.0%, 95% CI = 0.4–1.5%) spaces. **Figure 2** shows the distribution of intracranial suppurations by location within the brain.

The most prevalent causative mechanism was otitis (37.4%, 95% CI = 34.7–40.1%), followed by heart defects (14.8%, 95% CI = 12.8–16.7%) (**Figure 3**).

Streptococcus species were the most common causative organisms (19.4%, 95% CI = 17.2–21.6%) and 12.8% (95% CI = 10.9–14.6%) of cultures were negative. 5.5% (4.2–6.7%) of intracranial suppurations were polymicrobial (**Table 2**). Data on the specific causative organisms responsible for 58 cases of subdural empyema and one case of epidural abscess was available (**Appendix S1**).

The results show that computed tomography (CT) scan (71.2%, 95% CI = 68.7–73.7%) was more commonly used than magnetic resonance imaging (MRI) (8.9%, 95% CI = 7.3–10.5%). Antibiotics were the most common treatment offered (100%), followed by burr hole aspiration (47.4%, 95% CI = 44.6–50.1%). The most common antibiotics used were metronidazole (23.6%) and cephalosporins (20.4%) across all types of suppurations. For subdural suppurations, a greater number of cases were surgically managed *via* a burr hole (n = 71) than a craniotomy (n = 50). The study also reports a mortality rate of 11.0% (95% CI = 9.3–12.8%) (**Table 3**).

TABLE 1 | Characteristics of the 75 studies included in the review.

Characteristic	Frequency (percentage)
Study setting	
India	33 (44.0)
Pakistan	7 (9.3)
Malaysia	6 (8.0)
Iran	5 (6.7)
Nigeria	4 (5.3)
Turkey	4 (5.3)
Thailand	2 (2.7)
Benin	1 (1.3)
Brazil	1 (1.3)
Cameroon	1 (1.3)
China	1 (1.3)
Egypt	1 (1.3)
Gabon	1 (1.3)
Indonesia	1 (1.3)
Malawi	1 (1.3)
Nepal	1 (1.3)
Senegal	1 (1.3)
South Africa	1 (1.3)
South Korea	1 (1.3)
Tunisia	1 (1.3)
Zambia	1 (1.3)
Year of publication	
1970–1979	2 (2.7)
1980–1989	2 (2.7)
1990–1999	6 (8.0)
2000–2009	33 (44.0)
2010–2019	27 (36.0)
2020	1 (1.3)
Study design	
Case report	40 (53.3)
Cross-sectional	18 (24.0)
Case series	9 (12.0)
Cohort	7 (9.3)
Letter to the editor	1 (1.3)

DISCUSSION

Key Findings

This scoping review is the first to describe the epidemiology, management, and outcomes of paediatric intracranial suppurations across LMICs. The average age of the included children were 8.2 years, with a male predominance. Most of the intracranial suppurations had a supratentorial intra-axial location with the most prevalent causative mechanism

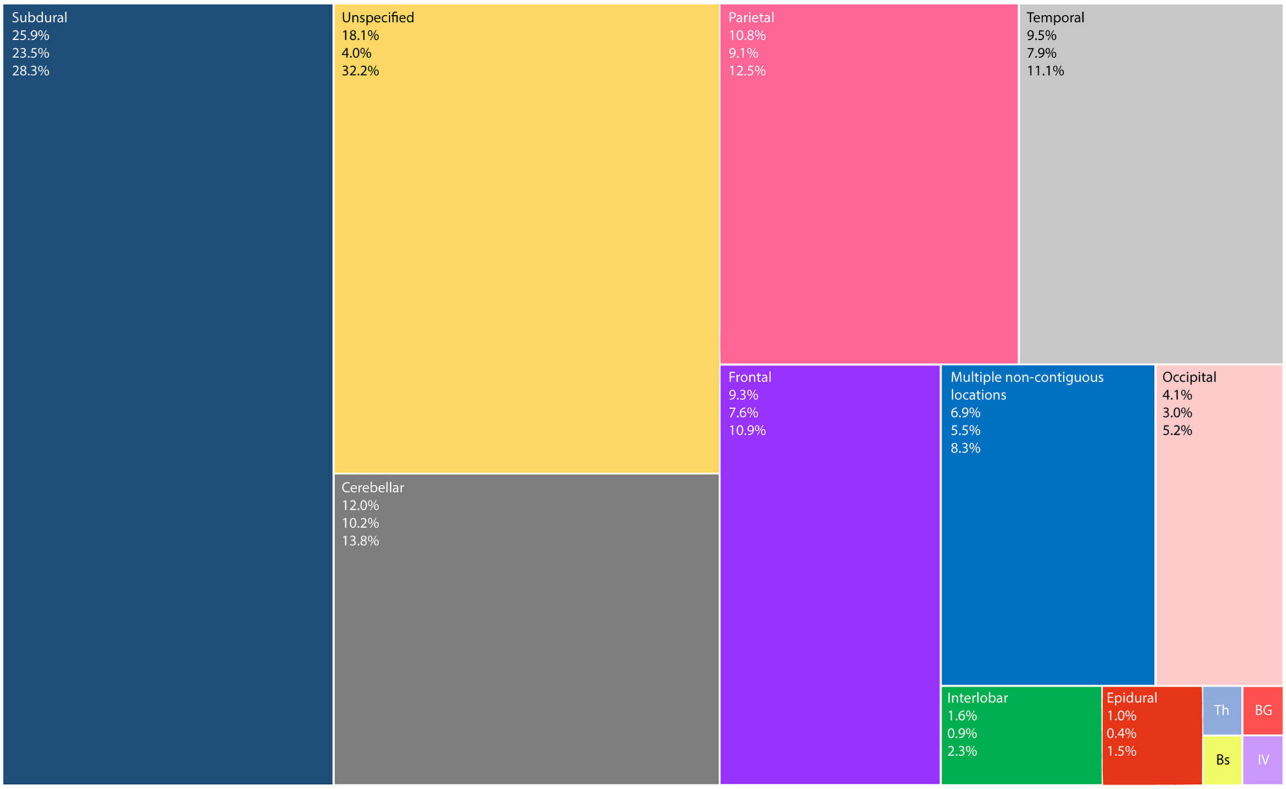

FIGURE 2 | TreeMap showing the distribution of intracranial suppurations (words at the top left corner), their mean percentage (first number), lower and upper limits of the 95% confidence interval (second and third numbers, respectively). Th—Thalamic 0.2% (95% CI = 0.0 to 0.5%); BG—Basal Ganglia 0.2% (95% CI = −0.1 to 0.4%); Bs—Brainstem 0.2% (95% CI = −0.1 to 0.4%); and IV—Intraventricular 0.2% (95%CI = −0.1 to 0.4%). Unspecified corresponds to supratentorial intra-axial lesions, whose locations were not further clarified.

being otitis. Streptococcus species were the most common causative organisms isolated on positive cultures, however, a few positive cultures yielded polymicrobial growths. CT scan was the neuroimaging technique for diagnosis and follow-up in the majority of studies. All patients received antibiotics. Where surgical management was required, the most common approach used was burr hole aspiration, followed by craniotomy. Resolution of symptoms was the most frequent outcome pattern after treatment; however, there was a considerable rate of readmission and a low but significant mortality rate.

Implications

The pattern of location of intracranial suppurations across LMICs found in this review is similar to reports from single countries (18, 19), suggesting that our scoping review is representative of the international picture and has not been biased by reports from single centres or articles focusing on a particular location of intracranial suppurations. However, otitis followed by heart defects were the most common predisposing factor in our study. This is contradictory to a national report of intracranial suppurations conducted by Ozsurekci et al. in 2012 in Turkey, who reported congenital cyanotic heart disease to be the most common predisposing factor (33.3%) with otogenic infections and meningitis accounting for just 16 and 8% respectively (19). This can be attributed to the introduction of the pneumococcal vaccine into the Turkish national immunisation schedule in 2008 and highlights a potential public health intervention that other LMICs may emulate to decrease the incidence of otogenic infections and intracranial suppurations in their country (19, 20). As of 2016, 59 countries did not have the pneumococcal vaccine in their childhood immunisation schemes. Access to vaccines in most LMICs has been limited by cost but this challenge has been addressed by GAVI, the Vaccine Alliance which has sponsored the pneumococcal vaccine in 54 countries (21, 22). Given otitis has been identified to be the most prevalent predisposing factor to intracranial suppurations across LMICs, it may also be possible to reduce intracranial suppurations by promptly treating otitis with effective antibiotics. However, clinicians should also be mindful to assess the efficacy of the antibiotic in treating otitis to prevent antibiotic overuse (23). It is currently best practice in the treatment of otitis for a clinician to reassess the patient 72 h after initiation of treatment to note any progress and if there is no significant improvement to change the antibiotic treatment (24).

An important finding is that despite MRI with contrast being the gold standard imaging technique in diagnosing and managing intracranial suppurations (12), CT scan was the neuroimaging technique used in 72.9% of cases. This is possibly

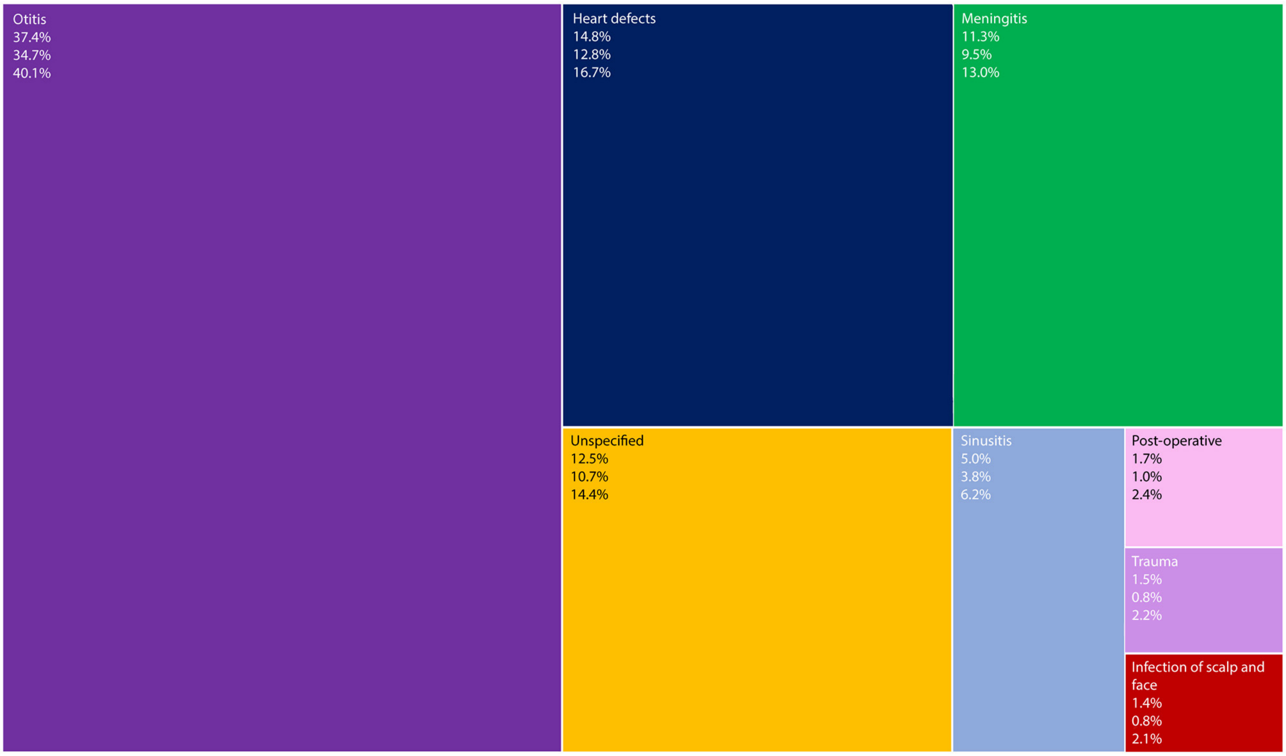

FIGURE 3 | TreeMap showing causative mechanisms of intracranial suppurations (words at the top left corner), their mean percentage (first number), lower and upper limits of the 95% confidence interval (second and third numbers, respectively).

due to reduced access to MRI neuroimaging in LMICs (11). All patients in our study received a course of antibiotic therapy, which is a positive sign for the movements that have cited the importance of access to antibiotics globally (25). However, it was unclear from the included texts whether the most appropriate antibiotics were being used in each case. A minority of cases did not have any surgical management. This may be because surgical management was not needed, due to limited access to neurosurgical centres, difficulty in surgical drainage for certain intracranial suppurations and/or lack of aseptic equipment in certain LMIC centres. There is a disparity between LMICs and HICs in terms of the surgical technique utilised: our findings suggest that LMICs primarily used burr hole aspiration, whilst existing reports from HICs suggest craniotomies have a greater prevalence (18). The lack of craniotomies conducted in LMICs may be accounted for by several reasons: (i) the difficulties in maintaining the higher levels of sterilisation required for that procedure in resource-limited environments (26); (ii) the longer operating times and higher re-operating rates typically associated with craniotomies (27); (iii) the higher perceived costs of craniotomies; and (iv) the difficulties in following up a patient after discharge. Given the lack of data around this topic, it is pertinent that a study is conducted to identify the relevant factors that influence the surgeons' decision to conduct a burr hole or a craniotomy in LMICs. The lack of access to gold-standard diagnostic tools and management may explain the high rate of mortality of intracranial suppurations in LMICs (11.0%), with similar studies in HICs reporting mortality rates of 3.2% (28).

Receiving adequate treatment at a facility is unlikely to be the only factor behind the overwhelming difference in mortality rates between LMICs and HICs with the "Three Delays Model" (29) also citing delays in (i) seeking neurosurgical care, and (ii) identifying and reaching an appropriate neurosurgical facility as further compounding issues. The lengths of these delays may be a product of socioeconomic and cultural factors, accessibility of neurosurgical facilities and the availability of treatment. A poor patient outcome is highly likely if any of these factors lead to the delay. However, various strategies have been established to tackle these delays in LMICs (29). In the context of our review, education and employment of parents are crucial (29–31). Educating the public on the importance of recognising the signs and symptoms and the repercussions of inaction or delayed action will be a key step to address the first delay. Employment plays a key role in addressing the first and second delays as the lack of financial means may influence: (i) the urgency to seek care due to concerns of insurance and health costs and (ii) the mobility of the parent and child as this is reliant on the mode of transport the family uses. The second and third delays can be tackled through the role of local governments and stakeholders. Providing affordable and accessible public transport and building safe roads to hospitals and clinics would be recommended as means to approach the issues of the second delay. As for the third

TABLE 2 | Causative organisms of intracranial suppurations.

Organisms	Percentage	Lower limit 95% confidence interval	Upper limit 95% confidence interval
Streptococcus species	19.4%	17.2%	21.6%
Negative culture	13.1%	11.2%	15.0%
Polymicrobial	5.5%	4.2%	6.8%
Staphylococcus species	5.4%	4.2%	6.7%
Proteus species	4.9%	3.7%	6.1%
Haemophilus influenza	2.6%	1.7%	3.5%
Pseudomonas species	2.6%	1.7%	3.4%
Escherichia coli	1.5%	0.8%	2.2%
Bacteroides species	1.4%	0.8%	2.1%
Unspecified anaerobes	1.4%	0.8%	2.1%
Salmonella	1.4%	0.8%	2.1%
Klebsiella species	1.2%	0.6%	1.8%
Bacillus cereus	0.6%	0.1%	1.0%
Mycobacterium tuberculosis	0.5%	0.1%	0.9%
Citrobacter	0.5%	0.1%	0.9%
Peptostreptococci species	0.4%	0.0%	0.7%
Enterococcus	0.4%	0.0%	0.7%
Enterobacter species	0.3%	0.0%	0.6%
Providentia species	0.2%	0.0%	0.5%
Ps. Pyocyaneus	0.2%	−0.1%	0.4%
Morganella morgagni	0.1%	−0.1%	0.2%
Eikenella	0.1%	−0.1%	0.2%
Plasmodium falciparum	0.1%	−0.1%	0.2%
Mycobacterium fortuitum	0.1%	−0.1%	0.2%
Cladosporium bantianum	0.1%	−0.1%	0.2%
Haemophilus aphrophilus	0.1%	−0.1%	0.2%

TABLE 3 | Management and outcomes of intracranial suppurations.

Management and outcomes	Percentage	Lower limit 95% confidence interval	Upper limit 95% confidence interval
Neuroimaging			
CT scan	71.2%	68.7%	73.7%
MRI	8.9%	7.3%	10.5%
Treatment			
Antibiotics	100%		
Burr hole aspiration	47.1%	44.3%	49.9%
Craniotomy	34.7%	32.1%	37.3%
Insertion of drain	10.3%	8.6%	12.0%
Mastoidectomy	5.5%	4.2%	6.8%
Subdural paracentesis	1.5%	0.8%	2.2%
Shunt	1.2%	0.5%	1.8%
Bone flap removal	0.1%	−0.1%	0.2%
Craniectomy	0.1%	−0.1%	0.2%
Outcomes			
Neuro-intensive care admission rate	3.3%	2.4%	4.3%
Symptoms resolved	23.7%	21.3%	26.0%
Symptoms improved	15.3%	13.3%	17.3%
Symptoms unchanged	2.2%	1.4%	3.1%
Symptoms worsened	4.7%	3.5%	5.9%
Mortality rate	11.0%	9.3%	12.8%
Readmission rate	18.8%	16.7%	21.0%

delay, the standardisation of training programmes, organisation of visitor teaching programmes, and expansion of recruitment of healthcare professional recruitment may resolve issues such as variability in practice, lack of competence in the management of the disease and shortage of staff.

Another important implication for LMIC healthcare systems is that more than 1 in 20 intracranial suppurations were found to be caused by polymicrobial infections. Polymicrobial infections increase the cost of management, placing an additional burden on resource-limited settings (32). These infections have been found to lead to a longer length of stay in hospitals, prolonged intravenous antibiotic administration (33), the use of more costly antibiotics (32, 34, 35), and a wide variety of complications and sequelae (36). Given its prevalence, clinicians should consider the use of broad-spectrum antibiotics early in the management course as a strategy to prevent potential complications due to polymicrobial infections; albeit being cautious of *Clostridium difficile* infection.

Limitations

Whilst a scoping review is purposefully extensive in breadth, the inclusion of multiple heterogenous evidence sources limits the comparisons that can be made between studies. Specifically, different methodological approaches were used across the studies, with a lack of uniformity in outcome reporting. Conclusions that can be drawn from this review are limited by the quality of evidence in the available literature; the majority of included articles were case reports, with few cohort studies, and no randomised controlled trials. Our review was also limited to articles in English and French, and so failed to capture data from any studies published in alternative languages. Whilst English is the most common language of publication for medical journal articles (37), this is not universal, especially in LMICs. Furthermore, a number of studies were excluded on the basis of the lack a separate analysis for paediatric and adult populations. Whilst adherence to strict exclusion criteria was necessary to maintain the relevance of data, it may have led to the omission of useful information. Despite these limitations, our study provides a plethora of novel and useful information that can guide relevant stakeholders as to which areas need to be tackled to reduce the burden of intracranial suppurations.

There is an urgent need for a multisectoral and multidimensional approach to effectively curb the burden of paediatric intracranial suppurations in LMICs (38). Stakeholders involved in reducing health inequalities and ameliorating the well-being of populations are vital for this mission (39). This mission falls in line with the sustainable development goals number 1, 3, 4 and 10, which are no poverty, good health and well-being, quality education and reduced inequalities, respectively (40). Tackling poverty is particularly key, as poverty promotes poor health practices, and inadequate health infrastructures promote factors leading to paediatric intracranial suppurations (41). Moreover, paediatric intracranial suppurations can keep patients away from school, which may lead to poor quality of education in this age group. Therefore, there are multiple reasons a well-coordinated action of all stakeholders is necessary to reduce the burden of paediatric intracranial suppurations (42, 43). Reducing inequalities will permit patients in LMICs to receive the appropriate care required (44).

CONCLUSION

This scoping review provides an overview of the management and outcome of paediatric intracranial suppurations in LMICs. The intracranial distribution of suppurations matched prior literature, as did the predominance of *Streptococcus* species as the causative organism. CT was commonly used, but the use of the gold standard diagnostic imaging modality (MRI) was limited. As MRI scans are better than CT scans at diagnosing suppurations, the choice of investigations may have delayed diagnosis. We also found that burr holes are more commonly used compared to craniotomies. As craniotomies have reduced rates of reoperations and are more likely to definitively clear the intracranial suppuration, the surgical management choice may have delayed definitive treatment. Moreover, whilst all studies reported management with antibiotic therapy, surgical management was less prevalent than in prior literature. Delays of diagnosis and definitive treatment are known to increase morbidity and mortality rates; this may explain the 1 in 10 patients in our review who died, which is higher than reported in studies of populations in HICs, highlighting the necessity for improvements in care.

However, solving these issues may go beyond acquiring MRIs and encouraging surgeons to perform craniotomies. MRIs are expensive to maintain and may not be economically feasible to have. Craniotomies have increased infection risk and the lack of sterile fields may increase the rate of infections. Therefore, stakeholders in surgical care and the health of underserved populations should focus on tackling this area through strategies such as national vaccination programmes or the development of cheap sterile gowns. Lastly, as otitis is the most prevalent causative mechanism, early treatment with appropriate analgesia would be recommended as a preventative measure to developing intracranial suppurations. Timely interventions as such would cost less and lead to better patient outcomes than treating intracranial suppurations itself.

Future published literature regarding intracranial suppurations in LMICs should be encouraged to provide the anonymised dataset from which their data is based. Having access to this data would enable valuable disaggregated information, such as the management of different types of suppurations, to be extracted and combined with other studies focusing on the same research topics.

AUTHOR CONTRIBUTIONS

SO: conception, design, data extraction, data analysis, data curation, writing, reviewing and editing, and project administration. DS: conception, design, data extraction, writing, reviewing and editing, visual abstract. DD, BT, and GH: data extraction and writing. YD, SC, NB, and JK were involved in data extraction. AE: design, data extraction, writing, reviewing and editing. SN, YZ, and RK: writing. SB: conception, design, data extraction, writing, reviewing and editing. UK: conception, design, data analysis, writing, reviewing and editing. All authors contributed to the article and approved the submitted version.

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APPENDIX S1

Microorganism	Subdural empyema	Epidural abscess
Escherichia coli	4	1
Haemophilus influenzae	13	0
Pseudomonas species	5	0
Staphylococcus species	6	0
Streptococcus species	15	0
Klebsiella species	2	0
Anaerobes	3	0
Bacillus cereus	1	0
Plasmodium falciparum	1	0
Mycobacterium tuberculosis	1	0
Mycobacterium fortuitum	1	0
Ps. Pyocyaneus	2	0
Salmonella	1	0
Polymicrobial	3	0

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Severe Pediatric TBI Management in a Middle-Income Country and a High-Income Country: A Comparative Assessment of Two Centers

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Background: Traumatic brain injury (TBI) is a global public health issue with over 10 million deaths or hospitalizations each year. However, access to specialized care is dependent on institutional resources and public health policy. Phoenix Children's Hospital USA (PCH) and the Neiva University Hospital, Colombia (NUH) compared the management and outcomes of pediatric patients with severe TBI over 5 years to establish differences between outcomes of patients managed in countries of varying resources availability.

Methods: We conducted a retrospective review of individuals between 0 and 17 years of age, with a diagnosis of severe TBI and admitted to PCH and NUH between 2010 and 2015. Data collected included Glasgow coma scores, intensive care unit monitoring, and Glasgow outcome scores. Pearson Chi-square, Fisher exact, *T*-test, or Wilcoxon-rank sum test was used to compare outcomes.

Results: One hundred and one subjects met the inclusion criteria. NUH employed intracranial pressure monitoring less frequently than PCH ($p = 0.000$), but surgical decompression and subdural evacuation were higher at PCH ($p = 0.031$ and $p = 0.003$). Mortality rates were similar between the institutions (15% PCH, 17% NUH) as were functional outcomes (52% PCH, 54% NUH).

Conclusions: Differences between centers included time to specialized care and utilization of monitoring. No significant differences were evidenced in survival and the overall functional outcomes.

Keywords: traumatic brain injury, pediatric neurosurgery, global health, TBI, pediatric

INTRODUCTION

Traumatic brain injury (TBI) is an etiologically heterogeneous condition that represents a global public health issue with significant socioeconomic impact (1). According to the School of Public Health at Harvard, 57 million people have sought care for TBI at some point in their lives, and at least ten million of those events have been severe enough to result in death or require hospitalization (2). In the United States, pediatric TBI alone is estimated to have caused ∼1,484 deaths; 17,930 hospitalizations; and 641,935 emergency department visits in 2013 (3). While epidemiological data on pediatric TBI in Latin America is limited, it is known that TBI-associated death rates are more than 75 per 100,000 in the continent, and these ascend to 125 per 100,000 in Colombia (4). TBI is the leading cause of death in children in Medellin, a major city in Colombia (5).

Guidelines for the acute medical management of severe TBI in infants, children, and adolescents were initially published in 2003 and most recently revised in 2012 by the Brain Trauma Foundation (6, 7). These guidelines provide information about intracranial pressure, perfusion, and oxygenation monitoring as well as recommendations for their management. The guidelines also address the use of imaging, seizure prophylaxis and management, sedation, pain management, temperature control, nutrition, and surgical intervention. Despite the beneficial effects of adherence to standardized approaches (8–13), there are a multitude of factors that may prevent clinicians or institutions from adhering to such guidelines. The evidence level of the proposed interventions, hospital infrastructure, and policy, provider training, staffing adequacy, equipment availability, and consumable supplies have previously been identified as some of those factors (14, 15).

Phoenix Children's Hospital (PCH) is a pediatric hospital ranked among the best in the United States for neurology and neurosurgery (16), and the Neiva University Hospital (NUH) is a tertiary care hospital and Level I trauma center in Neiva, Colombia (17). While both institutions are located in urban areas, one is in a high-income country and the other at a middle-income country (18). This is a socioeconomic factor that has shown to affect adherence to evidence-based care and effective decision-making, especially due to differences in resources (19). NUH is a public hospital with an important burden of general adult and pediatric patients coming from urban-rural areas of southern Colombia. Resources are limited, especially related to neuromonitoring devices and some medications that can be considered expensive. PCH is one of the largest private pediatric centers in the western region of the United States and has easy access to a variety of advanced resources for the care of pediatric patients. In this study, we compared the characteristics, management, and outcomes of children with severe TBI, admitted to PCH and NUH. Prehospital care systems in Phoenix are different than in Neiva due to less advanced resources for care during transport in the Colombian city. Emergency care and surgical care wards are similar with some variations in resource availability. Intensive care units (ICU) at PCH have more neuromonitoring resources than in NUH. We hypothesized that mortality could be larger in NUH when compared with the mortality at PCH.

METHODS

Our team performed a retrospective chart review of patients ages between 0 and 17 years, who presented to PCH, USA, and the NUH, Colombia with a diagnosis of severe TBI between July 1, 2010 and July 31, 2015. Records of patients with severe TBI were considered for analysis. For the purpose of this review, severe TBI is defined as a reported or evidential mechanical insult to the brain where the patient presents with Glasgow coma score (GCS) of 8 or less at admission or with GCS of 9 to 12 at admission, but with rapid deterioration within the first 24 h to GCS of 8 or less in the absence of underlying conditions that may influence their neurological function.

Collected data included demographic characteristics of the patients, information about the injury event, prehospital and hospital management, and imaging findings and discharge status. Record selection and data extraction were performed simultaneously. At PCH, case identification was accomplished by querying the electronic medical records system for diagnostic codes corresponding to TBI and subsequent exploration of ancillary database systems from the emergency department, surgery, anesthesia, and the ICU. The NUH research team identified subjects by searching the electronic medical record of the hospital pediatric ICU for diagnostic codes corresponding to TBI. Subjects were then screened for eligibility, and their information was extracted by medical students utilizing a data collection form.

Identifying information about patients was removed from both datasets and compiled for analysis after data extraction was completed. Data analysis was performed by the PCH group using IBM SPSS Statistics software (Chicago, IL). A descriptive analysis was performed to visualize population and site characteristics. Pearson Chi-square, Fisher exact, *T*-test, Kruskal–Wallis, or Wilcoxon-rank sum test was used to compare interinstitutional patient characteristics, management, and outcomes. Univariate linear regression was used to assess potential associations between associated injuries and radiological findings and hospital outcomes.

TABLE 1 | Cause and type of injuries.

Cause of injury	PCH *n* (%)	NUH *n* (%)
Accidental falls	21 (31.8)	6 (17.1)
Assault	6 (9.1)	2 (5.7)
Motor vehicle accident	34 (51.5)	24 (68.6)
Self-inflicted	3 (4.5)	0 (0.0)
Other	2 (3.0)	3 (8.6)
Type of injury		
Closed	62 (93.9)	30 (85.7)
Penetrating	3 (4.5)	4 (11.4)
Crush	1 (1.5)	1 (2.9)

TABLE 2 | Time from injury to arrival by patient origin.

Patient origin	PCH (h:m)	NUH (h:m)
Scene	1:45	3:52
Home	2:30	6:20
Other hospital	1:18	6:53
Total	1:51	5:31

TABLE 3 | Number of additional non-TBI injuries.

Number	PCH *n* (%)	NUH *n* (%)
None	21 (32)	2 (7)
1	14 (21)	15 (56)
2	11 (17)	6 (22)
3	20 (30)	4 (15)

RESULTS

Sixty-six patients (34 males, 32 females) from PCH and 35 patients (24 male, 11 female) from NUH met the criteria for inclusion in the study. The mean age at PCH and Neiva was 7.7 and 6.6 years, respectively. GCS at presentation was similar between the groups (PCH 5.42 and NUH 5.46). Motor vehicle accidents were the primary cause of injury at both institutions (PCH 51.5% and NUH 68.6%) (**Table 1**). Most patients were transferred from the scene of the injury or home to PCH (68.0%). Transfers from a different hospital were the most common source for patients receiving care at NUH (80%). Subsequently, the overall time from injury to arrival at the treating hospital was significantly longer at NUH (NUH 5 h and 31 min, PCH 1 h and 51 min, $p = 0.025$) (**Table 2**). Most patients received advance life support before their arrival to the respective treatment centers. Both resuscitation efforts and ventilatory support were more commonly provided at NUH [NUH 46 (97%), PCH 9 (68%), respectively].

Traumatic brain injury was often associated with injuries to other anatomical locations (NUH 93%, PCH 68%; **Table 3**). The most affected areas were upper and lower extremities (NUH 37%, PCH 42%), face (NUH 34%, PCH 15%), and thorax (NUH 17%, PCH 18%). No association was observed between the number or type of associated injuries and hospital outcomes, and hospital and length of stay in the ICU. The lack of association was independent of location (PCH, NUH). Computer tomography (CT) was performed at admission in all patients from both institutions. Skull fractures were the most common findings among patients from both locations, followed by subdural hematomas and contusions at PCH and by diffuse axonal injury and midline shift at NUH. Notable differences were observed in the reported incidence of subdural hematomas and diffuse axonal injuries (**Table 4**). An association was observed between the imaging presence of subarachnoid hemorrhages, intraparenchymal hemorrhages, and midline with the length of the hospital stay of the patients ($p = 0.02$, 0.02, and 0.43, respectively).

TABLE 4 | CT findings.

CT finding	PCH *n* (%)	NUH *n* (%)	Significance
Skull fracture	43 (65)	26 (74)	0.24
Subdural hematoma	36 (55)	4 (11)	<0.01
Contusion	34(51)	9(26)	0.01
Sub-arachnoid hemorrhage	28 (42)	7 (20)	0.02
Cisterns partial or full collapse	27(41)	4(11)	<0.01
Intra-parenchymal hematoma	22 (33)	5 (14)	0.03
Midline shift	20 (30)	10 (29)	0.52
Intra-ventricular hemorrhage	13 (20)	0 (0)	<0.01
Diffuse axonal injury	10 (15)	16 (46)	<0.01
Epidural hematoma	7(11)	8(23)	0.09

TABLE 5 | Invasive monitoring and ICP management.

Monitoring modalities	PCH *n* (%)	NUH *n* (%)
Intracranial pressure	45 (68)	5 (14)
Tissular oxygen pressure	16 (24)	0 (0)
Intraparenchymal temperature	13 (20)	0 (0)
Pharmacologic		
Hypertonic saline + Mannitol	13 (20)	18 (51)
Hypertonic saline	19 (29)	10 (26)
Mannitol	14 (21)	5 (14)
Surgical		
EVD placement	37 (56)	0 (0)
Decompressive craniectomy	21 (32)	3 (9)
Unilateral	17 (26)	2 (6)
Bifrontal	4 (6)	1 (3)

Intracranial pressure (ICP) monitoring was used more often at PCH (PCH 68.0%, NUH 14.0%). This trend was also observed with other invasive monitoring modalities such as intraparenchymal temperature and brain tissue partial pressure neuromonitoring. NUH favored pharmacological management for ICP control (NUH 94%, PCH 70%), whereas PCH opted for surgical management through external ventricular drain (EVD) placement and decompressive craniectomy (**Table 5**). Drainage of intracranial fluid collections (epidural, subdural, and intraparenchymal) was performed at a higher rate at PCH (PCH 32%, NUH 11%).

Seizure prophylaxis was widely used in both institutions, but the medications utilized varied widely. At PCH, either fosphenytoin or levetiracetam was used in 74% of the patients, either as monotherapy or in combination. At NUH, phenytoin was used almost exclusively (86%). Seizure reporting in the early ($\leq$7 days) and late ($>$7 days) periods was similar for both institutions. PCH reported early seizures in 29.0% of patients and late seizures in 6.0%, whereas NUH saw a rate of 26.0 and 6.0%, respectively. Levetiracetam was the medication of choice for seizure management at PCH, and it was used as monotherapy in 63.0% of the patients who developed seizure activity and in combination with fosphenytoin in 10% of the

TABLE 6 | Functional and institutional outcomes.

Length of stay (days)	PCH μ (SD)	NUH μ (SD)	Significance
Hospital	33 (44)	28 (34)	0.32*
Intensive care unit	12 (13)	13 (25)	0.09*
Glasgow outcome scale	**PCH *n* (%)**	**NUH *n* (%)**	**Significance**
1. Death	10 (15)	6 (19)	0.26‡
2. Persistent vegetative state	3 (5)	0 (0)	
3. Severe disability	18 (28)	7 (22)	
4. Moderate disability	16 (25)	4 (12)	
5. Low disability	18 (28)	15 (47)	
Outcome categories			
Dead	10 (16)	6 (19)	0.56‡
Severe disability	21 (32)	7 (22)	
Low disability	34 (52)	19 (59)	

**P-value from Kruskal-Wallis test.*
‡P-value from Fisher-exact test.

cases. Fosphenytoin and phenobarbital were periodically used as monotherapy. Carbamazepine, phenytoin, and valproic acid were equally used for seizure management at NUH.

While the length of stay varied widely within institutions, no significant differences were observed between the mean length of stay at the hospital or in the ICU. Functional outcomes were assessed using the Glasgow outcome scale (GOS), and despite evidencing disparity in absolute numbers and distribution, the difference failed to attain statistical significance. Outcomes were further grouped as dead, severely disabled, or with low disability. This simplified outcome scale was chosen to limit the potential inaccuracies of excessive stratification; yet the overall behavior of the sample remained similar and no statistical difference was observed (**Table 6**).

DISCUSSION

The results of this comparison reveal the experiences of two different institutions at managing severe pediatric TBI in populations that were demonstrated to be homogeneous in age, gender, and injury severity. Considering the geographic location of these institutions, one at a high income, developed country and the other one at a middle income, developing county, assumptions can be drawn about resource availability and access to care. Despite motor vehicle accidents being the most common mechanism of injury in both populations, transport from the scene to the treating hospital was predominant among patients treated at PCH. Transport from the scene to the treating hospital was seen in only 20% of the cases treated at NUH. This difference would likely explain the longer mean time from injury to arrival at the treatment facility observed among the NUH cohort. However, this delay in access to specialized care does not necessarily translate into treatment delay considering that most patients treated at NUH were transferred from other hospitals, and advance life support measures were in place upon arrival more often than at PCH. Pre-hospital care has previously been considered as a potential confounder of clinical outcomes in studies comparing TBI management between developed and developing countries. Gupta et al. found similar transport times between a hospital in New Delhi and a hospital in Seattle, but because of similar limitations as the ones in our study, a direct relationship between pre-hospital care and outcomes was not drawn (20).

The presence of associated injuries in locations other than the head was more often seen in the NUH cohort. However, neither the presence of injuries at specific locations nor the number of areas compromised demonstrated to have any impact on hospital or ICU length of stay. Skull fractures were the most common imaging finding, and no difference was observed in the frequency at which it was reported between cohorts. With the exemption of diffuse axonal injury and epidural hematomas, most radiological findings were most reported among the PCH cohort. Whether this difference is due to the absence of findings, the quality of the scan, or the reporting practices at each institution warrants further exploration.

Significant differences were observed in invasive monitoring and ICP management. Patients at NUH were treated more conservatively with minimal use of invasive monitoring and predominance of pharmacologic management. In contrast, PCH frequently employed invasive monitoring for ICP and used other invasive monitoring modalities in the most severe cases. EVD placement and cranial decompression were used more often, while pharmaceutical ICP management was used less often.

Seizure prophylaxis was widely used in both institutions. There was substantial variability in the medications used between institutions, but the incidence of seizure was vastly the same among cohorts.

No significant differences were observed on any of the variables selected as outcomes. Length of stay remained within 10% of the overall mean for hospital and ICU stay at both institutions. NUH patients displayed a higher mortality rate, but the mortality rates observed at both institutions seemed to be at the lower end of those reported in similar populations (21). Survivors from the NUH group also presented lower disability in GOS at discharge than patients at PCH. However, neither of these differences attained statistical significance and became more homogeneous when grouped as either dead, having a severe disability, or a mild disability.

The institutions selected for the comparison were intended to provide a surrogate view of the countries they belong to and their socio-economic environments. While institutional policies are usually a significant driver for care, management characteristics can indicate resource availability and utilization. Thus, the increased use of invasive monitoring and management at PCH is suggestive of higher resource utilization when compared to NUH. Interestingly and contrary to previously described by other authors, neither advance monitoring nor early decompression surgery seemed to have an effect in mortality rates or short-term neurological outcomes (22).

Limitations of this study begin with its methodology as a retrospective chart review. Thus, the study lacks the accuracy and reliability a prospective cohort study would offer. As a result, the study is inherently limited by coding mechanisms, record completeness, and information availability.

Furthermore, the relatively small sample size may have affected the lack of statistical significance in the heterogeneous areas contributing to the mortality rate that we hypothesized would be statistically significant.

CONCLUSION

Despite the heterogeneous character of severe TBI and differences in the time from injury to specialized treatment, radiologic findings, monitoring, and surgical management, we found no significant differences in functional or hospital outcomes between two similar pediatric cohorts of patients treated for severe TBI at PCH, in a high-income country, and NUH, in a middle-income country. However, given the retrospective character and the relatively small sample size of our study, we call for cautiousness when interpreting our results and rather move the focus toward the disparities in clinical resources between developing countries and developed countries in which most TBI research is conducted and guidelines are written, and highlight the need for resource consideration when disseminating practice guidelines.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Global Surgery Indicators and Pediatric Hydrocephalus: A Multicenter Cross-Country Comparative Study Building the Case for Health System Strengthening

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Objective: The aim of this study is to compare specific three-institution, cross-country data that are relevant to the Global Surgery indicators and the functioning of health systems.

Methods: We retrospectively reviewed the clinical and socioeconomic characteristics of pediatric patients who underwent cerebrospinal fluid (CSF) diversion surgery for hydrocephalus in three different centers: the University of Tsukuba Hospital in Ibaraki, Japan (HIC), the Jose R. Reyes Memorial Medical Center in Manila, Philippines [low-to-middle-income country (LMIC)], and the Federal Neurosurgical Center in Novosibirsk, Russia (UMIC). The outcomes of interest were the timing of CSF diversion surgery and mortality. Statistical tests included descriptive statistics, Cox proportional hazards model, and logistic regression. Nation-level data were also obtained to provide the relevant socioeconomic contexts in discussing the results.

Results: In total, 159 children were included, where 13 are from Japan, 99 are from the Philippines, and 47 are from the Russian Federation. The median time to surgery at the specific neurosurgical centers was 6 days in the Philippines and 1 day in both Japan and Russia. For the cohort from the Philippines, non-poor patients were more likely to receive CSF diversion surgery at an earlier time (HR = 4.74, 95% CI 2.34–9.61, $p <$ 0.001). In the same center, those with infantile or posthemorrhagic hydrocephalus (HR = 3.72, 95% CI 1.70–8.15, $p = 0.001$) were more likely to receive CSF diversion earlier compared to those with congenital hydrocephalus, and those with postinfectious (HR = 0.39, 95% CI 0.22–0.70, $p = 0.002$) or myelomeningocele-associated hydrocephalus (HR = 0.46, 95% CI 0.22–0.95, $p = 0.037$) were less likely to undergo surgery at an earlier time. For Russia, older patients were more likely to receive or require early CSF diversion (HR = 1.07, 95% CI 1.01–1.14, $p = 0.035$). External ventricular drain (EVD) insertion was found to be associated with mortality (cOR 14.45, 95% CI 1.28–162.97, $p = 0.031$).

Conclusion: In this study, Filipino children underwent late time-interval of CSF diversion surgery and had mortality differences compared to their Japanese and Russian counterparts. These disparities may reflect on the functioning of the health systems of respective countries.

Keywords: health systems, global neurosurgery, pediatric hydrocephalus, Japan, Philippines, Russia

INTRODUCTION

The Global Surgery Indicators

The Global Surgery movement has ushered in an awareness of the existing inequities in surgical care the world over (1–4). A call was made for nation-level solutions in improving access to essential surgery, in order to ultimately achieve health, welfare, and economic development by the year 2030 (1). The Global Surgery indicators, with the corresponding working definitions and targets for countries, became the standardized metrics by which the extent of the problem in the healthcare system of a country can be defined and elucidated in relation to surgical processes and outcomes (5). These six core indicators are (1) access to timely essential surgery, (2) specialist surgical workforce density, (3) surgical volume, (4) perioperative mortality, and protection against (5) impoverishing and (6) catastrophic expenditures.

Outcome Disparities Borne From the Country of Origin and Social Determinants

Few studies have examined the association between patient-level socioeconomic factors and outcomes following treatment for pediatric hydrocephalus (6–8), and these studies are mostly situated in a single country. And yet, neurosurgical outcomes are also affected by systemic factors, particularly the availability or the absence of resources and investments within a health system. Cross-country disparities in patient outcomes are especially apparent in diseases like stroke and cancer (9, 10). The worse outcomes appear to be explained not only by patient factors but also by the perioperative care systems situated in a given hospital or country. The level of functionality of the health system of a country, which depends on the economic infrastructure (11), public policy (12, 13), responsive governance (14), and effective financing (15) arrangements, can, in turn, mitigate barriers and increase access to neurosurgical care. In this respect, the Global Surgery indicators can become useful in assessing and providing insight into the effectiveness and responsiveness of the surgical system in a neurosurgical center of a given country.

Surgery for Pediatric Hydrocephalus as Situated in Country Contexts

Low-to-middle-income countries (LMICs) have a disproportionately larger case volume of pediatric hydrocephalus than high-income countries (HICs), owing to differences in crude birth rate and incidence of congenital and postinfectious etiologies (11, 16). The greater burden of this disease in LMICs is further compounded by the fact that access to neurosurgical care and resources for health service delivery is limited (11). As cerebrospinal fluid (CSF) diversion surgery for hydrocephalus is considered a highly equitable and cost-effective bellwether procedure (17, 18), exploring the nation-level barriers to this kind of care can provide a snapshot of the functioning of the healthcare and surgical systems of a country, and give insight into the disparities in the outcomes of patients undergoing the procedure. Using the lens of nation-level social determinants of health and the framework of Global Surgery indicators, we aim to determine whether differences in outcomes exist between specific institutions and countries of varying income levels in relation to the neurosurgical management of all-cause pediatric hydrocephalus.

MATERIALS AND METHODS

Study Setting and Population

After approval by the institutional review boards from the three participating centers, we conducted a retrospective, cross-sectional study across countries of differing income levels. The study was conducted in three neurosurgical centers that are the hospitals of non-children: (1) the University of Tsukuba Hospital, in Tsukuba, Ibaraki, Japan, (2) Jose R. Reyes Memorial Medical Center, in Manila, Philippines, and (3) the Federal Center of Neurosurgery, Federal State Budget Institution, in Novosibirsk, Russian Federation. The population included in the study were pediatric patients admitted in a period between January 1, 2019, and December 31, 2019, at the three centers and who had either obstructive or communicating hydrocephalus with etiologies including the following but not limited to infantile-posthemorrhagic, post-infectious, congenital-structural, associated with or related to central nervous system tumors, or associated with neural tube defects like myelomeningocele. They should have undergone the minimum operation of CSF diversion, which were any one of the following: ventriculoperitoneal shunt (VPS) insertion with or without revisions, external ventricular drain (EVD) insertion, endoscopic third ventriculostomy (ETV), Ommaya reservoir insertion, or combinations thereof. Children with hydrocephalus but those who underwent another surgery without or other than CSF diversion were excluded.

Study Variables and Other Data

Patient-level variables consisted of clinical characteristics of individual patients collected from chart review. The outcome variables were patient-level covariates: (1) time from admission-to-surgery and (2) perioperative mortality, while the explanatory variables included patient age, sex, socioeconomic status, the type of hydrocephalus, the timing of CSF diversion, and the type of CSF diversion surgery. The time to CSF diversion surgery was the outcome of interest for cross-country comparison of institutions and was subdivided into descriptive categories based on the reasonable time frames of hydrocephalus management by Mansouri and colleagues (19). Nation-level data consisted of country-specific metrics of health-system functions based on Global Surgery indicators, as well as surrogate measures of the economy and growth. Secondary data from the World Bank (20), literature on global health (21–24), and other studies of the health systems of each country (25–27) were obtained for comparison. However, these nation-level data were not subjected to statistical analyses.

Statistical Analysis

Descriptive statistics was used to summarize the general and clinical characteristics of the participants. Frequency and proportion were used for categorical variables. The Shapiro–Wilk test was used to determine the normality distribution of continuous variables. Continuous quantitative data that did not meet the normality assumption of distribution were described using median and range. For the timing of CSF diversion surgery as a time-to-event variable, Cox proportional hazards model was used to plot the Kaplan–Meier curves. For perioperative mortality as a dichotomous variable, logistic regression was performed. The final results from regression were presented as hazard ratios and odds ratios with their associated confidence intervals. Missing data were neither replaced nor estimated. Null hypothesis was rejected at a 0.05α-level of significance. Stata 15.0 (StataCorp, College Station, TX, USA) was used for data analysis.

RESULTS

Clinical and Socioeconomic Characteristics

The medical records of 159 children, 99 (62%) from the Philippines, 47 (30%) from Russia, and 13 (8%) from Japan, were reviewed (**Table 1**). Their median age was 2.4 (range 0–17) years, with proportions of sexes roughly similar. Using the World Bank definition of poverty, whereby those living above US$3.10 per day are "non-poor," those living between $1.90 and $3.10 per day are "poor," and those living below $1.90 are "extremely poor," we found that most of the children in the Philippines belonged to poor households (77%), whereas 72 and 100% of the Russian and Japanese patients came from non-poor families, respectively. Almost 6 in 10 hydrocephalus cases in the Philippines were either post-infectious, congenital, or tumor-related. About 7 in 10 of those in Russia were infantile/post-hemorrhagic (49%) or tumor-related (21%). Two-thirds of the cases from Japan were congenital (38%) or infantile/post-hemorrhagic (23%) hydrocephalus. VPS insertion was the most common procedure for CSF diversion in the Philippine center (92%). Likewise, in the Russian center, VPS was the surgery for the majority (64%), while varied methods of CSF diversion were conducted in the Japanese center. The revision rates were 7.7, 11.1, and 25.5% in the Japanese, Philippine, and Russian centers, respectively; however, these only reflected the revisions that were done for the study duration and also included patients who were admitted for shunt dysfunction after surgery that was performed during an earlier time period.

Primary Outcomes: Timing of CSF Diversion Surgery and Mortality

For the timeliness of access to care, a majority of the cases from the Russian (85%) and Japanese (70%) centers were able to access CSF diversion within 2 days of confinement. In the Philippine center, only 36% of patients were able to undergo surgery by the second hospital day. The median time to CSF diversion was 6 days in the Philippine center, whereas it was 1 day for both the Japanese and Russian centers (**Table 2**; **Figure 1**). The delivery of surgical care for pediatric hydrocephalus was significantly more efficient in the Russian center compared to that in the Philippine center (HR = 2.94, 95% CI 1.99–4.35, $p < 0.001$). In terms of all-cause mortality, three children died in the Philippine cohort (proportion of 3.03, 95% CI 0.63–8.60), but none in the Russian and Japanese cohorts (**Table 2**).

Patient-Level Determinants of Primary Outcomes

For the cohort from the Philippines, non-poor patients were more likely to receive CSF diversion at an earlier time (HR = 4.74, 95% CI 2.34–9.61, $p < 0.001$). In the same center, those with infantile or post-hemorrhagic hydrocephalus (HR = 3.72, 95% CI 1.70–8.15, $p = 0.001$) were more likely to receive CSF diversion earlier compared to those with congenital hydrocephalus, and those with post-infectious (HR = 0.39, 95% CI 0.22–0.70, $p = 0.002$) or myelomeningocele-associated hydrocephalus (HR = 0.46, 95% CI 0.22–0.95, $p = 0.037$) were less likely to undergo surgery at an earlier time. For Russia, older patients were more likely to receive or require early CSF diversion (HR = 1.07, 95% CI 1.01–1.14, $p = 0.035$). For Japan, evidence was insufficient to identify significant factors associated with the timing of CSF diversion (**Table 3**). Because the cohorts of Japanese and Russian children had zero mortality, only the cohort of Filipino children was analyzed for logistic regression (**Table 4**). EVD insertion was found to be significantly associated with mortality (cOR 14.45, 95% CI 1.28–162.97, $p = 0.031$).

Other Global Surgery Indicators and Social Determinants of Health

In terms of metrics that represent health-system indicants, the various indices appear to depend on and follow the trend of the income level of each respective country. The Philippines as an LMIC, when compared with the higher-income countries (**Table 5**), has lesser absolute numbers, proportions, and percentages of the variables that are generally accepted as social determinants of health. In terms of the Global Surgery indicators, Japan has the best neurosurgical workforce density and provides better financial risk protection as evidenced by the low out-of-pocket payment shares and a high universal health coverage (UHC) effective coverage index. The purely neurosurgical center in Russia has the highest neurosurgical volume for the duration of this study period (**Table 6**).

TABLE 1 | Clinical and socioeconomic characteristics of the patients.

	Total ($n = 159$)	Japan ($n = 13$)	Philippines ($n = 99$)	Russia ($n = 47$)
	Median (Range); Frequency (%)			
Patient and case characteristics				
Age (years)	2.42 (0–17)	3 (0–16)	2 (0–17)	3 (0.08–16)
Sex				
Men	75 (47.2)	5 (38.5)	46 (46.5)	24 (51.1)
Women	84 (52.8)	8 (61.5)	53 (53.5)	23 (48.9)
Socioeconomic status*				
Nonpoor	58 (36.5)	13 (100)	11 (11.1)	34 (72.3)
Poor	89 (56.0)	0 (0)	76 (76.8)	13 (27.7)
Extreme poverty	12 (7.5)	0 (0)	12 (12.1)	0 (0)
Hydrocephalus type				
Congenital/diagnosed prenatally	34 (21.4)	5 (38.5)	24 (24.2)	5 (10.6)
Infantile/posthemorrhagic	38 (23.9)	3 (23.1)	12 (12.1)	23 (48.9)
Postinfectious	31 (19.5)	0 (0)	27 (27.3)	4 (8.5)
Associated with myelomeningocele	14 (8.8)	2 (15.4)	11 (11.1)	1 (2.1)
Tumor-related	35 (22.0)	3 (23.1)	22 (22.2)	10 (21.3)
Others	7 (4.4)	0 (0)	3 (3.0)	4 (8.5)
CSF diversion surgery				
ETV	22 (13.8)	5 (38.5)	2 (2.0)	15 (31.9)
VPS	99 (62.3)	1 (7.7)	80 (80.8)	18 (38.3)
VPS revision	24 (15.1)	1 (7.7)	11 (11.1)	12 (25.5)
EVD	6 (3.8)	0 (0)	6 (6.1)	0 (0)
EVD + subsequent conversion to VPS	3 (1.9)	1 (7.7)	0 (0)	2 (4.3)
Ommaya	1 (0.6)	1 (7.7)	0 (0)	0 (0)
Ommaya + conversion to VPS later on	4 (2.5)	4 (30.8)	0 (0)	0 (0)
Revision surgery rate	24 (15.1)	1 (7.7)	11 (11.1)	12 (25.5)
Time from admission to CSF diversion (days)				
<24 hours (<1 day)	22 (13.8)	2 (15.4)	8 (8.1)	12 (25.5)
24–48 hours (1–2 day)	63 (39.6)	7 (53.8)	28 (28.3)	28 (59.6)
3–7	26 (16.3)	0 (0)	20 (20.2)	6 (12.8)
8–10	4 (2.5)	1 (7.7)	3 (3.0)	0 (0)
11–14	3 (1.9)	0 (0)	3 (3.0)	0 (0)
>14	41 (25.8)	3 (23.1)	37 (37.4)	1 (2.1)

**World Bank definition of poverty: those living above US$3.10 per day are "non-poor," those living between $1.90 and $3.10 per day are "poor," and those living below $1.90 are "extremely poor."*

DISCUSSION

Hydrocephalus and Treatment Realities in Low-Resource Settings

At the Philippine neurosurgical center in this study, the usual pathway for a pediatric patient requiring CSF diversion surgery starts out with triaging the child to undergo either an elective or an emergency operation. Once the decision to shunt is made, for instance, the shunt kit will have to be sourced by the parents or caregiver from a non-profit philanthropic foundation because the catheter kits are not available at the state-financed public hospital. The time spent on shunt procurement contributes to the late time interval of surgery. Since the medical center caters primarily to the poorer segments of the population, the high volume of surgical cases coupled with limited bed capacity and constraints in the operating-room workforce also cause delays in surgery. Compounding this is the high prevalence of hydrocephalus in LMICs. These cases are commonly addressed by shunting as the procedure of choice, which is observed to have higher morbidity and mortality rates than in HICs (11, 28, 29). ETV as a procedure appears to be underutilized in the Philippine center compared to its Japanese and Russian counterparts, perhaps owing to the differences in hydrocephalus etiologies and corresponding indications, as well as variations in the institutional practice patterns. Although many studies with large patient series do not show significant differences in outcomes regardless of the kind of CSF diversion surgery employed (30, 31), or whether performed in developed or developing countries (32), the results

TABLE 2 | Primary outcome variables across different centers from the three countries.

	Median time from admission to CSF diversion surgery		Perioperative mortality	
	Days	(95% CI)	Count ($n = 3$)	Proportion (95% CI)
Japan	1	(1–9)	0	0 (0–24.7)
Philippines	6	(3–10)	3	3.03 (0.6–8.6)
Russia	1	(1–1)	0	0 (0–7.5)

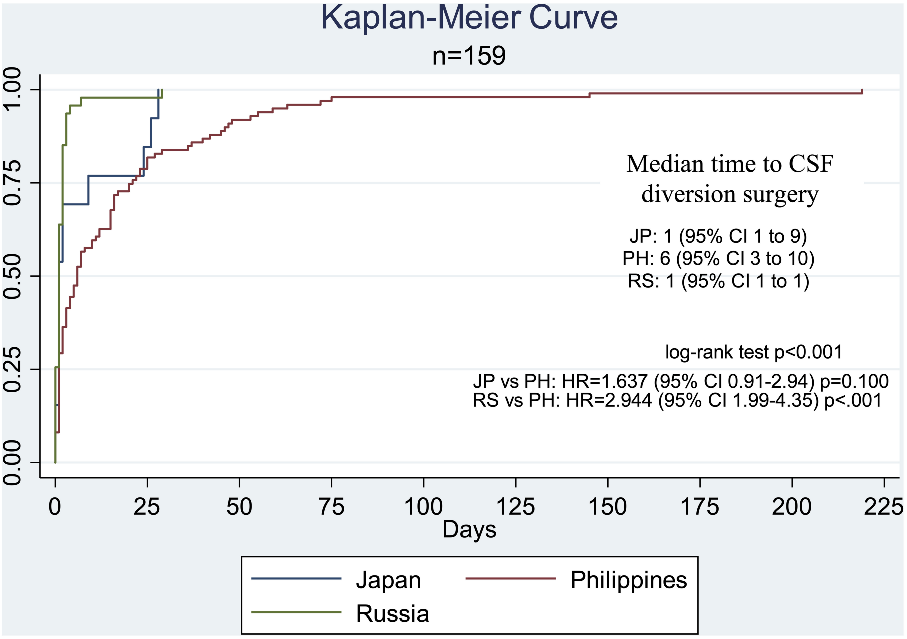

FIGURE 1 | Kaplan–Meier curve comparing the time-to-CSF diversion surgery by country. The median time for the Philippine center was significantly different from that in the Russian center (HR = 2.944, 95% CI 1.99–4.35, $p < 0.001$) but not the Japanese center (HR = 1.637, 95% CI 0.91–2.94, $p = 0.100$).

in this cross-country comparative study show that mortality in the Philippine cohort appears to be associated with the procedure of EVD insertion. This finding, however, may largely be due to the more critical physical condition of patients who underwent EVD instead of other CSF diversion procedures. Patients who are in extremis resulting from late intervention or from perioperative complications always require resource-intensive care pathways that resource-challenged neurosurgical centers in LMICs often fail to provide. This so-called "capacity to rescue," referring to the institutional capability to mitigate surgical risks, improve safety, and provide adequate postoperative intensive care, is the feature of quality and responsive surgical systems that can avert mortality and can improve chances of survival (10). Moreover, this statistic belies the financial and social risks that patients and their families who had unfavorable outcomes are exposed to. These risks include the high out-of-pocket expense for hospitalization, the indirect economic costs of job loss from caregiving, and their overall impoverishment even after the demise of the patient brought about by loss of livelihood, among others. In stark contrast, the Japanese university hospital and the Russian public neurosurgical center, through their highly functional national health insurance schemes and relatively well-funded surgical systems, are able to provide the families of their patients a high degree of financial risk protection from the economic shocks of hospitalization. Indeed, the undergirding health systems of the neurological centers of this study might be inextricably linked to better outcomes.

Disparities in Health Systems: Workforce, Infrastructure, and Financing

Japan and Russia have surplus resources, better UHC, and higher public financing for health (**Table 5**), borne from deliberate policies of placing a prime value on public health (26, 27), and this becomes important given that the increased expenditure on surgery can easily allow the proportional expansion of surgical capacity (1, 10, 22, 33). Studies that analyzed large patient databases (34, 35) have examined the effect of nation-level socioeconomic factors on conditions treated by neurosurgeons. Remick and colleagues (34), after multivariate mixed-effects logistic regression, identified two nation-level variables, physician density and

TABLE 3 | Determinants of the timing of CSF diversion surgery, by country, after univariate Cox regression.

	Japan		Philippines		Russia	
	Crude Hazard Ratio (95% CI)	***p-value***	**Crude Hazard Ratio (95% CI)**	***p-value***	**Crude Hazard Ratio (95% CI)**	***p-alue***
Age	1.05 (0.95–1.16)	0.334	1.00 (0.96–1.05)	0.869	**1.07 (1.005–1.14)**	**0.035**
Male sex	1.56 (0.47–5.13)	0.464	1.14 (0.76–1.69)	0.530	0.90 (0.50–1.60)	0.714
Socioeconomic status						
Poor/extreme poverty	Reference	–	Reference	–	Reference	–
Non-poor	–	–	**4.738 (2.34–9.61)**	**<0.001**	1.00 (0.52–1.91)	0.996
Hydrocephalus type						
Congenital/diagnosed prenatally	Reference	–	Reference	–	Reference	–
Infantile/posthemorrhagic	0.74 (0.16–3.41)	0.704	**3.72 (1.70–8.15)**	**0.001**	0.97 (0.36–2.62)	0.953
Postinfectious	–	–	**0.39 (0.22–0.70)**	**0.002**	1.23 (0.33–4.58)	0.761
Associated with myelomeningocele	1.26 (0.22–7.28)	0.794	**0.46 (0.22–0.95)**	**0.037**	1.52 (0.1–13.36)	0.704
Tumor-related	2.08 (0.43–9.98)	0.359	0.56 (0.31–1.01)	0.054	1.79 (0.59–5.48)	0.305
Others	–	–	2.17 (0.63–7.46)	0.217	1.47 (0.39–5.54)	0.568
CSF diversion surgery						
ETV	8.64 (0.98–76.14)	0.052	0.64 (0.16–2.63)	0.540	1.22 (0.60–2.48)	0.577
VPS	8.71 (0.49–156.26)	0.142	Reference	–	Reference	–
VPS + subsequent revision	4.78 (0.28–81.27)	0.279	0.74 (0.38–1.43)	0.367	1.17 (0.56–2.44)	0.681
EVD	–	–	1.04 (0.45–2.39)	0.934	–	–
EVD + subsequent conversion to VPS	8.71 (0.49–156.26)	0.142	–	–	0.19 (0.02–1.46)	0.110
Ommaya	4.78 (0.49–156.26)	0.279	–	–	–	–
Ommaya + conversion to VPS later on	Reference	–	–	–	–	–
Revision surgery	1.07 (0.13–8.67)	0.949	0.74 (0.38–1.44)	0.381	1.21 (0.62–2.35)	0.575

The bold values indicate the statistical significant difference.

mean GDP growth, as significantly associated with good seizure outcomes following pediatric epilepsy surgery. Similarly, Guha and colleagues (35) identified a higher-country GDP and a greater neurosurgeon-to-population density as two nation-level variables that are independent predictors of good outcome following the treatment for aneurysmal subarachnoid hemorrhage. The Philippines, in contrast to the two countries, has a lower neurosurgeon workforce density (**Table 5**), thus expectedly restricting the breadth of access to care for children requiring CSF diversion surgery.

The increased likelihood of the inability to undergo an early CSF diversion surgery for the Filipino cohort of patients (**Figure 1**; **Table 2**), especially the poor and extremely poor subsets of Filipino patients, can be explained chiefly by financial barriers (1, 5, 19, 24, 33, 36). These barriers, direct and indirect costs relating to treatment, cause economic hardships to the household in which a patient belongs to. Families in which one of the members is a patient requiring neurosurgical care are at risk for financial catastrophe and impoverishment, and this is especially true in LMICs like the Philippines (1, 24, 28). Furthermore, out-of-pocket expenditures and the risks for catastrophic and impoverishing expenditures are higher in the Philippines than in Japan and Russia (**Table 5**). This is particularly disadvantageous given that our results show that a higher socioeconomic status is significantly associated with an earlier time interval of the CSF diversion surgery (**Table 3**). Financial risk protection, therefore, is important for the acceptability and accessibility of any surgical intervention (33), especially in countries where a significant proportion of the population is poverty-stricken (1, 21, 24, 37). This necessitates countrywide UHC for health insurance in any form or combination, precisely the kind of social structure that Japan excels at (21, 27), that would subsidize the treatment-related costs incurred by the families of the patients. While all patients from the three centers in this study have some form of health insurance coverage, those from the Japanese and Russian neurosurgical centers receive the broad range of inpatient and outpatient services with negligible out-of-pocket expenses after substantial subsidies by public insurance and government funding. These institutional features improve health-seeking behavior and provide consultations during the initial presentation of a disease more likely. Furthermore, Japan leads in having a high UHC effective coverage index (**Table 5**), in what could be considered as having an effective social safety net that offsets household expenditures against costly

TABLE 4 | Determinants of mortality, in the subgroup from the Philippines, after binary logistic regression.

	Crude Odds Ratio (95% CI)	*pValue*
Age	0.98 (0.78–1.23)	0.872
Female sex	1.47 (0.19–11.59)	0.713
Socioeconomic status		
Poverty	4.46 (0.54–37.01)	0.166
Non-poor	Reference	–
Hydrocephalus type		
Congenital/diagnosed prenatally	Reference	–
Infantile/posthemorrhagic	1.96 (0.04–104.76)	0.740
Postinfectious	2.77 (0.11–71.35)	0.538
Associated with myelomeningocele	7.00 (0.26–186.26)	0.245
Tumor-related	3.42 (0.13–88.40)	0.459
Others	7.00 (0.12–412.69)	0.350
CSF diversion surgery		
ETV	10.60 (0.34–330.35)	0.179
VPS insertion	Reference	–
VPS insertion + revision later on	7.57 (0.72–79.62)	0.092
EVD insertion	**14.45 (1.28–162.97)**	**0.031**
Revision surgery	4.94 (0.59–41.31)	0.140
Time from admission to CSF diversion (days)	1.01 (0.99–1.03)	0.260
Time from admission to CSF diversion >14 days	12.68 (0.64–252.73)	0.096

The bold values indicate the statistical significant difference.

neurosurgical management (38). Financial risk protection is indeed important because inadequate or poor-quality health insurance coverage poses an increased likelihood of poor outcomes following CSF diversion procedures for pediatric patients (7, 39).

Governance Structures and Social Determinants of Health in a Country

While a comprehensive review of the health systems of Japan (27), the Philippines (25), and the Russian Federation (26) is beyond the scope of this article, our results show that across the majority of nation-level metrics, the Philippines lags behind Japan and Russia in terms of both the Global Surgery indicators and the social determinants of health (**Tables 5**, **6**). The provision of adequate standard of care is also shaped by the social determinants of health within a country. Several studies have shown that the economic robustness and level of resources of a country, i.e., being a HIC, translate into better patient-level outcomes, particularly when investments in perioperative care and surgical systems are made (10, 22, 34–36). Perennial lack of resources in public hospitals contributes to the inability to provide safe and quality surgical services, thus diminishing the capacity to rescue patients from avoidable deaths due to treatment complications. At the level of the neurosurgical centers, effective domestic resource mobilization in healthcare institutions is necessary for securing the health financing required to achieve improved patient outcomes. Investing in surgical services is therefore paramount, but this responsibility lies beyond the sphere of influence of organized neurosurgery.

Policy Work and Resource Management Can Be the Way Forward

Policies that increase government expenditure on health appear to improve the composite metric that reflects the nation-level performance of a health system (22, 34). Advocacy for more strategic policies and investments that address social determinants of health can strengthen governance and financing arrangements (14, 15). These, in turn, help to reshape more responsive and equitable health and surgical systems, as certain strategies can be undertaken to reduce variations in the use of surgery (40). LMICs have the task of providing the full range of a responsive neurosurgical system, from as simple as the availability of shunt catheter kits to more capital-intensive measures such as comprehensive facility development, progressive hospital billing, strategic purchasing, and catastrophic case packages (41), that all in all curbs out-of-pocket payments and helps achieve UHC. A multilevel system approach (12, 40) by the involved policymakers can result in improvements in care processes of the surgical and health systems, which, in turn, result in a better quality of care and upon which hinges the hope of ultimately translating to better patient outcomes.

Limitations of the Study and Future Directions

The study includes patients with considerable heterogeneity in terms of the etiology of hydrocephalus. Additionally, the neurosurgical centers are not entirely representative of their countries because of the inherent intra-national heterogeneity of

TABLE 5 | Country-level data of the three countries in terms of relevant metrics of Global Surgery indicators and social determinants of health.

	Japan	Philippines	Russia
Health financing and socioeconomics			
Income level*	High income	Lower middle income	Upper middle income
GDP per capita, PPP (current international $, year 2019) (20)	43,235.7	9,302.4	29,181.4
Total health expenditure (as % of GDP) (23)	10.7%	4.4%	5.3%
Government and prepaid private spending on health (as % of total health spending) (23)	87.1%	44.5%	59.9%
Public health insurance and tax funding share of financing (as % of total health financing) (25–27)	84.0%	34.3%	39.4%
Out-of-pocket payment share of financing (as % of total expenditure on health) (25–27)	14.0%	53.7%	28.8%
UHC Effective Coverage Index (21)	96	55	69
Infrastructure and workforce			
Number of neurosurgeons	10,014	134	2,900
Neurosurgeon-to-population density	1:12,600	1:780,000	1:49,600
Hospital beds per 10,000 population (25–27)	132.0	10.1	96.8
Healthcare Access and Quality Index (22)	89	52	72

Based on the World Bank country classification (20), for the current 2020 fiscal year, low-income economies are defined as those with a GNI per capita, calculated using the World Bank Atlas method, of US$1,025 or less in 2018; lower middle-income economies are those with a GNI per capita between $1,026 and $3,995; upper middle-income economies are those with a GNI per capita between $3,996 and $12,375; high-income economies are those with a GNI per capita of $12,376 or more.

TABLE 6 | Institution-level data in terms of relevant metrics of Global Surgery indicators.

	Japan	Philippines	Russia
Institution	University of Tsukuba Hospital, Ibaraki	Jose R. Reyes Memorial Medical Center, Manila	Federal Neurosurgical Center, Novosibirsk
Institutional neurosurgical bed capacity	54	30	95
Pediatric neurosurgical bed capacity (as a share of the total neurosurgical bed capacity)	<5	<8	15
Neurosurgical volume (total number of operations during the year 2019)	714	710	4,236
Pediatric neurosurgical volume (total number of operations on children during the year 2019)	80	153	393
Neurosurgical staff (total number of consultants and residents in the year 2019)	24	12	32

institutions, especially between the public and private sectors. Selection bias and information bias may have been present because of the limitations of a retrospective review. Attributing certain outcomes to a policy when they are, in fact, owed to unmeasurable variables runs the risk of secular trend bias as well. Due to the limited sample size, the limited regression analysis, and the non-randomized and unmatched observational study design, confounding factors and their impact may not have been adequately lessened. Regardless, our study ventures into a cross-country comparison of outcomes and explores issues that are of larger socioeconomic context as related to the granularity of patient outcomes for a particular disease entity after neurosurgical intervention. If and when the Global Surgery indicator targets are met, the outcomes of neurosurgical patients in low-resource centers of LMICs after certain policy changes can be compared using the difference-in-difference study design (42). Finally, the authors look forward to increasing the center recruitment or prospectively gathering further primary patient-level data for the next phase or form of the present study. We recommend further studies with large sample sizes that allow the inclusion of nation-level covariates into a hierarchical mixed-effect statistical analysis (34, 35) that can, in turn, determine the magnitude of effect of those variables.

CONCLUSION

In this study, we compared the Global Surgery outcomes following CSF diversion surgery for pediatric hydrocephalus among neurosurgical centers from different countries of varying income levels. We found that the cohort of Filipino children underwent late time interval of CSF diversion surgery compared to that of their Japanese and Russian counterparts. The differences in the timeliness of surgery were significantly related to the etiology of hydrocephalus, as well as to the socioeconomic status of the household that the child belongs to. In the cohort from the Philippines, from which three children suffered mortality, EVD insertion was associated with mortality. The variation in these outcomes may reflect the robustness of the health system of a country. Certain institution- and nation-level factors may explain the differences when viewed through the lenses of the Global Surgery indicators and social determinants of health.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary files, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Tsukuba Hospital Institutional Review Board, Jose R. Reyes Memorial Medical Center Institutional Review Board, Federal Neurosurgical Center Novosibirsk Local Ethics Committee. Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

KF, SK, and HM: conception and design. EP, SK, and HM: acquisition of data. KF and VC-R: analysis and interpretation of data. KF, EP, and MY: drafting the article. KF: approved the final version of the manuscript on behalf of all authors. VC-R: statistical analysis. EP: administrative/technical/material support. KF, GL, AM, RB, JA, KS, and JN: study supervision. All authors critically revised and reviewed submitted version of manuscript.

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State of Accredited Endovascular Neurosurgery Training in India in 2021: Challenges to Capacity Building in Subspecialty Neurosurgical Care

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INTRODUCTION

Stroke is the second leading cause of death worldwide, accounting for nearly 5.5 million deaths annually along with significant long-term disability. Currently, there exist >80 million stroke survivors worldwide and the condition is responsible for 5.2% of disability-adjusted life years (DALYs) lost globally (1, 2). Stroke is not just a clinical condition but a massive public health emergency for which work is needed throughout the healthcare spectrum—from prevention to optimal management. While the former is primarily the domain of primary care and public health, the latter falls in the domain of specialist care. The burden of stroke, however, is disproportionately borne by developing nations, which house a large proportion of the world's population.

Endovascular neurosurgical care has been demonstrated to be a safe and highly efficacious treatment strategy for stroke and related conditions, such as aneurysms, subarachnoid hemorrhage, carotid artery disease, amongst others (3, 4). Neuroendovascular specialists in HICs are either interventional neuroradiologists, interventional neurologists, or neurosurgeons. Given that endovascular therapy has especially proved to be superior to intravenous thrombolysis in acute ischemic stroke (AIS) and can be utilized beyond 6 hours of symptom onset with appropriate patient selection, neurointerventional management has hence become a standard of care in high-income countries (HICs) (3).

Unfortunately, the above situation is almost exclusive to HICs with endovascular care being neither available nor widely accessible in low-middle-income countries (LMICs). Several issues have come together to result in a state of significant disparity in the availability of endovascular care, ranging from infrastructural cost considerations to the presence and distribution of trained specialists. However, it is in LMICs where the greatest need for endovascular neurosurgery exists. For instance, stroke in South Asia, relative to HICs, is known to have a higher prevalence, younger age, higher mortality, and an increased burden of modifiable risk factors (5). In addition, neuroendovascular specialists in LMICs are predominantly neuroradiologists, given that radiologists were the earliest in large parts of the world to venture into this subspeciality.

The primary specialty of the neurointerventionalist has been demonstrated to be of significant value. In a seminal paper in 2016, Fennel et al. reported that, for endovascularly treated intracerebral aneurysms, neurologists had the highest rates of complications (11%) and deaths (3%), followed by radiologists, while neurosurgeons had the lowest rates of complications (5.4%) and mortality (1.4%) (6). These large differences suggest that endovascularly-trained neurosurgeons should be one of the key neuroendovascular subspecialists available worldwide.

India, in particular, has seen a rise in stroke cases from 2.8 million in 1990 to 6.5 million in 2016 (2). However, the state of endovascular care services by neurosurgeons in India remains nearly non-existent, as we describe below. This opinion piece utilizes the Indian case scenario to highlight how the disparity of endovascular neurosurgical care exists against excellent training being available for general neurosurgery and its other subspecialties (7). The challenges in India echo those of other LMICs with regards to capacity building in high-quality neurosurgical care in various subspecialties.

NEUROSURGICAL RESIDENCY TRAINING IN INDIA

To put the near absolute lack of formally trained endovascular neurosurgeons in India in context, one must first understand the state of neurosurgical residency training in India, which is currently quite well-developed in number and distribution (7).

After 5.5 years of medical school, graduates then sit for annually held, national, standardized examinations. Ranks on these examinations, now consolidated into just two, serve as the sole basis for selection into all residency programs and all specialties. Two types of residency training programs exist, those accredited by the National Board of Examination (NBE) and those accredited by the National Medical Council (NMC), erstwhile known as the Medical Council of India (MCI). For all specialties, the NMC-accredited programs are usually at publicly-funded, non-profit institutions, while the NBE-accredited programs exist typically at private hospitals and/or for-profit institutions. Completion of neurosurgery training leads to the award of Magister Chirurgiae (M.Ch.) if completed at NMC-accredited institutions or the award of Doctorate of the National Board in Super-Speciality (DNB-SS) if completed at NBE-accredited residencies.

Neurosurgery training in India is currently through two pathways (**Figure 1**). The first pathway comprises of 3-year-long programs, whose selection test is given after completion of a 3-year general surgery residency. This pathway provides the bulk of neurosurgical training positions in India. The other, which is far more limited, includes 5/6-year-long programs straight after medical school. The latter is quite similar to all neurosurgery training positions in the US, Canada, and to the run-through programs in the United Kingdom (**Figure 1**).

The number of neurosurgery, neurology, and neuroradiology training programs in India is given in **Supplementary Table 1** (8, 9). India, as of May 2021, has a total of 482 accredited intake positions for neurosurgery training annually, likely the highest number worldwide. Notably, neurology training in India is solely a 3-year program, done after a 3-year training in internal medicine. It leads to the award of the degree of Doctorate of Medicine (DM) at MCI/NMC-accredited institutions or the DNB-SS by the NBE-accredited residencies. This is in contrast to the US where neurology is a 4-year residency program after medical school. With regards to neuroradiology, it is a 3-year program after 3-years of radiology residency. Most neuroradiology programs in India have some degree of training in neurointerventional management.

STATE OF SUBSPECIALTY TRAINING IN ENDOVASCULAR NEUROSURGERY IN INDIA

Currently, for endovascular training for neurosurgery residency neurosurgery, there exist zero training programs in India accredited by the MCI/NMC. For the same, a 2-year program accredited by NBE was introduced in 2020, open not just to neurosurgeons but to radiologists and neurologists as well, and awards the degree of Fellow of the National Board (FNB) in Neurovascular Intervention. It currently has just 4 training positions at a total of 3 programs (**Supplementary Table 1**). With regards to non-accredited training, there exist a handful of centers offering endovascular neurosurgery training, but their number is extremely limited, the duration is highly variable and the training is non-standardized (10, 11). Thus, despite the adequate state of neurosurgery residency training, there simply exists little high-quality training to become an endovascular neurosurgeon in India.

Currently, there exist 7 NMC-accredited neuroradiology programs offering 22 seats annually. Notably, all of them offer some degree of neuro-interventional training. However, these are open to apply only to radiologists while also having a large degree of heterogeneity in trainee procedural volume.

In contrast, other neurosurgical subspecialties have well-developed training programs in India. While several reasons for this disparity exist, one major factor is the need for the additional logistical framework for delivering endovascular care, like dedicated catheterization labs. This is in contrast to other neurosurgical subspecialties that primarily utilize the pre-existing infrastructure such as complex skull-base surgery.

DISCUSSION

Understanding the current accessibility of endovascular neurosurgery training in India is thus an essential first step to address the growing disparity in service provision and to develop recommendations to improve training systems (12–14).

In the US, there are ∼116 neuroendovascular fellowship programs for neurosurgeons that are accredited and/or listed by the Society of Neuro-interventional Surgery (SNIS), Committee on Advanced Subspecialty Training (CAST), and Accreditation Council for Graduate Medical Education (ACGME) (15–17). Another accrediting body for neurointerventional fellowships is United Council for Neurologic Subspecialties (UCNS). Notably, it is the ACGME that accredits all residency training in US. In India, equivalent nationally recognized bodies exist such as NMC and NBE, along with professional societies like the Neurological Society of India (NSI) and the Neurological Surgeons Society of India (NSSI). However, accrediting such fellowships is not a part of their scope to date.

In a recent national survey study of 104 Indian neurosurgical trainees, 61% described exposure to endovascular surgery

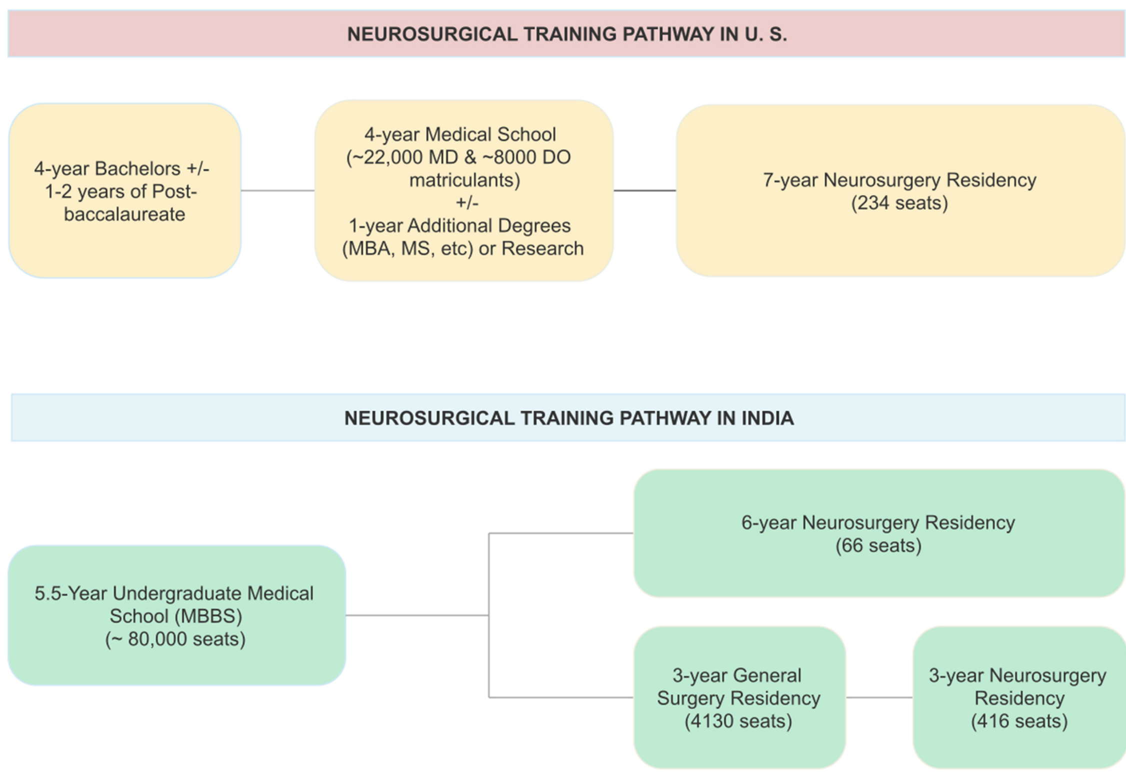

FIGURE 1 | Comparison between the United States and India of training lengths and positions for the training of a neurosurgeon. Seat numbers in India are sum totals for programs accredited by either National Medical Council (NMC) or National Board of Examinations (NBE) in India.

as uniformly poor (18). In the coexistence of both poor exposure during residency and complete dearth of experience via accredited fellowships, it is likely that those neurosurgical trainees initially interested in neuroendovascular turn to other subspecialties.

Amidst such sentiments, it is not surprising that many young Indian neurosurgeons have to apply for and complete training in developing nations to become competent in endovascular neurosurgery. This carries its own challenges, as countries differ with regard to how they define fellowship. It has been noted by prominent academic neurosurgeons in India that some neurosurgeons undertake only a few weeks of observership abroad and return to India declaring themselves as endovascular neurosurgeons (12, 19). Some who complete fellowships in North America choose to practice there.

Thus, with endovascular neurosurgery enthusiasts either turning to other specialties or seeking opportunities abroad, the specialty's workforce growth stagnates, resulting in less momentum for the development of training programs, and hence a vicious circle perpetuates. Therefore, the first and the most important point of input must be into starting accredited programs for endovascular training at major neurosurgical departments in the country.

Secondly, these national bodies, working with local non-profit organizations, must commission and/or fund epidemiological studies looking to conclusively quantify the need for endovascular neurosurgeons. This data may then be utilized to request greater funding from federal agencies for such subspecialists. Given India's demographic transition from a developing into a developed nation, which carries with itself a greater prevalence of obesity, hypertension, dyslipidemia, and thereby stroke, the need has only grown in recent decades.

Thirdly, given the non-accredited nature of the vast majority of neurosurgery subspecialty fellowships in India (7, 10, 11), professional neurosurgical societies must play a key role in either beginning fellowship accreditation themselves or supporting external accrediting agencies. This may be done by developing strict procedural volumes, training outcomes, and milestones-based competency criteria, which may be adapted from the standards adopted by ACGME and CAST based on the case-mix and disease burden in India. Notably, lack of fellowship accreditation in other neurosurgical subspecialties has led to significant heterogeneity in their training quality and the operative volume, a scenario which can be preemptively avoided in the case of endovascular fellowships given its blank slate in India.

Additionally, the Indian neurosurgical professional bodies would do well to increase collaboration with international organizations to build capacity. The NSI is a particular leader that could forge directed collaborations for developing the training of endovascular neurosurgeons with organizations such as the World Federation of Neurosurgical Societies

(WFNS), the American Association of Neurological Surgeons (AANS), Congress of Neurological Surgeons (CNS), and the European Association of Neurosurgical Societies (EANS) (14). Such mechanisms would allow for a large expert collaborative community which is essential for the exposure required by the early-career neurosurgeons interested in endovascular neurosurgery. The collaboration would allow high-quality training programs in India to develop having been mentored by global experts from the start.

Furthermore, given that most neurosurgery training programs in India lack neuroendovascular rotations for residents, a major reform would be the incorporation of such rotations during residency, similar to programs globally. Six-year training programs are especially poised to offer a 1-year enfolded training option, including in endovascular neurosurgery, similar to the enfolded fellowship model in the US.

Finally, in conjunction with previous literature, we recommend expanding the number of 6-year programs and converting the 3-year pathways to 6-year ones, given that 3 years has been noted to be too little a time to train competent and safe neurosurgeons (7, 10, 11). This will greatly help training programs in accommodating a neurointerventional rotation for trainee neurosurgeons. Herein, thought must also be given to providing trainees early autonomy and decreasing the amount of scut work, two considerations that have long plagued neurosurgical training in India (7, 10, 11, 18).

In summary, these recommendations represent the first steps toward raising the profile and the value of endovascular neurosurgery amidst trainees and the wider neurological care systems in India (**Supplementary Figure 1**). Despite this, it is important to acknowledge other considerations that would impede its growth including expanding rural-urban divides, health commodification, misgovernance, and bureaucratic apathy (20). For a call for more endovascular neurosurgeons is a recommendation laced with an assumption that the Indian ecosystem would support this; based on these external factors it would be like building the second floor before laying the brick and cement. It is only by addressing these systemic issues alongside the recommendations laid out herein that Indian neurosurgeons can strive toward a high-quality endovascular neurosurgical workforce in India.

AUTHOR CONTRIBUTIONS

SSC and AO conceptualized, drafted and revised the manuscript. FR drafted and revised the manuscript. All authors contributed to the article and approved the submitted version.

SUPPLEMENTARY MATERIAL

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Financial Risk Protection for Neurosurgical Care in Indonesia and the Philippines: A Primer on Health Financing for the Global Neurosurgeon

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Which conditions treated by neurosurgeons cause the worst economic hardship in low middle-income in countries? How can public health financing be responsive to the inequities in the delivery of neurosurgical care? This review article frames the objectives of equity, quality, and efficiency in health financing to the goals of global neurosurgery. In order to glean provider perspectives on the affordability of neurosurgical care in low-resource settings, we did a survey of neurosurgeons from Indonesia and the Philippines and identified that the care of socioeconomically disadvantaged patients with malignant intracranial tumors were found to incur the highest out-of-pocket expenses. Additionally, the surveyed neurosurgeons also observed that treatment of traumatic brain injury may have to require greater financial subsidies. It is therefore imperative to frame health financing alongside the goals of equity, efficiency, and quality of neurosurgical care for the impoverished. Using principles and perspectives from managerial economics and public health, we conceptualize an implementation framework that addresses both the supply and demand sides of healthcare provision as applied to neurosurgery. For the supply side, strategic purchasing enables a systematic and contractual management of payment arrangements that provide performance-based economic incentives for providers. For the demand side, conditional cash transfers similarly leverages on financial incentives on the part of patients to reward certain health-seeking behaviors that significantly influence clinical outcomes. These health financing strategies are formulated in order to ultimately build neurosurgical capacity in LMICs, improve access to care for patients, and ensure financial risk protection.

Keywords: health financing, global neurosurgery, social health insurance, strategic purchasing, conditional cash transfer (CCT), out-of-pocket (OOP) expenses

INTRODUCTION

The costs accompanying the provision of neurosurgical care in low middle-income countries (LMICs) constitute as barriers to access among the socioeconomically disadvantaged (1). For the often life-threatening neurosurgical conditions, financial barriers that need to be overcome frequently cause economic hardships to the household in which a patient belongs to. Families with a patient needing neurosurgical care are at risk for financial catastrophe and impoverishment, and this is especially true in LMICs (2, 3). The increasing costs of healthcare—including neurosurgery—also further burdens the existing health financing mechanisms in the health systems of LMICs. Particularly in low-resource settings of public hospitals where the poorer segments of the population are served, financial risk protection becomes an important consideration (4, 5). The elimination of catastrophic and impoverishing expenditures remains an important goal for health systems to improve the accessibility of neurosurgery. In this article, we explore the most financially catastrophic neurosurgical disorders that are encountered in public neurosurgical centers in Indonesia and the Philippines. We also describe public-health perspectives that may provide insight for potential solutions.

MATERIALS AND METHODS

Cross-Sectional Survey

The primary aim of the survey was to determine the most commonly encountered neurosurgical conditions that result in financial catastrophe. A secure online survey tool (Google Forms®) was used to disseminate the questionnaire to neurosurgeons currently practicing at public hospitals in Indonesia and the Philippines. Respondents comprised a purposive sample of neurosurgeons invited through the electronic mailing lists of neurosurgical training programs, email to personal contacts, and social media platforms (WhatsApp and Viber). The survey was open between 16th February 2021 and 16th March 2021. Those eligible to complete the survey were neurosurgeons—either as residents or as consultants—whose practice involves a publicly-funded neurosurgical center as part-time or full-time healthcare provider. Duplicates were removed via matching those of an identical name and hospital. Because no patient information was requested from the survey, approval by an institutional review board was not needed. It is of note that while the vantage point of patients would be most ideal to take, the survey has the limitation of inquiring only from the perspective of neurosurgeons as health service providers because of its cursory nature in bringing the more important discussion on solutions to the fore.

Application of Public Health Perspectives

Using principles and perspectives from public health, contractual management, and financial management, we proffer potential solutions that can address the gaps in health financing of neurosurgical services in Indonesia and the Philippines. When viewed in a public-health context, the problem of catastrophic and impoverishing expenditures becomes more manageable. Existing frameworks from these disciplines permit exploration of financial risks that burden the patients that can potentially be averted by the roles of various agents in the surgical and health systems. We propose a conceptual framework for implementation to inform future policymaking related to the financing of public neurosurgical services in Indonesia and the Philippines.

RESULTS AND DISCUSSION

Survey Results

A total of 43 neurosurgeons−29 (67%) from Indonesia and 14 (33%) from the Philippines—had valid responses to the survey. Majority of respondents (31.8%) cited malignant intracranial tumors as the neurosurgical condition that causes the worst economic hardship among patients and their families, followed by traumatic brain injury (27.3%), spinal trauma and spinal cord injury (15.9%), and aneurysmal subarachnoid hemorrhage (15.9%).

In terms of out-of-pocket (OOP) expenses for these conditions, malignant intracranial tumors were reported to impose the highest OOP expenses (43.2%), followed by emergency vascular diseases (38.6%), traumatic brain injury (34.1%), and degenerative spine disorders (34.1%) (**Figure 1**).

Among the neurosurgical conditions needing greater financial subsidy, traumatic brain injury (27.3%) needed the most, followed by malignant intracranial tumors (18.2%), aneurysmal subarachnoid hemorrhage (15.9%), and spinal trauma and spinal cord injury (13.6%) (**Figure 2**).

Socioeconomic Context of Neurosurgical Care

Few studies have examined the association between patient-level socioeconomic factors and outcomes across various diseases that are treated by the specialty of neurosurgery—pediatric hydrocephalus (6–8), craniosynostosis (9), intracranial tumors (10–13), aneurysmal subarachnoid hemorrhage (14, 15) and stroke (16, 17), traumatic brain injury (18–21), spine disorders (22) and spinal cord injury (23, 24). Many of these studies describe the more frequently unfavorable outcomes among the inadequately insured and those with lower socioeconomic status. Due to the inherently costly nature of neurosurgical interventions, many of the socioeconomically disadvantaged patients seek the necessary care from public hospitals (4, 5). Whereas such public neurosurgical centers in Indonesia and the Philippines are mandated by legislation and government regulation to provide healthcare at minimum or zero cost, the reality is that many patients still incur out-of-pocket expenses (25, 26). These expenses are often catastrophic and push their families into impoverishment. Financial catastrophe from accessing surgery remains high in LMICs, and most of those exposed to such financial risk live in sub-Saharan Africa and Southeast Asia (1). On the basis of the dearth of literature on global surgery research related to health financing (27), we explore the contextual solutions for the costly care of socioeconomically disadvantaged patients suffering from malignant intracranial tumors and traumatic brain injury in Indonesia and the Philippines.

Supply and Demand Sides of Neurosurgical Care

There are various reasons for the still prevalent high out-of-pocket expenses in LMICs, particularly in Indonesia and the Philippines. From the demand side of the healthcare system, both medical and non-medical costs account for the financial catastrophe suffered by poor patients following surgery (2). Surgical conditions result in a greater household poverty effect relative to other health problems and diseases (1, 2, 28). Poverty plays a role in the unaffordability of transportation costs and caregiving expenses, while prolonged hospitalization results in income regression, unemployment, and opportunity costs for both the patient and the caregiver. The sociocultural disadvantage of lower levels of education among the poorer patients contributes to the more advanced presentation of disease at the time of first consultation. Inadequate health insurance also contributes to hesitancy in timely health-seeking behavior—a problem that poses a disadvantage in outcomes after treatment and prognosis. Furthermore, it does not help that any neurosurgical intervention, or any surgical treatment for that matter, is perceived to be costly and expensive (1). Globally, LMICs have the highest rates of catastrophic expenditures following receipt of surgical care; and within any country, most of the burden falls on the poorer segments of the population (2).

From the supply side of the health system—the healthcare providers—publicly-funded hospitals generally provide the needed wide range of emergency and elective neurosurgical care for poor patients. These hospitals are primarily financed from taxation and are appropriated a yearly budget from the national government through the Department or Ministry of Health, or from local or state-run universities. Many public hospitals do not have the bare minimum neurosurgical implements, surgical intensive care units, and even a computed tomography scanner. These complicate the usual treatment pathway for a neurosurgical patient—turning it into a cumbersome navigation around a generally disjointed referral network of hospitals (4, 5, 29). Despite the finite resources that beset government-financed hospitals, neurosurgical care provision in most centers has been largely sustained by the presence of an academic neurosurgical training program. The few hospitals with neurosurgical residency programs in Indonesia and the Philippines are generally better equipped to handle the more complicated and full range of neurosurgical diseases and conditions (30). And yet, like many of the public hospitals in low-resource settings, the efficiency of care is hampered by bureaucratic processes and protocols (1). Commonplace problems like the breakdown of equipment can take time to repair. The purchase of new equipment often gets encumbered in elaborate procurement processes (31). In these respects, the financing of equipment purchase and patient management can have an important impact on the quality and efficiency of neurosurgical care.

Health Financing: An Important Health Systems Function

Broadly, health financing comprises the mechanisms by which money is mobilized to fund and pay for health-sector activities, and how it is used, raised, and paid out to achieve health-related outputs (32). Financing and payment arrangements determine how much money is available or paid out, who bears the financial burden, who controls the funds, whether healthcare costs are controlled, and which groups or health-system actors are given the incentive (33). A chief method of health financing is by way of health insurance. The organization and pooling of both funds and risks are foremost functions of a health insurance scheme. Many countries, including both Indonesia and the Philippines, have some form of social health insurance that is overseen or managed by the government. Health financing, in a pragmatic sense, is also a matter of policy. These policies and regulations create powerful incentives that influence the actions of individuals and organizations in a given healthcare system.

Socioeconomically disadvantaged patients who seek healthcare services are often price-sensitive because their limited means do not allow them to have the capacity to economically withstand adverse life events such as having a neurosurgical illness requiring hospitalization. In countries that do not have a fully responsive health financing or social protection mechanism—which is more often the case in LMICs—poor households with a sick member would finance their health-related costs by way of out-of-pocket expenses (1, 2). The out-of-pocket expenses they bear can become "catastrophic," i.e., household spending equal or above 40% of non-subsistence income (1, 2). Incurring health-related catastrophic expenditures pushes patients' families into impoverishment and affects the volume and timeliness of healthcare used, in turn influencing overall health outcomes (32). As far as healthcare utilization is concerned, the extent of social health insurance coverage in public hospitals is therefore important. Universal health coverage and a high degree of responsiveness in curbing out-of-pocket expenses on the part of the social health insurance can improve the accessibility of surgical services, including that of neurosurgery.

Expanded Functions for Social Health Insurance

Social health insurance (SHI) at the national level acts as a payer for health care goods and services in a country. The Badan Penyelenggara Jaminan Sosial Kesehatan (BPJSK) is the single SHI agency in Indonesia while its counterpart is the Philippine Health Insurance Corporation (PHIC) in the Philippines (26, 34). The BPJSK and the PHIC finance essential primary care and specialized care of majority of the acute and chronic illnesses throughout both the private and public hospital networks. In the face of limited resources in the public health sectors of Indonesia and the Philippines, SHI agencies have to do "strategic purchasing" —essentially to be cost-conscious and efficient in the selection of cases to be paid for from the pooled funds.

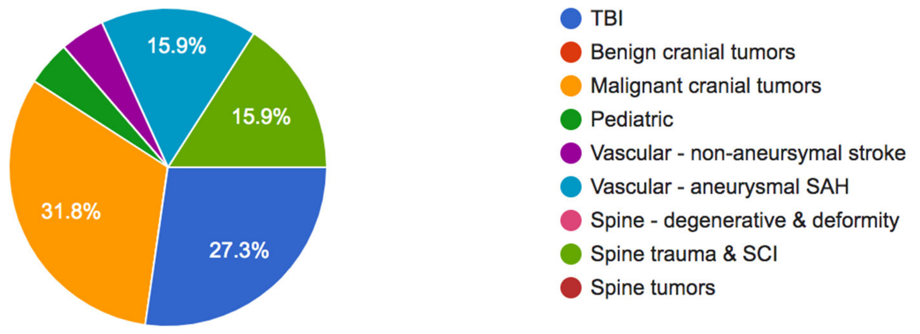

FIGURE 1 | Neurosurgical conditions causing the worst economic hardship among patients.

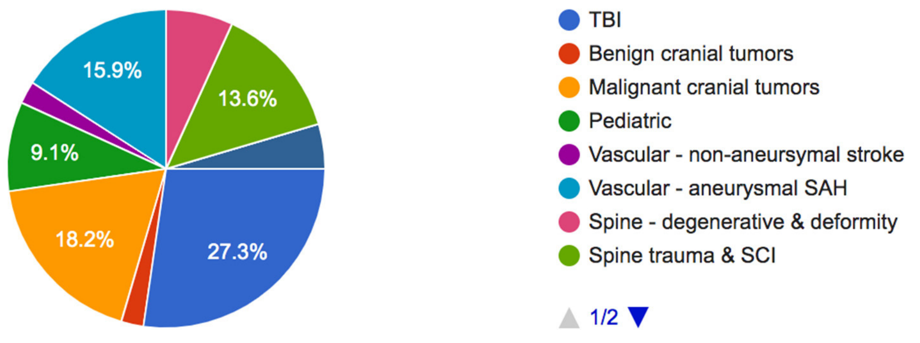

FIGURE 2 | Neurosurgical conditions necessitating greater financial subsidy.

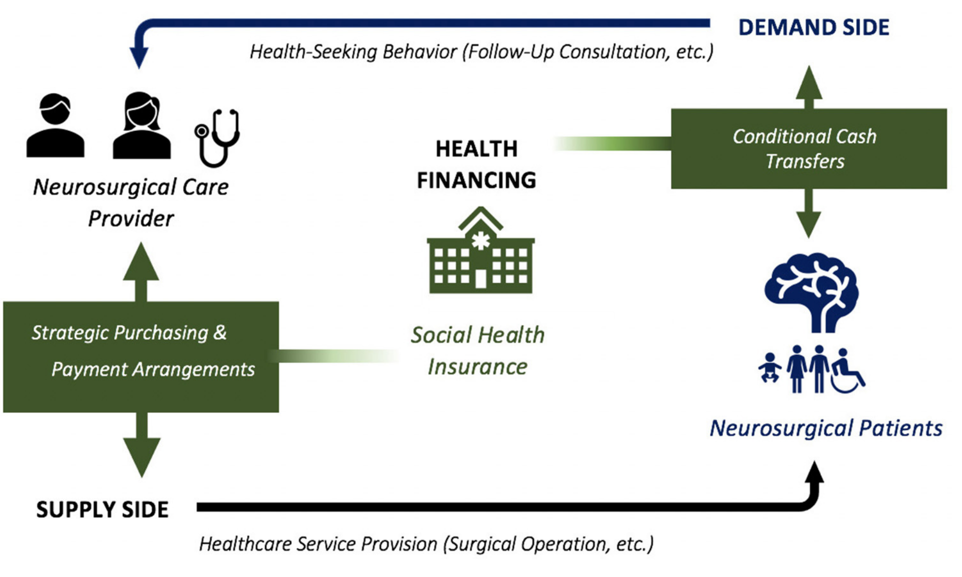

FIGURE 3 | Framework for policy and implementation of health financing as applied to neurosurgery.

Financial incentives or other mechanisms can motivate surgical providers to improve quality and efficiency of care, or to respond to increased patient demand. Similarly, poor patients respond to cost savings in the treatment of their illnesses. SHI agencies can certainly play a role in providing economic incentives—in the form of conditional cash transfers, for example—for improving intermediate indicators of treatment success as well as clinically important outcomes. See **Figure 3** above for the framework.

POTENTIAL HEALTH FINANCING SOLUTIONS

Supply-Side Financing: Strategic Purchasing of Neurosurgical Services

Ideally, the role of the SHI is to ensure that adequate resources are mobilized to meet the service entitlements of insured patients—ideally the whole population—and thus achieve "universal health coverage." While financial risk pooling is important for equity considerations and financial risk protection of the insured, an added function of strategic purchasing by the SHI can drive the quality and efficiency of healthcare provision (1, 32, 35). Certain strategic purchasing methods can modify healthcare providers' behaviors in their treatment decisions and ultimately influence the quantity, quality, and efficiency of neurosurgical care for example. The choice of which disease condition to subsidize is a matter of policy and executive decision, but is mostly founded on data on the costs of treatment, the burden of the disease, and the cost-effectiveness of interventions (36). Assuming the role of strategic purchaser, the SHI selectively enters into a contract with neurosurgical care providers. Providers in this sense would mean the hospital or institution including the neurosurgeons and allied health professionals. The purchaser and the provider then agree on a provider payment method for a standard treatment regimen.

Consider for example—traumatic brain injury (TBI)—for which the current standard of neurosurgical management is entrenched in universally accepted clinical practice guidelines (37). Prehospital management of a brain-injured patient is time-critical. In an analysis of the largest TBI database—the International Mission for Prognosis And Clinical Trial (IMPACT) database—Mushkudiani and colleagues concluded that outcome following TBI is also dependent on race and to a lesser extent on the level of education of the patient, even when adjusting for other causes (18). The underlying reason can be traced to limited access to acute and post-acute care (20, 21); therefore, prehospital and acute hospital care systems ought to be efficiently responsive to socioeconomically disadvantaged patients with TBI (38). Indonesia and the Philippines have the twin problem of a low neurosurgeon-to-population ratio −1 per 731,000 and 1 per 807,000, respectively (30)—and a high prevalence of TBI estimated at around 930 per 100,000 population in the Southeast Asia/Western Pacific region (39). This situation is exacerbated by constraining financial considerations whereby a poor TBI patient often gets rushed to the emergency department of a much farther public hospital despite the proximity of a private hospital with neurosurgical services at the time of injury. This adverse selection by private hospitals presents an added disadvantage for an already economically disadvantaged patient with TBI, whose clinical outcome could have been better were it not for a delayed neurosurgical treatment.

Conceptually, strategic purchasing allows buying of health services for certain groups of patients and uses financial levers and payment schemes that influence the behavior of providers including hospitals and neurosurgeons (35, 36, 40). The results of our survey in this study indicate that TBI is viewed as requiring greater financial subsidies, as similarly found in other studies (22, 23, 41). The case for subsidizing the full costs of treatment for patients with TBI is also justified by its cost-effectiveness (42). Strategic purchasing can realize this through contractual arrangements that would link attractive payment mechanisms to the goal of broadened access to emergency neurosurgical care for TBI patients who are brought to the nearest emergency care facility without regard to the patient's ability to pay or the type of facility, whether public or private. Given the context of a low neurosurgical workforce in both Indonesia and the Philippines, a task sharing scheme with colleagues from the fields of trauma and general surgery can also be contractually set in place with the goal of increasing access to timely neurosurgical trauma referral (43). A catastrophic illness benefit package may be formulated by both the BPJSK and the PHIC that would elevate the financial incentive for all neurosurgical care providers to accept and manage TBI patients regardless of socioeconomic status (44, 45). Greater acceptability and buy-in of this mechanism by neurosurgical providers are afforded by strategic purchasing because the costing and payment schedules are negotiated and prearranged in collaboration with the providers themselves. The payments from SHIs to neurosurgical providers can be further complemented by an element of pay-for-performance (32), with a proportion of the fixed payment withheld and paid according to certain indicators such as timeliness of the surgical operation (46), long-term outcomes assessment (47), and even patient satisfaction with the neurosurgeon-patient engagement (48). In this way, the goal of quality care can be achieved for the neurosurgical management of patients with TBI.

A prospective payment scheme brought about by strategic purchasing can enable the pooling of paid out funds on the part of provider hospitals to accrue future savings (36). The increased generation of revenue at the level of the hospitals can result in upfront investments that will finance the capital outlay costs for scaling up infrastructure and equipment needs, e.g., expansion of neurosurgical bed capacity, addition of dedicated neurosurgical operating theaters, or procurement of costly neurosurgical equipment. In this manner, the improved capacity of the provider hospital can increase neurosurgical volume and the goal of increased access to neurosurgical care can be achieved. In **Table 1** below, we summarize other examples of strategic purchaser-provider arrangements.

Demand-Side Financing: Conditional Cash Transfers for Neurosurgical Patients

Neurosurgical patients, herein considered the demand side of healthcare provision, constitute an important stakeholder in terms of health financing. Despite the fact that surgery in public hospitals is completely subsidized by the BPJSK in Indonesia and the PHIC in the Philippines—at little to zero cost for indigent patients—there remain substantial financial barriers (36). Frequently, financial catastrophe comes from non-medical costs of care, such as the cost of transportation and living expenses of the caregiver (1, 2). For socioeconomically disadvantaged patients in the Philippines, even in-person outpatient follow-up after neurosurgery entails catastrophic

TABLE 1 | Purchaser-provider contractual management for health financing.

Strategic purchasing functions*	Examples for neurosurgery
1 Providing an appropriate range of services and locations relative to the distribution of the population by means of effective gatekeeping and referral	• Assignment of tiered neurosurgical centers (e.g., higher level and lower level) with a predefined catchment population based on geography and complexity of disease condition • Creation of centers of excellence for certain neurosurgical disease conditions based on available expertise of subspecialist neurosurgeons
2 Selecting providers for accreditation	• Designating and credentialing private hospitals that are capable of accepting and managing traumatic brain injury and emergency neurovascular diseases • Selective contracting and progressive policy of deliberated reimbursement of expenses by accredited private hospitals that are incurred during emergency operations for indigent patients with traumatic brain injury and stroke
3 Implementing provider payment methods efficiently, as in a prospective payment system	• Creation of a catastrophic illness benefit package for traumatic brain injury and/or malignant intracranial tumors • Capitation funding for every indigent patient who gets admitted in a private hospital on an emergency basis and who needs life-saving neurosurgical intervention
4 Making use of monopsonistic purchasing power	• Public-private partnership and debt financing for the capital outlay of infrastructure projects • Economies of scale purchasing arrangements for neurosurgical consumable implements
5 Introducing generic essential drugs, devices, or implants lists	• Creation of a medicines access program for disease-altering drugs, e.g., temozolamide for patients with gliomas • Consignment and purchasing arrangements for steady supply of cranial and spinal implants and instrumentation
6 Monitoring provider performance in terms of quality and efficiency	• Establishing a prospective database of outcomes report following surgery and adjuvant chemoradiotherapy for patients with gliomas • Merit-based payment and reimbursement of neurosurgical centers based on volume-outcome relationships, e.g., high-volume centers doing >10 intracranial aneurysms per year will have seamless financing for purchase of aneurysm clips
7 Ensuring mutual accountability between purchasers and providers through timely payments to healthcare providers and appropriate audit systems	• Checks and balances system that would minimize fraud and pilferage of payments and reimbursements, e.g., repeated neuroimaging of neurosurgical patients will have to be easily cross-checked through linkage with information technology systems • Strict penalty system for breach in contracts when it comes to timeliness of reimbursements, especially for time-critical and life-threatening neurosurgical operations

**Adapted from: Trisnantoro L, Hendrartini J, Susilowati T, Miranti PAD, Aristianti V. Chapter 3: A critical analysis of selected healthcare purchasing mechanisms in Indonesia. In: Honda A, McIntyre D, Hanson K, Tangcharoensathien V. ed. by. Strategic Purchasing in China, Indonesia, and the Philippines (Comparative Country Studies, Vol. 2 No. 1 2016). Geneva: World Health Organization; 2016. p. 124.*

expenses and may cause adverse life events that can negatively impact health-seeking behavior overall (49).

The results of our survey show that out-of-pocket expenses surrounding the management of those with malignant intracranial tumors are a prevalent form of health financing in Indonesia and the Philippines. For majority of patients with brain cancer in Indonesia and the Philippines, the standard Stupp protocol for the treatment of glioblastoma could bankrupt their families—often resulting in the patient never receiving or completing the disease-altering adjuvant chemotherapy and radiotherapy. Adjuvant chemotherapy for glioblastoma is carried out on an outpatient basis: consultations are done at the oncology clinic during the course of the patient's ongoing intake of oral drugs (temozolamide). However, SHIs are currently not fully responsive in the aspect of financing for adjuvant therapy and outpatient care. The responsibility of payment for the adjuvant treatments is frequently left to the social welfare division of the hospital or external charitable organizations (45). In the Philippines, the PHIC pays for a so-called "Z Benefit" package for the full treatment course of certain catastrophic illnesses including early breast, colon, and rectum cancers, but not brain cancer. The subsidies offered by the PHIC for colorectal and breast cancer patients have helped achieve better mortality rates and overall better compliance to treatment. In Indonesia, patients with glioblastoma get full subsidies but the BPJSK no longer routinely pays for the treatment costs of recurrent glioblastoma. In the two countries, this situation results in dismal follow-up at baseline and at worst, poor long-term survival among patients with glioblastoma.

The case for subsidizing the full costs of treatment for patients with glioblastoma is justified by its cost-effectiveness (50) and the fact that brain cancer is one of the leading neurological causes of mortality in the Southeast Asian region that are relevant to the neurosurgeon (51). While full subsidies for the Stupp protocol through some form of strategic purchasing appears to be the preeminent solution, the added strategy of using cash transfers for patients with glioblastoma can modify the behavior of the demand-side of neurosurgical care provision. Conditional cash transfers (CCT)—in which recipients are given some amount of money, often conditional on their adherence to a desired behavior—have been used by social welfare programs to reduce poverty and to incentivize salutary action for a number of public-health interventions (52, 53). In Indonesia and the Philippines, a CCT scheme is employed in both countries as a form of social assistance; but unique to the Philippine context is the use of CCT to encourage health-related behaviors among household beneficiaries in addition to the requirement of sending the children to school (54). This health-related requirement however, is only limited to attendance in family development lectures on parental, family, and community responsibilities (54). While there is high-quality evidence that the effects of CCT translate to better outcomes in terms of family and child health (55), similar evidence for surgical, or even neurosurgical care for that matter, currently remains limited. Determining the optimal amount of cash transfers that would modify the health-seeking behavior of surgical patients can be difficult but recent findings from a modeling study suggest a dose-response relationship between the amount of money given and compliance to scheduled surgery (56). The study by Strader et al. noted that until after baseline costs of surgery are paid for by the purchaser—and thus becomes free for the patient—only then can any incremental increase in the amount of cash transfer be expected to improve compliance.

CCTs for patients with glioblastoma may be done to decrease the no-show rate in follow-up consultation schedules and improve the all too common problem of loss to follow-up. The direct provision of cash for indigent patients can be made contingent on their adherence to adjuvant treatment following neurosurgical operation for glioblastoma. In turn, the families' non-medical costs are also subsidized. Furthermore, CCTs also have positive externalities and can be expected to increase the propensity of the household members to have some degree of trust in the systems of healthcare provision and health financing. In this manner, financial barriers to neurosurgical services are actually lowered and a system is set in place to reward beneficial health-seeking behavior that impacts patient outcomes.

CONCLUSION

Neurosurgical patients living in Indonesia and the Philippines who are socioeconomically disadvantaged to begin with have the added challenges of incurring out-of-pocket expenses and risking financial catastrophe whenever they navigate the health system for treatment. This situation calls for a more robust and responsive health financing for neurosurgical services. From an economic perspective, health financing for neurosurgery entails the proposition for addressing the demand (patient) or supply (provider) sides of healthcare provision. Strategic purchasing enables a systematic and contractual management of payment arrangements that provide performance-based economic incentives for providers that can in turn help achieve the goals of quality and efficiency of neurosurgical care provision. Conditional cash transfers similarly leverages on financial incentives on the part of patients to reward certain health-seeking behaviors that significantly influence clinical outcomes. These health financing strategies are formulated in order to ultimately build neurosurgical capacity in LMICs, improve access to care for patients, and ensure financial risk protection. It is hoped that this article provides a framework for implementation and affords a basic understanding of health financing that can inform policy and advocacy work among neurosurgeons globally.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

KF, MY, and MB initiated and conceptualized the article design. KF drafted the manuscript. KF and DW collected and interpreted the data. MY, MB, SM, IW, RR, KS, and JN critically examined and commented on the manuscript. All authors revised and approved the manuscript.

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The Incorporation of Neurosurgery as an Integral Part of the Strategic Priorities for Surgical Care in Nigeria

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INTRODUCTION

In 2015, the Lancet Commission on Global Surgery estimated nearly 70% of the world still lacked access to safe, affordable emergency and essential Surgical, Obstetrics and Anesthesia (SOA) care, which disproportionately affects those in low- and middle-income countries (LMICs) (1). Pursuant to this landmark study, the World Health Assembly (WHA) passed resolution 68:15 which mandated countries to include emergency and essential surgical, obstetrics and anesthesia care as an integral component of Universal Health Coverage (UHC) (2). This was catalytic in leading Nigeria's Federal Ministry of Health (FMoH) to develop and implement the National Surgical, Obstetrics, Anesthesia and Nursing Plan (NSOANP) in 2017 (3). This plan, dubbed Strategic Priorities for Surgical Care (StraPS), introduced specific surgical system targets and an implementation roadmap that prioritized monitoring, evaluation, and feedback for central and state governments to follow.

Although most Nigerians can reach a healthcare facility within 2 h, the vast majority of these public healthcare centers (aside from the tertiary hospitals) do not have the human resources and infrastructure to provide emergency and essential surgical care when needed. Furthermore, the lack of adequately equipped and fully functional children's hospitals limit the delivery of emergency and essential surgical care for children.

The importance of StraPS was that it afforded children under 15 years old (which constitute 43% of the population in Nigeria) to receive surgery in a surgical plan for the first time while addressing the surgical needs of this unique demographic entity. In addition, StraPS specifically included nursing care, which forms an inseparable component of surgical quality and safety, to ensure nursing is captured in surgical training and workforce development programs.

After brief historical context and an evaluation of the current NSOANP, we provide a brief overview of neurosurgery in Nigeria and current effort toward capacity-building. We then provide a list of recommendations the Nigerian government can adopt in order to improve the quality and delivery of neurosurgical services.

Neurosurgery and Nigeria's NSOANP

Despite the success of StraPS in prioritizing pediatric surgery and nursing, garnering political support and will for neurosurgical systems strengthening has remained a challenge in Nigeria.

Nigeria has a long tradition of producing excellent neurosurgeons, with the first training program being established in October 1962 under the leadership of the late E. Latunde Odeku (4). Since then, Nigeria has produced several training centers across the country, with close to 100 locally trained neurosurgeons in the last decade as well as the first female neurosurgeon in West Africa. However, lingering challenges which include limited training programs, a dearth of financial investment for educational resources, and insufficiently equipped health facilities continue

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to create difficulties in accessing care for many patients, which include the prohibitive upfront and catastrophic costs of neurosurgical intervention and follow up care. Therefore, given Nigeria's sizable population, the current workforce remains grossly inadequate despite the laudable recent efforts in increasing the neurosurgical workforce. In addition, this limited, inadequate neurosurgery workforce is largely domiciled within the urban setting, whereas, the large majority of the Nigerian population (60.4%) living in the rural communities are completely deprived of easy access to neurosurgical services (5, 6).

Neurosurgery has been addressed in several contexts in Nigeria's NSOANP, though there are specific areas that require further investigation and investment. For example, the World Health Organization's recommendation is an ideal ratio for every population to be 1 neurosurgeon to 100,000 individuals (7). Within Nigeria's NSOANP, that figure is currently cited to be 0.01 neurosurgeons per 100,000 individuals, which leaves significant room for improvement in order to achieve an acceptable standard of care.

Importantly, the NSOANP does cite neural tube defects as priorities of basic surgical care provision, which is in line with the commonly agreed upon comprehensive spina bifida and hydrocephalus recommendations. Additionally, the intermediate surgical care scope of practice emphasizes the diagnosis and stabilization of neurological trauma such as evacuations for epidural hematoma or emergency burr holes, which is specifically important given the preponderance of traumatic brain injury in LMICs such as Nigeria.

Under the tertiary level scope of practice, the NSOANP also highlights the importance of adequate neuro-anesthesia, which is essential to ensuring neurosurgical intervention can be performed safely and effectively. Neurovascular injuries are also prioritized within this scope, as are congenital anomalies such as meningomyelocele and hydrocephalus, and infections such as intracranial or vertebral osteomyelitis, all suggesting the NSOANP supports these critical elements of neurosurgical care provision.

While the NSOANP makes significant strides in highlighting essential components and the cost necessary for scaling up surgical (including neurosurgical), obstetric, and anesthesia care, it does not detail the specific investments necessary to bring about the desired improvements in prioritizing surgical intervention as well as the larger benefits to society. In other words, there does not appear to be a strategy for funding the plan. For example, per the World Health Organization's recommendations, each nation should dedicate at least 5% of its annual budget to health (7). Presently, per capita public spending for health remains significantly below the US$34 recommended by WHO for low-income countries. A significant increase in investment would be a necessary first step to providing sufficient financial investment for surgical/neurosurgical systems strengthening.

Additionally, plans for scaling up prehospital care which would significantly improve mortality rates from road traffic accidents and time to surgical intervention should be included in a subsequent iteration of this NSOANP. The current literature suggests neurosurgical intervention improves markedly provided timely arrival at a care facility and prompt provision of hemostasis or ICP monitoring, both of which are not specifically mentioned in this current version of the NSOANP. Additional investments such as these will be critical in garnering the necessary political will to invest in neurosurgery and meet both the appropriate workforce demands as well as the harrowing global neurosurgery case deficit, whose burden Nigeria disproportionately suffers from.

Neurosurgical Recommendation for Consideration in Nigerian's NSOANPS

In the light of this massive neurosurgery care deficit and the enormous challenges that limit the scope of neurosurgical practice within the country, there is a need for a concerted effort aimed at making these services available, accessible and affordable. A deliberate, multipronged approach may be required to address this harrowing issue, which may include the following:

There is an urgent need to include neurosurgical trauma (emergent craniotomies, burr holes and craniectomies) and neural tube anomalies as part of essential and emergency surgical care (i.e., Bellwether procedures) to be performed at minimum of a secondary (intermediate) care level. This is in keeping with the vision of NSOANPS, that is, of a national healthcare system responsive to the surgical needs of all citizens, at all times. This is supported by the fact that neurotrauma cases significantly account for the burden of surgical emergencies in most of the tertiary facilities in Nigeria (3, 6, 8, 9).

The NSOANPS should also consider within its armamentarium the development of a national neurosurgery or trauma care system. This should include, but not limited to, the development of an effective prehospital service system for neurotrauma care, akin to what several nations and regional blocs have recently implemented. In the immediate period, this can be achieved by training of some dedicated members of the available and already existing Federal Road Safety Corp (FRSC) officers and members of the national emergency management agencies (NEMA), to undertake immediate evacuation, Basic Life Support (BLS) resuscitation and transportation of trauma victim, to a nearby facility with capacity for immediate stabilization and resuscitation of such patients. On a long-term basis, a formalized neurotrauma registry should be developed for national monitoring. Such neurotrauma registries allow for simple demographic and case-specific information to be collated within a database for data, thereby allowing for tracking of disease pathologies, a reduction of delays to surgery and overall improved patient outcomes. Furthermore, the development of these registries could bolster other national health priorities, by being repurposed toward enhancing performance improvement processes through outcomes evaluation and allowing for streamlined provider credentialing, accreditation, and verification. In tandem, additional structures can be put in place to encourage private sector participation in prehospital emergency service delivery and transportation. This will encourage and strengthen the implementation of existing national ambulance policy, as suggested in the NSOANPS documentation (3).

As part of an effective approach to neurosurgery access, the Strategic Priorities for Surgical Care (StraPS) of the Federal Ministry of Health (FMoH) should consider the development of an appropriate referral, transport and feedback system, between hospitals with and those without neurosurgery services. Such a strategy will require a multi-disciplinary team approach, with well-defined roles and responsibilities and a proper communication network system. This approach will help eliminate the common yet erroneous perception that, surgery frequently consists of a surgeon and an anesthetist in a sterile environment. However, a more accurate perspective acknowledges an interdependent network of individuals and institutions all essential to the delivery of safe, timely, and affordable surgical and anesthesia care. Many of these components are not standalone requirements for a surgical system, but rather for a shared delivery infrastructure that is the basis of a functional health system.

There is an urgent need to address the scope and challenges of the neurosurgical work force deficit in Nigeria, which NSOANPS currently captures as 0.01 neurosurgeons per 100,000 individuals (3). A two-tiered approach to training can be adopted in order to address the immediate need while working on the long term strategy to improve the number of trained neurosurgeons in the country. For example, a fast – tracked, competency-based certification of General and Pediatric surgeons who are capable of performing neurotrauma operations and neural tube defect surgeries could be adopted. Secondly, the acceleration of neurosurgical training by both the National Post graduate Medical College of Nigeria (NPMCN) and West African College of Surgeon (WACS), through the promotion and retention of neurosurgery faculty and the establishment of an appropriate curriculum that allows interested candidates the opportunity to proceed immediately into neurosurgery training without going through a general surgery training. This approach was also recommended by Parks et al. in "addressing the problem of restricted access to neurosurgical care in rural sub-Saharan Africa" (10). Accordingly, novel training models could also be adopted, especially those aimed at improving the quality of neurosurgical education via electronic video or zoom conferences at partner institutions. Such platforms, examples of which include Proximie, OssoVR, and PrecisionOS, allow trainees to discuss complex cases simultaneously with other centers worldwide and should be incorporated into neurosurgery training programs (11).

The establishment of twinning programs with partner facilities and institutions in high income countries (HICs) for collaborative training and research opportunities has also been demonstrated to improve access to quality and safe neurosurgical service, and could be a priority for Nigeria (12). These novel paradigms, such as the International Neurosurgery Twinning Initiative Modeled for Africa (INTIMA), apply a multi-phased approach in resolving identified gaps in neurosurgical infrastructure and care pathway that will sustain or deepen the dimensions of unmet neurosurgery in a given local environment (13, 14). Moreover, there is a need to actively encourage, recruit and retain students and young physicians interested in neurosurgical practice into the field and also retain the existing neurosurgeons by preventing further "brain-drain" within the country, consistent with previous trends (10, 15).

Financing for Essential Neurosurgical Services

Surgical care financing in Nigeria follows the same trend as the financing of healthcare costs in the country, which remains suboptimal. Furthermore, due to the abysmal funding of health care services by the federal government budget in Nigeria, patient's out of pocket expenditures have been shown to be around 73%, yet this remains the most common source of financing health care cost in the country. Other means include public spending on healthcare (12%), health insurance (<3%) and the rest being donor funding. Neurosurgical services within Nigeria remain costly due to the high costs of manpower training and equipment, and accessing such services by households to cover surgical care frequently results in catastrophic expenditure. Therefore, the inclusion of all essential neurosurgical services (operative and non-operative) into the National Health Insurance Services (NHIS) scheme, in addition to the numerous recommendations for the financing of surgical care outlined in the NSOANPS document should be given serious consideration by government and policy makers. This will help bridge the gaps in accessing timely, affordable, quality and safe neurosurgical care (3).

The Importance of Neurosurgical Infrastructure

For a health care system to meet the surgical needs of the population there is also a need for appropriate infrastructure and equipment to support the human resources in delivering efficient health care and surgical services, which is equally important for neurosurgical services in Nigeria. Therefore, the establishment of efficient and effective procurement and logistics management systems is required. This helps to ensure the ongoing availability of medical and neurosurgical supplies and consumables at all levels of neurosurgery care.

Additional strategies, such as the provision of functional, up-to-date, affordable, high quality and durable equipment through an efficient import system, private public partnerships and international collaboration with agencies or hospitals that are willing to supply or donate equipment to developing countries, should be employed as well. Sustainable local production of all or parts of the necessary equipment should be encouraged, as should adequate training of biomedical engineers and technicians to manage and maintain the appropriate neurosurgical infrastructure. Planned regular maintenance and calibration of equipment, with up-to-date procurement or access to spare parts through maintenance and supply contracts with manufacturer services should also be put in place. Periodic audit of available and functional equipment and provision of back-up mechanisms, to ensure compliance with accepted international safe standards should be promoted.

The promotion of neurosurgery research, through national and international collaboration is an area largely neglected by most authors advocating for improved, affordable and accessible neurosurgical services in developing countries and Nigeria. The NSOANPS policy document laid little or no emphasis on research as an important aspect of improving surgical care. High-quality medical research can guide clinical practice, inform health policy formulation and implementation. Importantly, neurosurgery research was seen as an important recommendation for improving and expanding neurosurgery services by some authors (16–20).

CONCLUSION

The engagement of the neurosurgical community with health care planners and policy makers to establish and acknowledge the value of providing neurosurgical care in their countries was recently codified in the Bogota Declaration, signed by eminent members of the global neurosurgical community and endorsed by a representative of the WHO in late 2016 (15, 21).

The advocacy and sensitization of the Nigerian government and policy makers on the importance and need for improved, safe neurosurgery services that are easily accessible and affordable should be the driving force behind achieving the Strategic Priorities for Surgical Care (StraPS) with respect to neurosurgery in Nigeria. Such advocacy will also necessarily involve hospital administrators and end users as well. The neurosurgery community within the country needs to advocate for mentorship and training of its members as to how to achieve self-determination, self-improvement and self-motivation, all of which are key strategies to providing comprehensive and effective neurosurgical services, in addition to the strategies outlined above toward improving the provision of neurosurgical care in Nigeria.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Emphasizing the Role of Neurosurgery Within Global Health and National Health Systems: A Call to Action

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Background: Worldwide, neurological disorders are the leading cause of disability-adjusted life years lost and the second leading cause of death. Despite global health capacity-building efforts, each year, 22.6 million individuals worldwide require neurosurgeon's care due to diseases such as traumatic brain injury and hydrocephalus, and 13.8 million of these individuals require surgery. It is clear that neurosurgical care is indispensable in both national and international public health discussions. This study highlights the role neurosurgeons can play in supporting the global health agenda, national surgical plans, and health strengthening systems (HSS) interventions.

Methods: Guided by a literature review, the authors discuss key topics such as the global burden of neurosurgical diseases, the current state of neurosurgical care around the world and the inherent benefits of strong neurosurgical capability for health systems.

Results: Neurosurgical diseases make up an important part of the global burden of diseases. Many neurosurgeons possess the sustained passion, resilience, and leadership needed to advocate for improved neurosurgical care worldwide. Neurosurgical care has been linked to 14 of the 17 Sustainable Development Goals (SDGs), thus highlighting the tremendous impact neurosurgeons can have upon HSS initiatives.

Conclusion: We recommend policymakers and global health actors to: (i) increase the involvement of neurosurgeons within the global health dialogue; (ii) involve neurosurgeons in the national surgical system strengthening process; (iii) integrate neurosurgical care within the global surgery movement; and (iv) promote the training and education of neurosurgeons, especially those residing in Low-and middle-income countries, in the field of global public health.

Keywords: global neurosurgery, health system, global surgery, NSOAP, surgical system, UHC

INTRODUCTION

In 2015, the United Nations (UN) made a commitment to ensure safe and affordable access to healthcare for every person in the world through the 3rd Sustainable Development Goal (SDG3) (1). This goal will only be achievable with strong and efficient health systems that address the different categories of diseases in proportion to the epidemiological burden they represent. An article published in the same year, 2015, estimated that 5 million people worldwide do not have access to quality, safe and affordable surgical care (2). In recent years, both governmental and non-governmental agencies have developed a keen interest in promoting access to safe and reliable surgical care. The World Health Organization (WHO), an example of such organizations, has recognized the essential role of quality surgical care in global and national efforts to achieve universal health coverage (UHC) by 2030 (3).

There is a wide range of conditions that constitute surgical diseases, and many of them are debilitating. A subset of these conditions is neurologically related and require management by a neurological surgeon. Recently, many efforts have been made to improve access to surgical care in general-an example being the country-driven National Surgical, Obstetrics and Anesthesia Plans (NSOAPs) (4). However, little effort has been focused on neurosurgery despite neurosurgical diseases being a major contributor to the global burden of death and disability (5). Diseases such as traumatic brain injury, hydrocephalus and spina bifida affect millions of children and adults worldwide (6). It is, therefore, clear that UHC cannot be achieved if neurosurgical care is not integrated and prioritized through health policies and programs to strengthen health systems.

In this article, we present the major challenges in global neurosurgery and we aim to discuss the potential benefits an effective neurosurgical system can bring to healthcare systems. Finally, we launch a call to action to urge policymakers, global health leaders and country leaders to prioritize neurosurgery and integrate it into their public health and global public health interventions.

GLOBAL BURDEN OF NEUROSURGICAL DISEASES AND THE DISPROPORTIONAL EFFECT ON LMICs

Worldwide, neurological disorders are the leading cause of disability adjusted life years (DALYs) lost and the second leading cause of death, according to a 2016 analysis (5). Each year, 22.6 million individuals worldwide require neurological care due to diseases such as traumatic brain injury, stroke, brain tumor, and epilepsy, and 13.8 million of these individuals require surgical intervention (7). Traumatic brain injuries are common worldwide, with a prevalence between 55 to 69 million, but disproportionately affect individuals in low- and middle-income countries (LMICs) (8). This results in an increased neurosurgical burden of disease in LMICs. Yet, each year 5 million people in LMICs will require but not receive neurosurgical intervention because of limited capacity and resources, hence necessitating an additional 23,000 neurosurgeons to meet population demands (7).

Delays in accessing care for neurological diseases lead to poor outcomes for patients. The percentage of the population with access to neurosurgical services within a 2 h window is 25.26% in sub-Saharan Africa, 29.64% in East Asia and the Pacific, 52.83% in South Asia, 62.3% in Latin America and the Caribbean, 79.65% in the Middle East and North Africa, and 93.3% in Eastern Europe and Central Asia (9). These statistics highlight the large global disparities in access to timely neurosurgical care among different populations.

The unmet neurosurgical demand in LMICs not only increases unnecessary morbidity and mortality rates, but it also produces devastating economic effects. Differing models predict gross domestic product (GDP) losses of between \$3–4.4 trillion (in US dollars in 2013, adjusted for purchasing power parity (PPP) in LMICs due to the unmet need for neurosurgical care, mostly as a result of stroke and traumatic brain injuries (10), while a model looking at economic loss due to unmet epilepsy surgical needs project losses of \$258.95 billion (11) (in US dollars in 2016, PPP-adjusted). These economic losses hinder the ability of LMICs to reach both health and broader sustainable development goals, thus trapping citizens in a vicious cycle of poverty.

CURRENT STATE OF NEUROSURGICAL CARE AROUND THE WORLD: WORKFORCE DEFICIT AND LACK OF GLOBAL NEUROSURGERY CAPACITY BUILDING IN CURRENT GLOBAL HEALTH EFFORTS

Despite the advocacy efforts toward, ensuring surgical equity worldwide, an estimate of "5 billion people lack access to safe and affordable surgical and anesthesia services," and this number is predicted to increase if critical actions are not taken. To date, neurosurgery still records an overwhelming unmet need. LMICs, in particular, have the greatest unmet neurosurgical disease burden, attributed by the small ratio of neurosurgeons per capita, and the difficulty in accessing neurosurgical care (12–14). Poor access to neurosurgical services is a result of many factors such as insufficient infrastructure, inadequate training, limited workforce, and the geographical location of care centers (15, 16).

The neurosurgical workforce density is yet to meet the unmet burden of neurosurgical diseases, despite increasingly growing workforce density seen in many countries around the globe (14). Africa still has the lowest neurosurgical workforce density globally, yet there are no indicative initiatives that can fill this gap by 2030 (17). Moreover, an analysis on number of neurosurgeons in east Asian countries, conducted in 2019, found that LMICs such as Indonesia, Malaysia, and the Philippines have neurosurgeon to population ratios of 1 per 731,000, 1 per 210,000, and 1 per 807,000, respectively while high-income countries (HICs) such as Japan and Taiwan have ratios of 1 per 13,000 and 1 per 37,000, respectively (18). This geographic maldistribution of neurosurgical workforce, as seen in eastern Africa and east Asia (12), is an indication that neurosurgical equity is yet to be attained globally, therefore prompting the call for action by the WFNS Global Neurosurgery Committee to ensure that neurosurgery is well established as a global health priority.

Furthermore, the lack of neurosurgical research limits the development of neurosurgery; this is seen in countries in Southeast Asia and Africa. HICs such as the United States of America and Canada produce 90 times more research about neurosurgery than Africa and Southeast Asia combined (19). Of note, a review of the state of global neurosurgery research in the world found no published literature from 113 LMICs (20). Mitigating this issue would include initiatives such as bilateral partnerships between institutions in HICs and LMICs and the provision of opportunities for capacity-building to encourage researchers to conduct and publish research that contribute to the global neurosurgery literature in LMICs (21).

Conclusively, there is still limited global neurosurgery capacity building in training allied health professionals to aid the cases done by neurosurgeons as well as to decrease their burden. There is a huge disparity between neurosurgery programs in HICs and those in LMICs in terms of surgical equipment and the suitability of facilities, and this is compounded by the paucity of literature focused on information management for neurosurgical care in LMICs. Nevertheless, although the literature is still surfacing, there is hope that the few that exist can be used to advise policy changes in order to bridge the gap.

THE INHERENT BENEFITS OF STRONG NEUROSURGICAL CAPABILITY FOR HEALTH SYSTEMS

The development of the SDGs have emphasized different parameters that are integral to a sustainable development that range from healthcare to ecological welfare. SDG3 (good health and well-being) introduces the narrative of global surgery which, in turn, has accumulated interest in ensuring the development of global surgical provision is effective and equitable, especially through the 2015 Lancet Commission on Global Surgery which previously focused on the lack of surgical care worldwide (2). Within this scope, there is an increasing need for physician-led management and leadership to develop these health systems on a global scale. Currently, the recent yet rapid development of global neurosurgery has demonstrated that there are many neurosurgeons who possess the sustained passion, resilience, and leadership needed to advocate for improved neurosurgical care worldwide.

Given the cross-cutting nature of neurosurgical care, developing this area in healthcare systems creates the ecosystem for the majority of other health interventions. Therefore, improving neurosurgical care will improve the whole health system in every domain, especially in terms of workforce, infrastructure and service delivery. Furthermore, the key traits necessary in effective leadership and management are uniquely developed via the process of neurosurgical training. Neurosurgical training is an arduous and competitive process which involves making difficult decisions under highly stressful situations on a daily basis. The skills and attributes seen in neurosurgeons have piqued interest about potential neurosurgeon involvement in developing health systems (22). The duties and scope of neurosurgery has been linked to 14 of the current 17 SDGs highlighting the tremendous impact neurosurgeons can have within wider development, let alone health systems (23). Andrews et al. has suggested drawing inspiration from models of neurosurgical care in certain LMICs to build response systems to natural disasters (24).

THE GLOBAL NEUROSURGERY MOVEMENT: PURPOSE AND VISION

The primary purpose of global neurosurgery must be to reduce disparities in global care and to allow the area of need to become independent, self-sustaining, and creative in its care. Global neurosurgeons can play a role in inspiring the next generation of students interested in neurosurgery (25). Increasing the exposure of neurosurgery to medical students will enable the interest in the specialty to be nurtured in as many individuals as possible at an early stage in their career. Training more neurosurgeons and neurosurgery capable providers will be an effective solution for closing the gap in the neurosurgeon to population ratio.

Lastly, the success of global neurosurgery can only be realized if founded on the principles of cultural sensitivity (26). It is imperative to listen to the experts and leaders in the countries of need, to let them tell us their needs, goals, and aspirations, and to champion for sustainable change and progress in solving these problems.

DISCUSSION

The significant volume of neurosurgical diseases in the global burden of disease makes their treatment essential in the marathon toward UHC. Furthermore, neurosurgical care has been linked to the SDGs and the positive impact of neurosurgeons within health systems has been reported and established. The workforce is one of the most important pillars within a health system and the great disparity between the density of the neurosurgical workforce between HICs and LMICs is one of the biggest contributors of health inequity around the world.

Establishing the structures necessary for surgical care will have significant benefits for the overall health system.

Several advocates for global health have raised their voices recently to stress the fact that surgical care is neglected within overall health. Neurosurgery itself is yet to be of priority on the global health agenda despite being one of the most important disease categories in terms of disease burden and mortality. This is probably linked to the lack of involvement of neurosurgeons both globally and nationally in the decision-making spheres of public health policy. To remediate this problem, we urge policymakers, global health actors and governments to:

Increase the Involvement of Neurosurgeons Within the Global Health Dialogue

The most effective and efficient way to ensure that a topic is mentioned and meaningfully considered in a discussion is to have the actors concerned at the meeting. Global health conferences are important platforms to prioritize global health interventions and to decide, for example, the projects which will receive funding. They also make it possible to forge collaborations between actors from different countries and regions in order to advance research and interventions in the various fields of global health. Active inclusion of neurosurgeons in these high-stakes meetings is therefore essential to ensure that neurosurgical care is part of the overall health agenda. The representation of the World Federation of Neurosurgical Societies (WFNS) at the world's largest global health meeting, the World Health Assembly, is an example to be encouraged and replicated nationally and at other major global health meetings around the world (27).

It is important to stress, however, that representatives of LMICs are often under-represented at these conferences. Velin et al. have described the most important barriers to effective participation of global health actors from LMICs in global health meetings around the world (28). These barriers include high travel costs, difficulty obtaining visas, and a marginal acceptance rate for research presentations. The solutions offered to address these challenges include the relocation of conferences to countries more likely to issue visas for these conferences, the provision of travel grants for LMIC delegates, and the development of mentoring and research capacity building programs. We recognize that the involvement of neurosurgeons from LMICs will not be possible without the application of such or similar solutions.

Involve Neurosurgeons in the National Surgical System Strengthening Process

Following the recommendation of The Lancet's Global Surgery Commission, many countries have initiated the NSOAP process with the aim of strengthening their surgical systems (4). The NSOAP is a broad process that involves improving several areas of the national health system such as consolidating the workforce, constructing adequate infrastructure and enhancing service delivery.

Surgical care includes a range of subspecialties ranging from cardiothoracic surgery, transplant surgery to neurosurgery. An optimal surgical system should have all of these subspecialties available. We urge representatives of ministries and other local and international actors involved in the establishment of NSOAPs to include neurosurgeons in the team. Involving neurosurgeons will ensure that neurosurgical care is part of the discussion. The selection of a neurosurgeon as the lead of the WHO Emergency and Essential Surgical Care service has been acknowledged as a milestone for the development of the global neurosurgery field (29).

Integrate Neurosurgical Care Within the Global Surgery Movement

Global neurosurgery is a fairly new sub-discipline of global surgery which is already widespread. Global neurosurgery is defined as "the clinical and public health practice of neurosurgery with the primary purpose of ensuring timely, safe, and affordable neurosurgical care to all who need it" (30). As the global surgery movement is expanding, we must make sure that neurosurgery is fully integrated into its development. It is important to ensure that neurosurgery does not develop as a separate discipline, disconnected from the rest of the surgical community.

Promote the Training and Education of Neurosurgeons, Especially Those Residing in LMICs, in the Field of Global Public Health

National efforts are essential for the development of neurosurgical care that is safe, of quality and accessible within the recommended timeframes. However, actions taken at global and regional level have proven that they can be effective in improving access to surgical care, especially within the local workforce. The WFNS training center in Rabat is a good example. Established in 2002, within 15 years, the center has provided partial and full training to more than 58 neurosurgeons who have since been involved in the delivery of neurosurgical care in Sub-Saharan Africa (SSA) (31). The passion for training in neurosurgery, nurtured by this centre's success, has propagated a positive "ripple effect" which has led to a 5-fold increase in the number of neurosurgeons in SSA, from 79 in 1998 to 369 in 2016 (32). The long-term outcome of these initiative has been phenomenal and is worthy of replication and expansion in other populations. Such programs are golden opportunities to introduce a cluster of LMIC-based neurosurgeons to global health advocacy, particularly the global neurosurgery field.

These efforts would be similarly beneficial for other regions like Asia, particularly Southeast Asia. Published reports have described the first-ever Southeast Asian 3-day neurosurgical boot camp, held in Myanmar, which attracted 40 neurosurgery residents from 7 countries from Southeast Asia (33). An evaluation of the teaching delivered at the camp conducted 6 months after its completion found a significant improvement in the participant's knowledge, attesting to the effectiveness of these camps in increasing retained knowledge of the participants. While this is a step in the right direction, providing training beyond boot camps is critical if shortage of neurosurgeons is to be reduced. More, long-term training programs is needed to provide delegates with a wider range of skills and to boost their confidence in managing neurosurgical diseases. Sustainable North-South collaborations such as that between Mulago Hospital Department of Neurosurgery in Kampala, Uganda and Duke University Medical Center in Durham, USA should be encouraged in Southeast Asia (34, 35). This exemplary collaboration takes a threefold approach in developing neurosurgical capacity through technology, twinning and training. Within the 2 years after the program began, there was a reported significant increase in the number and complexity of cases performed as well as the number of multiple-case days; this was promising evidence of improved productivity and efficiency of the workforce.

Of note, Dr Iftikhar A. Raja has placed a spotlight on Japan as a potential leader and host of such initiatives in the region, given the advanced state of their neurosurgical education, workforce density, access to the adequate equipment and the latest technology, and mastery of high-leveled techniques (36). This article hopes to encourage HICs such as Japan to consider developing similar programs to help improve the state of education and training for neurosurgeons in Southeast Asia.

CONCLUSION

Neurosurgeons must be provided the opportunity to navigate the world of global health in order to contribute their skills, knowledge and tenacity in expanding their role to increase access to neurosurgical care for the populations they serve. We, therefore, strongly recommend that neurosurgeons, especially those in LMICs, are given the support they need, included and valued during discussions, and likewise, for them to make the most of the opportunities given, as a step in the right direction to achieving equitable health for all across the globe.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

JL: conceptualization, writing of original draft, and editing. OD, MH, SR, LS, WS, and KS: writing of original draft and editing. SO, AV, TK, and CK: reviewed the writing and editing. KP: validation, reviewed the writing, and editing. All authors contributed to the article and approved the submitted version.

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Management of Severe Traumatic Brain Injury: A Single Institution Experience in a Middle-Income Country

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Introduction: Severe traumatic brain injury (TBI) is a major public health problem usually resulting in mortality or severe disabling morbidities of the victims. Intracranial pressure (ICP) monitoring is recently recognized as an imperative modality in the management of severe TBI, whereas growing evidence, based on randomized controlled trials (RCTs), suggests that ICP monitoring does not affect the outcome when compared with clinical and radiological data-based management. Also, ICP monitoring carries a considerable risk of intracranial infection that cannot be overlooked. The aim of this study is to assess the different aspects of our current local institutional management of severe TBI using non-invasive ICP monitoring for a potential need to change our management strategy.

Methods: We retrospectively reviewed our data of TBI from June 2019 through January 2020. Patients with severe TBI were identified. Their demographics, Glasgow coma score (GCS) at presentation, treatments received, and imaging data were extracted from the charts. Glasgow outcome scale extended (GOS-E) at 6 months was also assessed for the patients.

Results: Twenty patients with severe TBI were identified on chart review. Ten patients received only medical treatment measures to lower the ICP, whereas the other 10 patients had additional surgical interventions. In one patient, a ventriculostomy tube was inserted to monitor ICP and to drain cerebrospinal fluid (CSF). This was complicated by ventriculostomy-associated infection (VAI) and the tube was removed. In our cohort, the total mortality rate was 40%. The average GOS-E for the survivor patients managed without ICP monitoring based on the clinical and radiological data was 6.2 at 6 months follow-up. The 6-month overall good outcome, based on GOS-E, was 33.3%.

Conclusion: Although recent guidelines advocate for the use of ICP monitoring in the management of severe TBI, they remain underutilized in our practice due to many factors. External ventricular drains were mainly used to drain CSF; however, the higher rates of VAIs in our institution compared with the literature-reported rates are not in favor of the use of ICP monitoring. We recommend doing a comparative study between our current practice using clinical-and radiological-based management and subdural or intraparenchymal bolts. More structured RCTs are needed to validate these findings in our setting.

Keywords: traumatic brain injury, ICP monitoring, middle-income, management, decompressive surgery

INTRODUCTION

According to the Centers for Disease Control and Prevention (CDC), traumatic brain injury (TBI) is defined as a bump, blow, or jolt to the head that disrupts the normal function of the brain (1). TBI is said to be severe when an extended period of unconsciousness or memory loss follows the injury (2). Severe TBI has been dubbed the term "silent epidemic" and is a major public health concern, usually resulting in mortality or severe disabling morbidities of the victims (3). Recent quantification of the global incidence of severe TBI in 2018 by Dewan et al. was estimated to be 5.48 million cases annually (73 cases per 100,000) (4). In addition, according to the WHO, it is expected that most severe TBI-related deaths occur in low and middle-income countries, where there is a relative paucity of evidence (5). This highlights the importance of contextualization of neurotrauma research as different regions have different needs and obstacles (6). Intracranial pressure (ICP) monitoring is recognized as an imperative modality in the management of severe TBI as dictated by Brain Trauma Foundation (BTF) Guidelines (7). On the contrary, Benchmark Evidence from South American Trials: Treatment of ICP (BEST TRIP) trial in the New England Journal of Medicine (NEJM) has questioned the external validity of the previously established BTF guidelines, suggesting a non-significant favorable outcome of ICP-based vs. clinically and radiologically-based management of severe TBI and no significant difference in hospital stay (8). In addition, there is some evidence in the literature that suggests that ICP monitoring does not affect the outcome when compared with clinical and radiological data-based management, as reviewed by Treggiari et al. (9). Harris et al.'s study is another similar study including 1,607 patients and concluding that no difference in outcome was observed in different healthcare settings of high-income and low-income countries (10). Also, ICP monitoring carries a considerable risk of intracranial infection that cannot be overlooked, with infection rate up to 7.29% in high-income countries as reported by Guyot et al. (11). Furthermore, it is important to mention that in the previously referenced study by Guyot et al. there was an association between the higher ventriculostomy-associated complication (12.04%) and GOS rather than the presenting Glasgow coma score (GCS) or the duration since the traumatic event. An independent-adjusted odds ratio of 4.3 for extracranial complications associated with ICP monitoring in pediatrics was reported by Salim et al. (high-income country) (12). Another complication is hemorrhage, which generally is of minimal clinical significance (13). Last, technical failure is a complication that is avoidable, early recognized, and poses minimal impact on the outcome (14). On the one hand, there is a strong body of evidence advocating the use of ICP monitoring as a basic standard of care, such as BTF guidelines and that in AL Saiegh et al. (36,929 patients) (15), on the other hand, ICP monitoring cost is high compared with non-invasive methods as shown in a recent study (16), where reported mean cost for ICP monitoring was 360,30 Mexican pesos vs. 356,37 for non-invasive methods. Also, the infection rate is higher, the application of EVD is difficult in normal-sized ventricles in absence of imaging assistance, and there is a lack of specialized neurosurgical critical care units (17).

Given the above, we conducted this study aiming to assess the different aspects of our current management of severe TBI for potential improvements and to question the external validity of using ICP monitoring as standard care in severe TBI cases in our setting.

MATERIALS AND METHODS

This is a single institution retrospective study that was carried out in Ain Shams University which is an academic public institution located in Cairo, Egypt. In this study, we retrospectively reviewed our data of TBI in Ain Shams University hospital from June 2019 through January 2020. All patients with severe TBI who visited our emergency department and were admitted to our neurosurgical service were included regardless their gender or age. Only patients with signs of brain stem death were excluded from our analysis. The demographics of the patients, GCS at presentation, treatments received including surgical interventions, ICP monitoring using external ventricular drain (EVD) when used, and imaging data were extracted from the charts. Glasgow outcome scale extended (GOS-E) at 6 months was also assessed. Descriptive statistical analysis was carried out using Microsoft Office Excel 2019. Our protocol for the management of severe TBIs is based on clinical data and interval imaging findings rather than ICP monitoring. Subdural or intraparenchymal bolts were not used for ICP monitoring as they are not nationally available for the management of severe TBIs. The only available method of ICP monitoring is ventriculostomy catheters that were used in cases with dilated ventricles mainly as a method of CSF drainage and also to monitor the ICP. This is primarily due to their difficult application in normal-sized ventricles in the absence of imaging assistance in our institution.

Our study protocol was reviewed and approved by the ethical board of the Neurosurgery department, and the study was

Abbreviations: BTF, Brain Trauma Foundation; CDC, Centers for Disease Control and Prevention; CSF, Cerebrospinal fluid; CT, Computed tomography; ER, Emergency room; EVD, External ventricular drain; GCS, Glasgow Coma Score; ICU, Intensive care unit; ICP, Intracranial pressure; LMICs, Low- and middle-income countries; RCT, Randomized controlled trials; RTA, Road traffic accidents; TBI, Severe traumatic brain injury; SD, Standard Deviation.

TABLE 1 | Baseline characteristics.

Baseline characteristics	
Age	
Mean	29.5 years
SD	22.8 years
Gender	
Men no. (%)	16 (80%)
Women no. (%)	4 (20%)
Mode of trauma	
Fall from height no. (%)	6 (30%)
Road Traffic Accidents no. (%)	13 (65%)
Direct head trauma by blunt object no. (%)	1 (5%)

TABLE 2 | Clinical characteristics.

Clinical characteristics	
Duration of hospital stay (in days)	
Mean	16.65
SD	12.8
Duration of ICU stay (in days)	
Mean	14.8
SD	11.2
GCS at presentation to ER (median GCS 7)	
GCS 8 no. (%)	9 (45)
GCS 7 no. (%)	6 (30)
GCS 6 no. (%)	2 (10)
GCS 5 no. (%)	1 (5)
GCS 4 no. (%)	1 (5)
Localizing brain injuries no. (%)	9 (45%)

TABLE 3 | Imaging characteristics.

Imaging characteristics	
Median Rotterdam score at initial brain CT: 4	
Basal cisterns	
Compressed no. (%)	7 (35%)
Absent no. (%)	8 (40%)
Midline shift > 5 mm on initial brain CT no. (%)	10 (50%)
Main pathology	
Brain contusion(s) no. (%)	9 (45%)
Acute subdural hematoma no. (%)	6 (30%)
Epidural hematoma no. (%)	2 (10%)
Mixed pathology no. (%)	3 (15%)

TABLE 4 | Clinical outcomes.

Clinical outcomes	
30-day mortality no. (%)	8 (40%)
Time to death	
Mean	9 days
SD	5.26
Complications	
Chest infection no. (%)	4 (20%)
Early post-traumatic fits no. (%)	2 (10%)
PCA territory infarction no. (%)	1 (5%)
Lost follow up no. (%)	2 (10%)
GOS-E for survivor patients at 6 months	
Mean	6.2
Overall good outcome at 6 months no. (%)	6 (33.3%)

approved by the Faculty of Medicine Ain Shams University Research Ethics Committee (FMASU REC). Written informed consent from the legal guardian/next of kin of the participants were not required to participate in this study in accordance with the national legislation and the institutional requirements since it is an observational retrospective study.

RESULTS

Among 156 patients with TBIs extracted from the charts of a 6-month period at AinShams University hospital, 20 patients with severe TBI were identified. Sixteen were men whereas four were women. The mean age was 29.5 years (± SD 22.8). The mode of trauma was as follows: fall from height in six patients, road traffic accidents (RTA) in 13 patients, and direct blow to the head with a blunt object in one patient (**Table 1**). The average duration of hospital stay was 16.65 days (± SD 12.8), whereas the average duration of intensive care unit (ICU) stay was 14.8 days (± SD 11.2). Median GCS at presentation to the emergency room (ER) was 7 (interquartile range 1.25) with none of the victims obeying commands on the best motor response. Nine patients were presented with GCS of 8, six patients with GCS of 7, two patients with GCS of 6, one patient with GCS of 5, one patient with GCS of 4, and one patient with a GCS of 3 with preserved corneal reflex and no signs of brain stem death at the time of presentation to the emergency department (ER). Nine patients (45%) had localizing brain injuries. In eight (40%) patients, one or both pupils were not reactive (**Table 2**). Median Rotterdam computed tomography (CT) score was four (interquartile range 2) at initial brain CT.

Basal cisterns were compressed or absent in 75% of the patients (compressed in 35% while absent in 40%). A midline shift of more than 5 mm was present in half of the patients. The main pathology was brain contusion(s) in nine (45%) patients, acute subdural hematoma in six (30%) patients, epidural hematoma in two (10%) patients, and mixed pathology of acute subdural hematoma and brain contusion(s) in three (15%) patients (**Table 3**). All the patients in the group of brain contusion(s) had received medical treatments including measures to lower the ICP without any surgical interventions, except one patient who developed secondary posttraumatic hydrocephalus and was operated on for ventriculoperitoneal shunt.

All patients in the group of acute subdural hematoma had received surgical interventions in the form of decompressive craniotomy and hematoma evacuation, except one patient who was presented to ER with GCS 3 in which case the legally authorized representative refused the surgical intervention. In

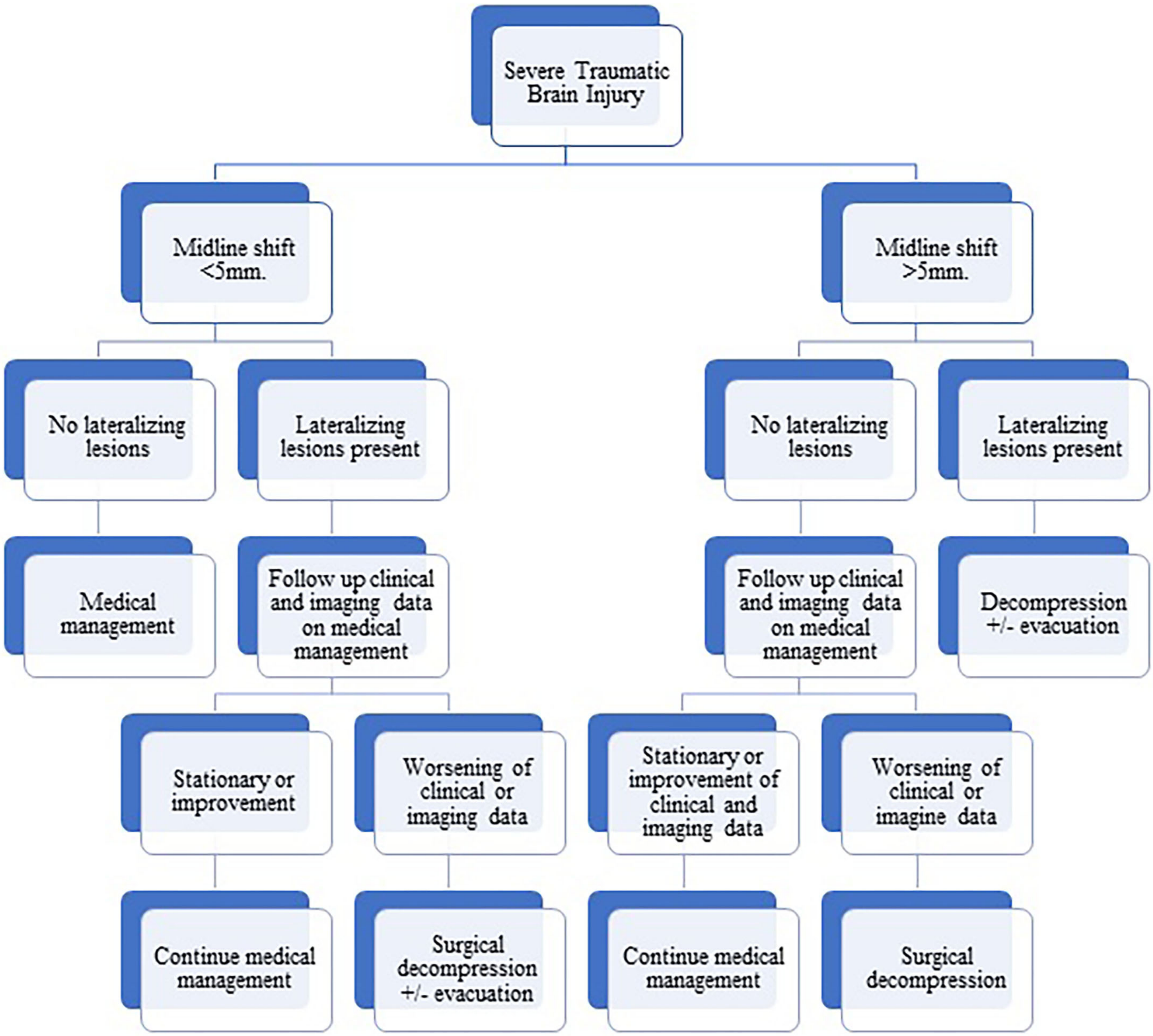

FIGURE 1 | Flowchart diagram showing our protocol of management of severe traumatic brain injury based on clinical and radiological data.

this group, five patients had supratentorial hematomas and only one patient had posterior fossa hematoma. This last patient was presented to ER with posterior fossa acute subdural hematoma and GCS of 8. He was operated on for posterior fossa decompressive craniectomy, left cerebellar acute subdural hematoma evacuation, and insertion of EVD through a Frazier burr hole into the dilated ventricles as a result of the presence of secondary obstructive hydrocephalus. This EVD was inserted mainly to drain CSF and was also used to monitor the ICP. One week after insertion of the EVD, ventriculostomy-associated infection (VAI) occurred as indicated by a CSF sample that was sent for laboratory workup. The culture showed no microbial growth. This can be justified by the fact that the patient was already on postoperative prophylactic antibiotics. This patient died 21 days after neurocritical care admission due to ventilator-associated pneumonia and systemic infection.

In the group of mixed pathology of brain contusion(s) and acute subdural hematoma, two out of three patients had surgical interventions in the form of decompressive craniotomy and hematoma evacuation. The patient who was not surgically treated was unfortunately presented to the ER 8 h after he was hit by a car. His GCS at presentation was four with lateralizing signs, but his legally authorized representatives refused to do surgery. Two patients were presented with epidural hematomas and both of them were operated on for evacuation of traumatic space occupying hematomas.

In our cohort, the 30-day mortality rate was 40%. The average time to death was 9 days (±SD 5.26). The 6-month mortality was not changed from 30-day mortality (no mortalities added after the initial 30 days). Coexisting injuries were found in 11 cases (55%) and had aggravated the outcome in two (10%) of the patients. Chest infection

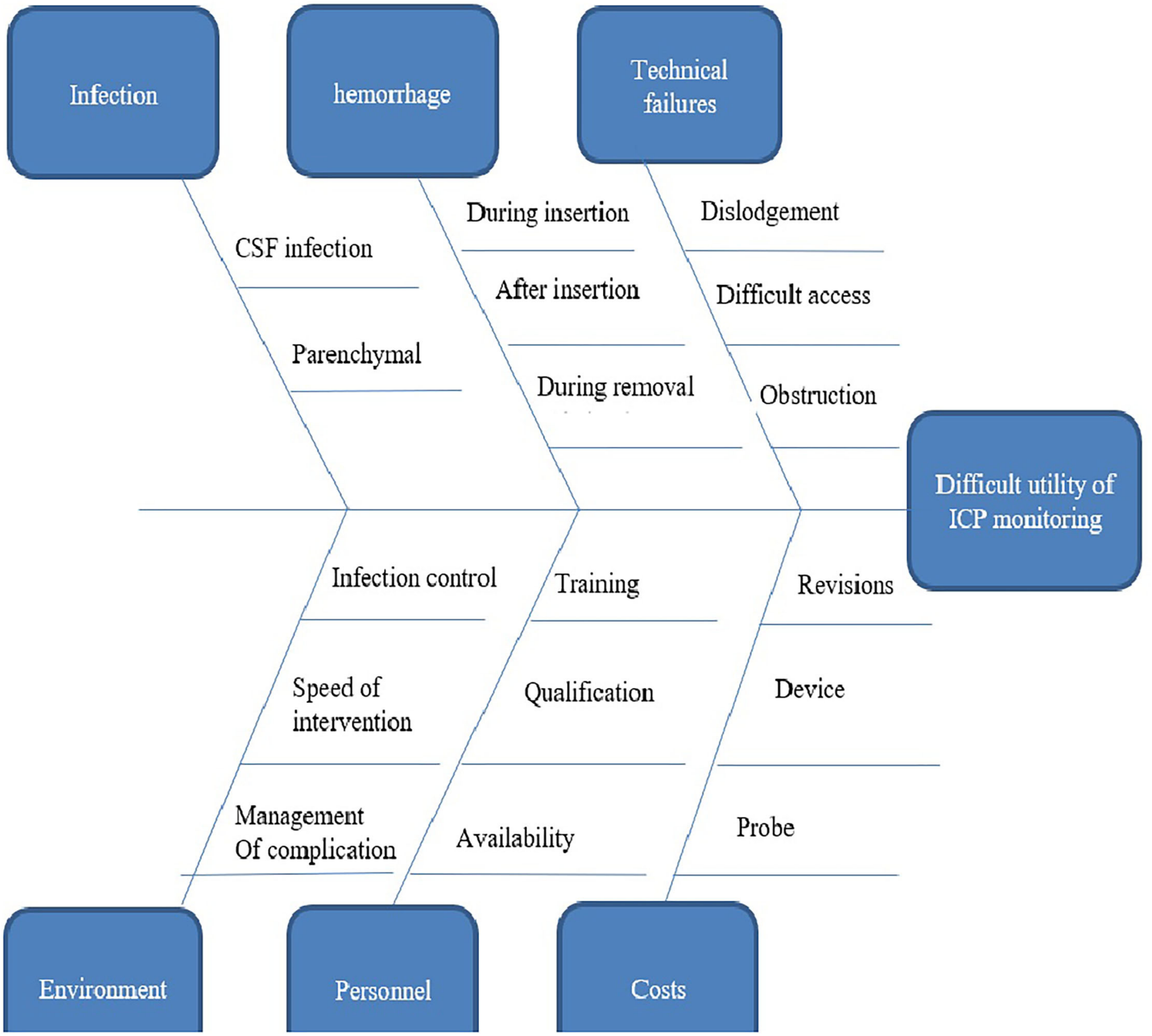

FIGURE 2 | Fish bones diagram showing reasons behind the reluctance to use intracranial pressure monitoring based management of severe traumatic brain injury in our institute.

was the most common complication occurring in four (20%) cases. Nervous system complications occurred in three (15%) patients. Two (10%) patients had developed early posttraumatic seizures and one patient developed posterior cerebral artery territory infarction as a result of uncal herniation.

Two patients (10%) were lost from follow-up. One of these two patients was presented with a GCS of 7 and his brain CT showed acute subdural hematoma, whereas the other patient was presented with an epidural hematoma and a GCS of 8. The average GOS-E for the survivor patients was 6.2 at 6 months follow-up. The 6-month overall good outcome based on GOS-E defined as patients with GOS-E of 7 or 8, was 33.3% (**Table 4**).

DISCUSSION

In this work, we present our experience in the management of severe TBI as a part of the developing world where the ICP monitoring (standard of care)-based management is not available. Our protocol of management is based on clinical data and mainly brain imaging (see **Figure 1**). Surgical intervention in the form of decompression with or without evacuation of the mass lesion is offered for patients with lateralizing lesions and midline shifts more than 5 mm. In the absence of lateralizing brain lesions, an ascending sequence of medical (non-surgical) interventions is being adopted, including elevation of the head of the bed, hyperventilation, brain dehydrating measures including mannitol, and finally inducing barbiturate coma. On certain occasions, some patients without lateralizing lesions may shift from the non-surgical into the surgical group. For example, clinical deterioration despite full medical measures or occurrence of posttraumatic seizures with the development of malignant brain edema requiring decompressive surgery.

Our results are comparable to other clinical studies using either clinical and imaging-based management or using ICP-based management. In our experience, the 30-day mortality rate and 6-month mortality are the same since all mortalities occurred during hospital admission, which is comparable with Myburgh et al. (18). Furthermore, the GOS-E at 6 months is comparable to the findings as in Corral et al. (19). Despite these comparable results with reported literature, there is a paucity of comparative evidence between these two methods of management. The literature lacks well-structured randomized controlled trials to compare the two methods; however, this is due to ethical concerns of randomization (20).

Given the unavailability of ICP-monitoring-based management, we seek to provide a fixed set number of patients with access to such care to compare with our otherwise conventional clinical-based protocol of management. This is a proposed solution to overcome the ethical notion of this comparison where all patients will receive the same standard of care in spite of having two comparison groups and then comparing the results of this set of patients with the results of conventional management. Reluctance to use ICP-monitoring-based management of severe TBIs could be explained by a variety of reasons (**Figure 2**). First, the a higher rate of infection from ventriculostomy catheters. The overall rate of VAI in our institution is 19.7%, which is higher in TBI cases reaching up to 27.9% (unpublished data) in comparison with 0–22% as reported by Sorinola et al. (21) with an average of 8.8% according to Tavakoli et al. (22) and 1–5% in Thailand (23). Second, the difficult EVD application in cases with normal ventricular size without imaging assistance, which also is not available in many institutions. Third, the evolution of growing evidence suggesting that there is no difference in outcome between ICP-monitoring-based management and clinical and imaging criteria-based management, which suppresses the motives behind shifting to adopt new management techniques. Fourthly, the unavailability of intraparenchymal and subdural bolts under insurance coverage in our country. Finally, the added costs in resource limited settings may have an impact on health care spending.

Study Limitations

Limitations of our work include the small number of cases presented, the wide range of age distribution, and the lack of comparative methodology.

CONCLUSION

Severe TBI is a major public health concern that causes significant mortality and morbidity worldwide (24). Although adopted as a standard of care in developed countries despite controversial evidence, the unavailability of ICP monitoring in developing countries poses the need for strong comparative evidence to advocate its use. Many factors raise concern for the use of ICP monitoring include infection rate, difficult application, high cost, etc. That said, we believe there is a strong need for a well-structured randomized body of evidence. We propose in the future providing a set of ICP monitoring in our institute to be compared with our conventional data.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Faculty of Medicine Ain Shams University Research Ethics Committee (FMASU REC). Written informed consent from the participants' legal guardian/next of kin was not required to participate in this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

AB formulated the research question and participated largely in manuscript writing. MM participated in manuscript writing and editing. MA, OA, and SE participated in data collection. AE participated in the discussion and in the final revision of the manuscript. AA-L and WA participated in formulating the research question and in the final revision of the manuscript. All authors contributed to the article and approved the submitted version.

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Predictive Value of the Serum Albumin Level on Admission in Patients With Spontaneous Subarachnoid Hemorrhage

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Objective: To determine the effect of the serum albumin level on admission in patients with spontaneous subarachnoid hemorrhage (SAH).

Methods: A total of 229 patients with SAH were divided into control and hypoalbuminemia groups. The serum albumin levels were measured. The data, including age, gender, co-existing medical conditions, risk factors, Hunt-Hess (H-H) grade on admission, Glasgow coma score (GCS) on admission, complications during hospitalizations, length of hospital stay, length of intensive care unit (ICU) stay, in-hospital mortality, survival rate, outcome at discharge, and the 6-month follow-up outcome, were compared between the two groups.

Results: Older age, an increased number of patients who consumed an excess of alcohol, and a lower GCS on admission were findings in the hypoalbuminemia group compared to the control group ($p < 0.001$). The ratio of patients with H-H grade I on admission in the hypoalbuminemia group was decreased compared to the control group ($p < 0.05$). Patients with hypoalbuminemia were more likely to be intubated, and have pneumonia and cerebral vasospasm than patients with a normal albumin level on admission ($p < 0.001$). Furthermore, the length of hospital and ICU stays were longer in the hypoalbuminemia group than the control group ($p < 0.001$). Hypoalbuminemia on admission significantly increased poor outcomes at discharge ($p < 0.001$). The number of patients with severe disability was increased and the recovery rate was decreased with respect to in-hospital outcomes in the hypoalbuminemia group than the control group ($p < 0.001$).

Conclusion: Hypoalbuminemia was shown to be associated with a poor prognosis in patients with SAH.

Keywords: albumin, spontaneous subarachnoid hemorrhage, Glasgow outcome scale, at admission, predictor

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INTRODUCTION

Subarachnoid hemorrhage (SAH) is a severe cerebrovascular disease caused by blood flowing into the subarachnoid space after intracranial vascular rupture. Subarachnoid hemorrhage is clinically divided into traumatic and non-traumatic types. Non-traumatic SAH, also known as spontaneous SAH, is a common and highly fatal stroke (1). The incidence of spontaneous SAH in China is approximately 2/100,000 per year, accounting for 5–10% of all strokes (2, 3). Intracranial aneurysms are the main cause of spontaneous SAH, accounting for approximately 85% of all cases. The clinical prognosis of SAH is relatively poor, and the mortality within 3 months of onset and the disability rate of surviving patients is also relatively high. At present, SAH is an acute hemorrhagic cerebrovascular disease that endangers human health (1, 4).

A low serum albumin level is associated with increased morbidity and mortality in various diseases (5–8). Albumin, a major component of plasma protein, has an important role in maintaining normal oncotic pressure and microvascular permeability (9–11). Hypoalbuminemia usually occurs in patients with acute ischemic stroke (12, 13). Furthermore, patients with intracerebral hemorrhage (ICH) and concurrent hypoalbuminemia are also more susceptible to poor functional outcomes (14).

There are limited data and studies that have focused on the effect of hypoalbuminemia on the outcomes of patients with SAH. Specifically, long term follow-up studies with a large number of patients have been insufficient (15–20). Therefore, we determined the influence of a low serum albumin level at the time of admission in patients with spontaneous SAH.

SUBJECTS AND METHODS

Subjects

This retrospective study was approved by the Hospital Review Board. A total of 229 patients who were admitted to our Neurosurgery intensive care unit (ICU) with a diagnosis of spontaneous SAH from December 2017 to December 2018 were enrolled. The diagnosis of SAH met the diagnostic criteria of the 2015 edition of Chinese Guidelines for the Diagnosis and Treatment of Subarachnoid Hemorrhage (2). The inclusion criteria were as follows: (1) spontaneous onset; (2) the diagnostic criteria for SAH were met; (3) hospitalized within 7 days of onset; (4) serum albumin levels were closely monitored within 24 h after admission; (5) a head CT, lumbar puncture, and head and neck CTA/DSA/MRA examinations obtained after admission; and (6) complete medical records. The exclusion criteria were as follows: (1) died within 24 h after admission; (2) traumatic or spontaneous SAH undergoing craniotomy; (3) heart, lung, liver, kidney, and other vital organ dysfunction; (4) a history of severe coagulation dysfunction; (5) incomplete medical records; and (6) no serum albumin level obtained on admission.

Determination of Serum Albumin Levels

The serum albumin levels were measured at 24 h and 1 week after onset. The serum albumin level was commonly measured by recording a change in absorbance upon binding to a dye, such as bromocresol green or bromocresol purple (21, 22). Hypoalbuminemia was established when the serum albumin level was <3.5 g/dl (23). Patients were divided into control and hypoalbuminemia groups depending on the diagnosis of hypoalbuminemia on admission.

Data Collection

The baseline demographics (age and gender), other diseases (diabetes mellitus, hyperlipidemia, and coronary artery disease), risk factors [hypertension, smoking, and excessive alcohol consumption (24)], admission Hunt-Hess (H-H) grade (25), Glasgow coma score (GCS) on admission, complications during hospitalization [intubation, pneumonia, cerebral vasospasm, re-bleeding, and delayed cerebral ischemia (DCI)], length of hospital stay, length of ICU stay, in-hospital mortality, survival rate, outcomes at discharge, and 6-month follow-up outcomes were collected. Hypertension was diagnosed if the systolic blood pressure was >140 mmHg or the diastolic blood pressure was >90 mmHg, or the patient was taking anti-hypertensive medications. Cerebral vasospasm was described as focal or diffuse temporarily narrowed vessel caliber due to the contraction of a smooth muscle in the wall of the arteries, which was detected by angiography, transcranial Doppler (TCD), magnetic resonance (MR), and CT (26). Rebleeding was identified as an acute clinical deterioration that was accompanied by evidence of rebleeding in the subarachnoid space, ventricular system, or brain parenchyma via a follow-up CT or an autopsy (27). Delayed cerebral ischemia (DCI) was defined as the development of new focal neurologic signs and/or a deterioration in the level of consciousness lasting for >1 h, or the appearance of new infarctions on CT or MRI (28–30).

Outcome Measures

Poor outcome was defined as in-hospital death, or transfer to hospice care or a nursing home facility [GOS scale ≤3 (27)]. Serious complications included another or several potentially fatal diseases triggered during the course of the SAH. Furthermore, the 6-month follow-up outcomes were also recorded.

Statistical Analysis

Statistical analysis was performed by SPSS17.0 (International Business Machines, Corp., Armonk, NY, USA). The differences between the two groups were compared by a chi-square test or Fisher's exact test for categorical data and Student's *t*-test or Kruskal test for continuous data. Multivariable logistic or linear regression analysis was carried out to study the relationship between the albumin level and outcomes. All the multivariable regression models were repeated for the characteristic variables. A p-value ≤ 0.05 was considered statistically different.

RESULTS

General Clinical Characteristics

Three hundred and fifteen patients with spontaneous SAH were admitted in the study. Among the 315 patients, 229 met the inclusion criteria, including 79 with normal albumin levels and 150 with hypoalbuminemia. The albumin level in the hypoalbuminemia group was decreased more than the control group ($p < 0.001$). The baseline data are shown in **Table 1**. The age in the hypoalbuminemia group was higher than the control group ($p < 0.001$). The number of patients that consumed excessive alcohol was greater and the mean GOS on admission was lower in the hypoalbuminemia group than

TABLE 1 | Baseline characteristics of patients with spontaneous subarachnoid hemorrhage.

Items	All patients ($n = 229$)	Low serum albumin ($n = 150$)	Normal serum albumin ($n = 79$)	Test method	Test statistic	*p*-Values
Age (years)	55.53 ± 13.11	58.84 ± 11.06	49.24 ± 14.39	Kruskal	22.68	0.001*
Gender (Males)	103 (45.0%)	61 (40.7%)	42 (53.2%)	Chi square	3.27	0.071
Admission H-H grade				Chi square	15.50	0.001*
I	59 (25.8%)	29 (19.3%)	30 (38%)	Chi square	3.52	0.002*
II	96 (41.9%)	57 (38.0%)	39 (49.4%)	Chi square	2.75	0.097
III	33 (14.4%)	29 (19.3%)	4 (5.1%)	Chi square	8.54	0.003*
IV	26 (11.4%)	20 (13.3%)	6 (7.6%)	Chi square	1.69	0.193
V	5 (2.2%)	5 (3.3%)	0 (0%)	Chi square	2.69	0.244
Hypertension	129 (56.3%)	82 (54.7%)	47 (59.5%)	Chi square	0.49	0.484
Smoking	90 (39.3%)	64 (42.7%)	26 (32.9%)	Chi square	2.06	0.151
Alcohol consumption	49 (21.4%)	47 (31.3%)	2 (2.5%)	Chi square	25.52	0.001*
Diabetes mellitus	18 (7.9%)	11 (7.3%)	7 (8.9%)	Chi square	0.17	0.683
Hyperlipidemia	6 (2.6%)	2 (1.3%)	4 (5.1%)	Chi square	2.82	0.213
Coronary artery disease	15 (6.6%)	13 (8.7%)	2 (2.5%)	Chi square	3.18	0.074
Admission Glasgow coma score	13.34 ± 3.31	12.86 ± 3.65	14.25 ± 2.28	Kruskal	15.45	<0.001*

Measurement data are expressed as means ± standard deviation (SD) and counting data are expressed as a percentage.
**$p \le 0.05$: low serum albumin group vs. normal serum albumin group. H-H grade, Hunt-Hess grade.*

the normal albumin group ($p < 0.001$). Moreover, the ratio of patients with H-H grade I on admission in the hypoalbuminemia group was lower than the control group (19.3 vs. 38%, $p < 0.05$). Furthermore, the ratio of patients with H-H grade III on admission was higher in the hypoalbuminemia group than the control group (19.3 vs. 5.1%, $p < 0.05$).

Comparison of Prognosis Between the Two Groups

Patients with hypoalbuminemia were more likely to be intubated, and have pneumonia and cerebral vasospasm than patients with a normal albumin level on admission (43.6 vs. 8.9%, $p < 0.001$; 46.3 vs. 13.9%, $p < 0.001$; and 50.7 vs. 32.9%, $p = 0.010$, respectively; **Table 2**). In addition, the length of hospital and ICU stays were longer in the hypoalbuminemia group than the control group (13.1 vs. 4.8 days, $p < 0.001$; and 12.2 vs. 4.6 days, $p < 0.001$, respectively). There was a significant increase in poor outcomes at the time of hospital discharge in the hypoalbuminemia group than the control group (30.0 vs. 2.5%, $p < 0.001$; OR = 33.4; 95% CI: 8.4–132.8). Considering the outcomes at the time of hospital discharge, the severe disability and recovery rates were significantly different between the two groups ($p < 0.001$), and this disparity persisted to the 6-month follow-up outcomes ($p = 0.045$; $p = 0.032$). The leading causes of death during hospitalization and at the 6-month follow-up included severe primary diseases (mainly with severe and high grade SAH) and severe complications (rebleeding, severe cerebral vasospasm, hydrocephalus, epilepsy, and cerebral hernia). Fourteen patients were lost to follow-up by the 6-month evaluation. The number of patients decreased from 229 at the beginning of the study to 215 after follow-up.

Independent Predictors

After adjusting for age, gender, H-H grade on admission, excessive alcohol consumption, coronary artery disease, and GCS on admission, we showed that hypoalbuminemia (OR = 4.7, $p = 0.006$), pneumonia (OR = 2.6, $p = 0.024$), poor outcome (OR = 18.51, $p = 0.006$), length of hospital stay (effect size: 5.33 days, $p < 0.001$), and length of ICU stay (effect size: 4.29 days, $p = 0.001$) were independent predictors for intubation (**Table 3**).

DISCUSSION

A low serum albumin level induces numerous health issues (5–8). The predictors of mortality and morbidity in patients with spontaneous SHA include age, hypertension, low GCS on admission, cerebral vasospasm, rebleeding, and DCI (24–29). In our study, most of these predictors, except for hypertension and DCI, were very different between the two groups, indicating that a multiple logistic regression analysis may be needed to further assess the correlation between hypoalbuminemia and outcomes at discharge.

The serum albumin level is a function of rates of synthesis, degradation, and distribution in the extracellular and intracellular spaces (9). Hypoalbuminemia may occur not only in patients with liver or kidney dysfunction and malnutrition, but also in the distribution or catabolism and the presence of inflammatory cytokines (31).

Only two-thirds of men 65–74 years of age with serum albumin levels ≥4.4 g/dl have developed strokes compared to patients with albumin levels ≤4.2 g/dl (32). The prevalence of renal dysfunction has been reported in 20–35% of patients with ischemic strokes and 30–46% of patients with ICH (33). Therefore, hypoalbuminemia may in part be a result of complex cerebrorenal interactions and renal dysfunction (34–36). A low

TABLE 2 | Correlation of serum albumin levels in patients with spontaneous subarachnoid hemorrhage.

Items	All ($n = 229$)	Low serum albumin ($n = 150$)	Normal serum albumin ($n = 79$)	Test method	Test statistic	*p*-Values
Intubation	72 (31.6%)	65 (43.6%)	7 (8.9%)	Chi square	28.88	<0.001*
Pneumonia	80 (35.1%)	69 (46.3%)	11 (13.9%)	Chi square	23.77	<0.001*
Cerebral vasospasm	102 (44.5%)	76 (50.7%)	26 (32.9%)	Chi square	6.60	0.010*
Delayed cerebra infarction	40 (17.5%)	27 (18.0%)	13 (16.5%)	Chi square	0.09	0.770
Rebleeding	18 (7.9%)	15 (10.1%)	3 (3.8%)	Chi square	2.79	0.095
Length of hospital stay (days, median)	10.19 ± 10.42	13.05 ± 11.34	4.76 ± 5.07	Kruskal	53.54	0.001*
Length of ICU stay (days)	9.54 ± 10.36	12.15 ± 11.44	4.60 ± 5.11	Kruskal	42.77	0.001*
Poor outcome	46 (20.1%)	45 (30.0%)	2 (2.5%)	Chi square	23.94	0.001*
Discharge outcome				Chi square	32.26	0.001*
Death	4 (1.7%)	4 (2.7%)	0 (0%)	Chi square	2.14	0.350
Vegetative stage	10 (4.4%)	9 (6.0%)	1 (1.3%)	Chi square	2.78	0.185
Severe disability	32 (14.0%)	32 (21.3%)	1 (1.3%)	Chi square	16.90	0.001*
Mild disability	39 (17.0%)	30 (20.0%)	9 (11.4%)	Chi square	2.71	0.100
Recovery	144 (62.9%)	75 (50.0%)	68 (86.1%)	Chi square	28.72	0.001*
6-month follow-up outcome				Chi square	10.38	0.040*
Death	25 (10.9%)	15 (10.0%)	5 (6.3%)	Chi square	1.17	0.280
Vegetative stage	2 (0.9%)	2 (1.3%)	0 (0%)	Fisher	-	0.546
Severe disability	10 (4.4%)	10 (6.7%)	0 (0%)	Chi square	5.51	0.045*
Mild disability	22 (9.6%)	14 (9.3%)	13 (16.5%)	Chi square	2.52	0.112
Recovery	156 (68.1%)	95 (63.3%)	61 (77.2%)	Chi square	4.59	0.032*

Measurement data are expressed as means ± standard deviation (SD) and counting data are expressed as a percentage.
**$p \leq 0.05$: low serum albumin group vs. normal serum albumin group. ICU, intensive care unit.*

albumin level could be a modifiable factor for patients with spontaneous SAH or other conditions.

There should be no major issue with the use of albumin in most developed countries and more advanced developing countries; however, for most low- and middle-income countries (LMICs), it is more difficult to assess serum chemistries, such as albumin, when it is even difficult to meet the requirements of essential medications and medical equipment (Is this change ok?). These issues are really difficult to overcome, and can only be handled according to the actual situation of the respective hospital departments.

There were some limitations in our study. The main limitation was the retrospective nature of the study. The simple laboratory test is needed to assess this alteration in the albumin level. Moreover, this was a single center study with a small sample size. The retrospective nature of data collection, the lack of information on the premorbid nutritional and volume status, the absence of serial albumin measurements, and long-term functional outcomes are all limitations. Larger prospective studies with serial measurements of serum albumin levels are needed. Therefore, the role of albumin supplementation in patients with spontaneous SAH are warranted.

TABLE 3 | Multivariable analysis of serum albumin levels in patients with spontaneous subarachnoid hemorrhage.

Items	Low serum albumin	
	OR (95%CI)	***p*-Values**
Intubation	4.7 (1.67–16)	0.006*
Pneumonia	2.6 (1.16–6.2)	0.024*
Vasospasm	1.75 (0.9–3.45)	0.100
Cerebral infarction	0.97 (0.4–2.41)	0.954
Rebreeding	3.77 (0.82–28.05)	0.124
Poor outcome	18.51 (3.41–349.03)	0.006*
	β (95%CI)	***p*-Values**
Length of hospital stay	5.33(2.81–7.85)	0.001*
Length of ICU stay	4.29(1.83–6.74)	0.001*

**$p \leq 0.05$.*

CONCLUSION

In conclusion, we demonstrated that hypoalbuminemia on admission is a risk factor for poor outcome in patients with spontaneous SAH. It is substantially relevant for prediction and prognosis of spontaneous SAH. Because measuring the serum albumin level is an affordable task, it may serve as an additional prediction marker in these patients. Larger prospective studies with serial measurements of serum albumin are required to identify the poor outcomes and thereby implement therapeutic interventions.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Xuanwu Hospital, Capital Medical University Committee. The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

FS and HZ: designed the project. FS, HZ, WC, MQ, and NW: were responsible for experiments data collection and analysis, and manuscript writing. XQ revised the manuscript. All the authors participated in the review of the manuscript.

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OPINION
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The Global NeuroSurg Research Collaborative: A Novel Student-Based Model to Expand Global Neurosurgery Research

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The Global NeuroSurg research collaborative (www.globalneurosurg.org) was initiated in May 2018 to (1) study the existing variations in management and outcomes of neurosurgical conditions between low- and middle-income countries (LMICs) and high-income countries and (2) determine the practices and factors associated with the best neurosurgical outcomes, therefore, helping to improve the current neurosurgical care. The collaborative is hosted and internally sponsored by the Neurological Surgery Department of Oregon Health and Science Institute, which acts as a secure host for the confidential patient data of all participating centers around the world.

The Global NeuroSurg collaborative recognizes the importance of engaging medical students in Global Neurosurgery (1); therefore, we implement a novel collaborative research model that supports the involvement of medical students in global neurosurgery research.

This model is justified by the fact that the ratio of neurosurgeons to the population is low in many LMICs. Therefore, research collaboration in global neurosurgery that starts by inviting senior neurosurgeons to join and participate in the studies might lead to a low representation of low-resource settings where neurosurgeons are few, busy, or unreachable. Hence, this conventional research model is susceptible to selection bias where the resulting datasets will be skewed away from the low-resource settings.

To overcome this problem, the Global NeuroSurg research Collaborative uses medical students who are more available to provide access to such low-resource settings. In this model, medical students act as a contact point who provide access to the healthcare centers after gaining support from consultants, who act as local research leads for the project.

For example, in the Global NeuroSurg I (GNS-I) study on the management and outcomes of traumatic brain injury (TBI) in low-, middle-, and high-income countries (2), the study was initially delivered by (1) contacting neurosurgeons from the personal connections of the steering committee and (2) using the International Federation of Medical Students Associations (IFMSA). The National Officer of Medical Education in Egypt shared the study invitation with 2,000+ medical students from all countries around the world. Only after students have registered on the GNS-I study website, they are asked to identify a neurosurgeon, intensivist, or neurologist who has direct responsibility for TBI cases in their setting.

In the GNS-I study, teams can include up to three members per team, collecting data of consecutive TBI cases for 2 weeks; however, at least one member should be a neurosurgeon

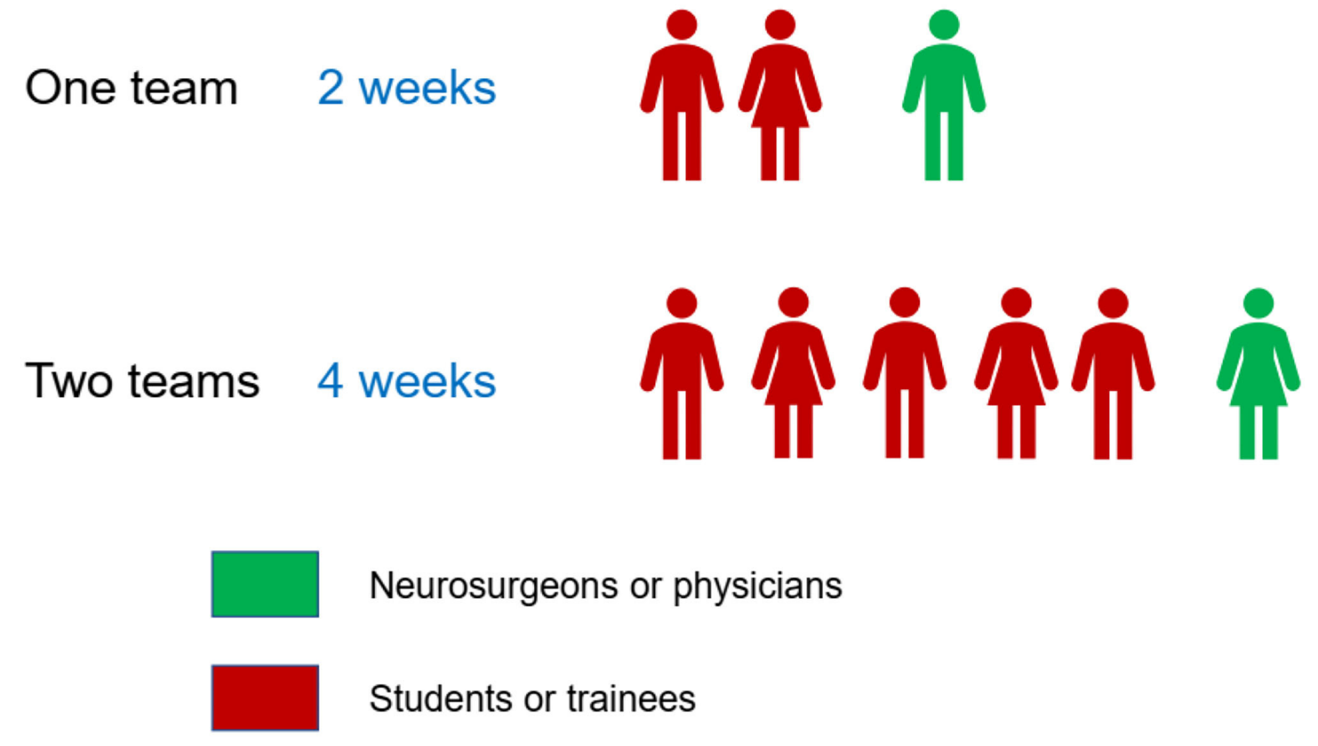

FIGURE 1 | Examples for GNS-I study team structures with maximum student representation in the same center.

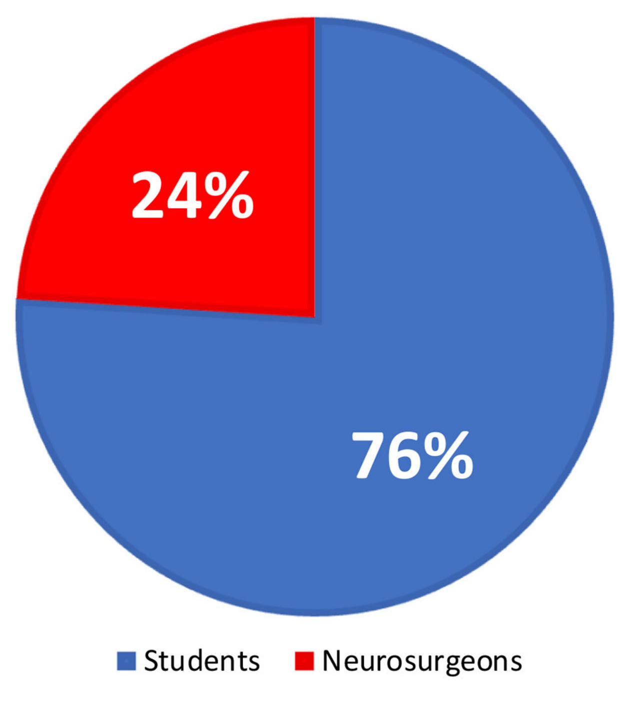

FIGURE 2 | A pie chart of the representation of medical students among all the GNS-I study collaborators.

who provides care to TBI patients. Examples of some team structures with maximum student involvement are shown in **Figure 1**.

Teams can also include neurosurgeons only. However, we encourage student participation whenever possible. As of July 10, 2021, 2,030 collaborators from 84 countries have registered in the first study of the Global NeuroSurg research collaborative (Global NeurosurgI study). Of them, 1,550 are medical students (76% of all collaborators; **Figure 2**).

The model of Global NeuroSurg research collaborative relies on creating a grassroots movement among medical students worldwide, which increases the access and coverage of the global neurosurgical workforce. A geo map representing the 84 countries from which collaborators have registered for the GNS-I study is shown in **Figure 3**.

Finally, we acknowledge that student- and trainee-led surgical research collaboratives are popular in the United Kingdom on the local and national levels as STARSurg collaborative and Surgical Trainees in East of England Research Collaborative Group; however, to the best of our knowledge, no collaborative groups have done the same in the global neurosurgery field. We believe that students are a proxy for low-resource settings and can help to expand the coverage of global neurosurgery research to include many underserved areas.

In the upcoming years, the Global NeuroSurg Research Collaborative will audit other areas of neurosurgical care around

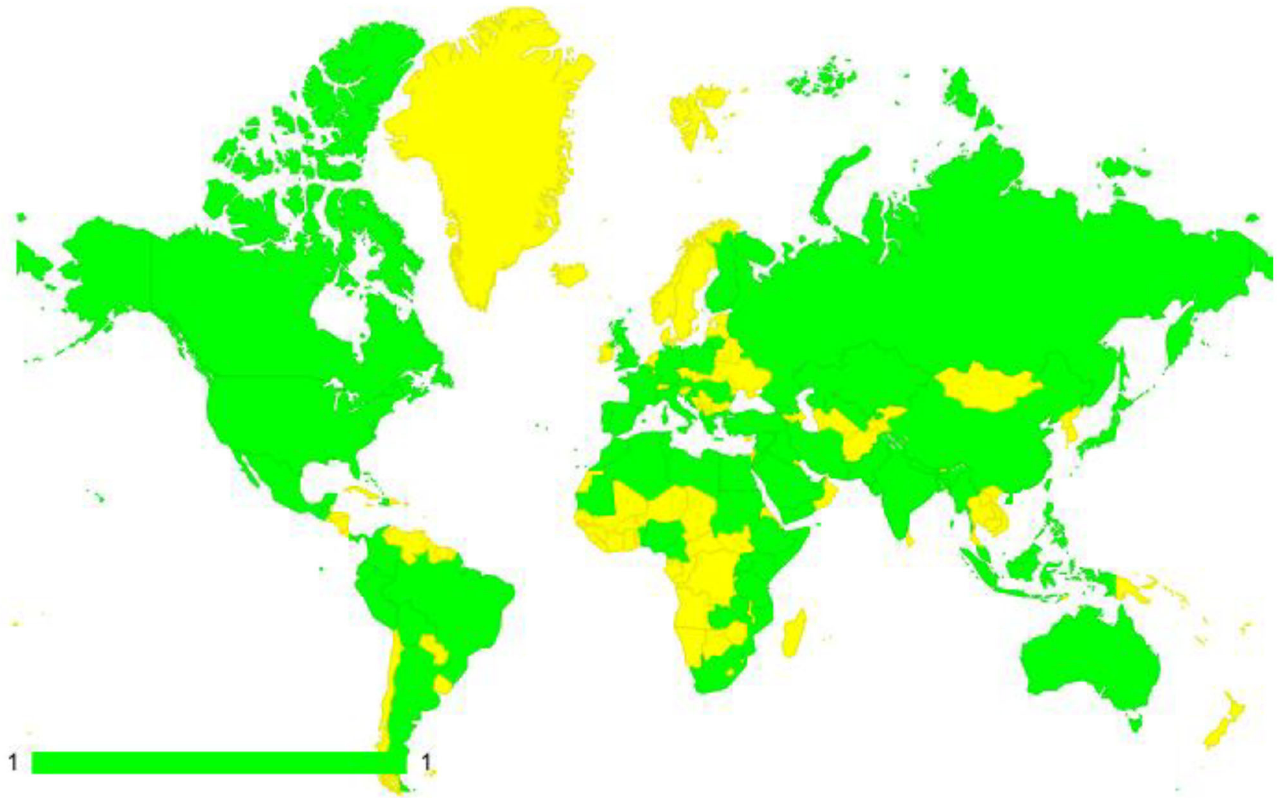

FIGURE 3 | A geo map of the 84 countries from which collaborators have registered for the GNS-I study (marked in green color). The yellow color represents countries that are not yet registered.

the world including stroke, epilepsy, hydrocephalus, and brain cancer surgeries. It is expected that these audit evaluations will identify the practices and factors associated with better patient outcomes and therefore, these future studies will inform neurosurgeons and decision makers. These studies will also highlight the gaps in neurosurgical care between HICs and LMICs, which will be a valuable tool for global neurosurgery advocacy, practice, and education.

In the future, it will be helpful to evaluate the benefits of involvement of medical students in the Global NeuroSurg research collaborative; however, we have not yet acquired the data to answer this question since the entire collaborative efforts are currently focused on finalizing a successful Global NeuroSurg I project. It is expected that the involvement of medical students in the Global NeuroSurg research collaborative will (1) increase their exposure to the neurosurgical OR, (2) enhance their participation in neurosurgical research and increase their CV and publication list, and (3) build their connections with the neurosurgical community.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

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Characteristics of Patients With Trigeminal Neuralgia Referred to the Indonesian National Brain Center Neurosurgery Clinic

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Trigeminal neuralgia (TN) is a debilitating neuropathic pain involving the fifth cranial nerve. There has been no study investigating the clinical and socioeconomical characteristics of patients with TN in Indonesia. A total of 100 patients were included in this study. Symptoms indicating a later stage of the illness, namely, involvement of all the trigeminal nerve branches, numbness, and concomitant persistent pain, were the common presentations found in our cohort. Only one TN diagnosis was made by a general practitioner (GP). None were immediately referred to a neurosurgeon following their diagnosis. Access to our clinic took as long as 4.7 ± 5.1 years (mean ± SD) from the onset. Older age was a significant predictor of an increased likelihood of not knowing their illness upon the referral (21.9%, $p = 0.008$). Upon their first presentation, 25.5% of patients had experienced drug-related side effects due to prolonged medication. Only 50% of patients were compensated by the universal health coverage (UHC) system. Seven patients spent ≥ 50 million rupiahs and eight patients had already lost their jobs. In conclusion, early contact with a neurosurgeon contributes to better management of TN, both for the patients and healthcare system in Indonesia. A refined understanding of TN nature is still needed in this country.

Keywords: trigeminal neuralgia, facial pain, Indonesia, neurosurgery clinic, epidemiology

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INTRODUCTION

Trigeminal neuralgia (TN) is a neurologic disease characterized by a sudden and triggered-bout severe pain in the sensory area of the fifth cranial nerve (1). Due to the severity of the pain, debilitating effects of TN on the life of patient, either physically, mentally, or socioeconomically, have been numerously documented (2–6).

Since first described in 1756, treatment methods of TN have been continuously developing. One of the most significant changes was the establishment of surgical treatment of TN. The procedure, called microvascular decompression (MVD), was popularized by Peter Jannetta and has been the only definitive treatment of TN to date. The pain resolution after MVD is expected in more than 76% of patients, even at 10 years following the surgery (7, 8). Furthermore, improved surgical instruments and techniques had achieved even better pain control in the recent studies (9–11). This advancement has emphasized the integral role of a neurosurgeon in the management of TN.

In 2014, Indonesia, a developing middle-income country, introduced its novel universal health coverage (UHC) system, covering more than 203 million people (12). Also, within the same year, first multidisciplinary, tertiary-level neurological center in Indonesia, the Indonesian National Brain Center, started to operate, commencing to provide a wide variety of neurology-related healthcare to the public. These establishments have given access to the curable opportunity with neurosurgical procedures for patients with TN.

An established epidemiological study is a vital foundation for clinical and public health practices. This basis is the gap of knowledge in achieving the utmost management of TN in Indonesia. Through epidemiological study, diagnostic accuracy can be improved and risk factors, disease progression pattern, and burden among the affected population can also be identified (13, 14). This study aims to develop the landscape of patients with TN in Indonesia who were referred to the Indonesian National Brain Center. Sharing this information among the medical professionals involved in treating TN may allow healthcare systems of other developing countries to manage patients with TN efficiently.

METHODS

Study Subjects

Consenting patients diagnosed with TN by the International Classification of Headache Disorders-3rd Edition (ICHD-3) criteria were enrolled in this study between April 2014 and January 2021. Consecutive sampling was employed. All of them were attending the Indonesian National Brain Center neurosurgery clinic in Jakarta, Indonesia.

Ethics Approval

This study has been done with prior written consent after an information sheet has been provided to all the subjects. Approval by the Indonesian National Brain Center Hospital Ethics Committee was obtained.

Data Collection

Data were collected through a checklist-guided interview by an attending neurosurgeon (MP), which consisted of the socioeconomic, demographical, and clinical characteristics of patient. Prior medical consultation and treatment concerning the facial pain were also noted including who made the diagnosis, frequency and economic burden of prior treatment, its effect, and knowledge of patient with respect to their illness. The pain history was also collected: onset, duration, side of pain, trigger, frequency, pain quality, severity, and progression. Effect of TN on the social-economical domain of patient was also documented. Data from electronic medical record (EMR) of patient was also included as an addition.

Statistical Analysis

Statistical analyses were conducted by independent physicians in R statistical environment (version 1.3.1093). The socioeconomic and clinical characteristics of patient were descriptively presented. The mean was expressed with ±SD, while the median was expressed with interquartile range (IQR) (first quartile to third quartile). The Shapiro–Wilk test was employed for normality testing. The chi-squared, Fisher's exact, Mann–Whitney *U*, Spearman's, Pearson's, and linear regression tests were used accordingly. A $p < 0.05$ was considered to indicate a statistically significant association or correlation.

RESULTS

Demographical Characteristics

A total of 100 subjects were included, with some variables were missing for some of patients. The demographical data are given in **Table 1**. The mean age (SD) at diagnosis was 55.2 (13.8) years, with female predominance (59%). Of these, 22% of patients ($n =$ 22/100) either had less than a high-school diploma or illiterate and 90% of patients ($n = 90/100$) lived within the island. A total of 90 patients ($n = 90/100$, 90%) of the cohort were head of the family and 24% of patients ($n = 24/100$) were full-time workers. Hypertension was found in 42 patients ($n = 42/100$, 42%), where more than half patients ($n = 26/42$, 62%) were females. No multiple sclerosis was identified and 10 patients (n $= 10/100$, 10%) were smokers.

Pain Characteristics, Severity, Progression, and Remission

The right side was most commonly affected ($n = 51/97$, 52.6%), with involvement of all (V1, V2, and V3) the trigeminal branches being the most common to be seen in our cohort ($n = 26/96$, 26.5%). The patients with episodes of paroxysmal pain mostly experience 2–10 episodes of daily pain ($n = 46/73$, 63%), with a duration of 2–30 mins seen in 57.1% of patients ($n = 52/91$). A total of 77 patients ($n = 77/91$, 84.6%) complained of having paroxysmal pain lasting more than 2 min, which was significantly associated with a longer duration of illness (Mann–Whitney *U* test, $p = 0.023$, median = 2.5 vs. 4.5 years).

Numbness in any division of trigeminal nerve was observed in 28 patients ($n = 28/96$, 29%), even though only two of them had undergone invasive procedures (one patient underwent MVD and one patient underwent percutaneous radiofrequency rhizotomy). However, 30% of patients with TN with numbness had a previous history of ischemic stroke, which was statistically significant (Fisher's exact test, $p = 0.002$) vs. 3% in patients with TN without numbness. The mean duration from the onset was longer among patients with numbness (5.3 vs. 4.6 years), although it was not statistically significant. **Table 2** presents the other clinical characteristics.

Table 3 depicts pain severity and its progression. Upon contact at the neurosurgery clinic, the median (1st quartile to 3rd quartile) numeric rating scale (NRS) for pain severity was 8 (6–9) and 71.7% of patients ($n = 71/99$) were having severe pain according to verbal rating scale (VRS) classification. A total of 40 patients ($n = 40/97$, 41.2%) had either severe pain without any relief with medication or not adequately controlled by medication [Barrow Neurological Institute (BNI) pain scale IV or higher]. Pain progression in terms of frequency and severity was seen in 76.5 and 74.7% of patients, respectively. An increase in severity and frequency was significantly associated with one

TABLE 1 | Basic demographical data.

Characteristic	Value
Age at diagnosis—year*	55.2 ± 13.8
Female sex—*n* (%)	59 (59%)
Ethnicity—*n* (%)	
Javanese	39 (39)
Betawi	17 (17)
Sundanese	17 (17)
Bataknese	7 (7)
Others†	20 (20)
Educational level—*n* (%)	
Bachelor's/master's degree	13 (13)
Associate degree	10 (10)
High school graduate	55 (55)
Less than a high school diploma	19 (19)
Illiterate	3 (3)
Marital status—*n* (%)	
Married	85 (85)
Separated	6 (6)
Single	5 (5)
Divorced/widowed	4 (4)
Head of family—*n* (%)	90 (90%)
Working status—*n* (%)	
Homemaker	34 (34)
Full-time worker	24 (24)
Not working	17 (17)
Retired	13 (13)
Part-time worker	9 (9)
Student	3 (3)
Living within the Java Island—*n* (%)	90 (90%)
Previous medical history—*n* (%)	
Hypertension	42 (42)
Ischemic stroke	9 (9)
Migraine headache	5 (5)
Diabetes Mellitus type 2	3 (3)
Others‡	76 (76)
Smoking history—*n* (%)	10 (10)

*Mean ± SD.
†Others, Bengkulunese; Buginese; Chinese; Manadonese; Medanese; Melayunese; Minangnese; Palembangnese.
‡Others, dyspepsia syndrome; chronic kidney disease; facial trauma; malignancy; hyperuricemia; benign paroxysmal positional vertigo.

TABLE 2 | Characteristic of facial pain.

Characteristic	Value
Side of pain—*n* (%)	
Right	51 (52.6)
Left	44 (45.4)
Bilateral	2 (2.1)
Trigeminal nerve branch involved—*n* (%)	
V1*	5 (5.1)
V2*	19 (19.4)
V3*	22 (22.4)
V1–V2*	10 (10.2)
V2–V3*	14 (14.3)
V1–V2–V3*	26 (26.5)
Types of facial pain—*n* (%)	
Purely paroxysmal	85 (85)
Paroxysmal with concomitant continuous pain	8 (8)
Purely concomitant continuous pain	7 (7)
Daily attack frequency—*n* (%)	
Single episode	5 (6.8)
2–5 episodes	23 (31.5)
6–10 episodes	23 (31.5)
>10 episodes	15 (20.5)
Variable frequency	7 (9.6)
Duration of each pain episode—*n* (%)	
<2 mins	14 (15.4)
2–30 mins	52 (57.1)
30–60 mins	9 (9.9)
>60 mins	14 (15.4)
Variable duration	2 (2.2)
Quality of pain—*n* (%)	
Electric shock-like pain	65 (65)
Sharp shooting pain	45 (45)
Stabbing pain	35 (35)
Burning pain	32 (32)
Throbbing pain	28 (28)
Others†	5 (5)
Pain attack triggered by—*n* (%)	
Chewing	85 (85)
Talking	80 (80)
Brushing teeth	78 (78)
Washing face	74 (74)
Blowing wind	60 (60)
Cold temperature	53 (53)
Shaving‡	40 (97.6)
Numbness in any division of trigeminal nerve—*n* (%)	28 (29)

*V1, ophthalmic branch; V2, maxillary branch; V3, mandibular branch.
†Others, tingling sensation; numb.
‡Only counted in males.

another (Fisher's exact test, $p < 0.0001$). A progression in pain frequency was significantly associated with younger age (≤51-year-old, chi-squared test, $p = 0.02$). However, younger age was not significantly associated with a progression in the pain intensity and no other clinical or socioeconomical factors were significantly associated with pain progression. In 40.4% ($n = 40/99$) of patients, a period of complete remission for at least 2 weeks was seen.

Previous History of Pain-Related Consultations

In total, 99% ($n = 99/100$) of the diagnoses were made by specialists at a secondary or tertiary healthcare facility, with most of them ($n = 85/100$, 85%) were made by a neurologist. Even though 56% ($n = 56/100$) of all the patients had a previous history of consultation with a general practitioner (GP) at a primary healthcare facility, only one patient was diagnosed by them. Before referral, 31% of patients ($n = 31/100$) had more than four

TABLE 3 | Pain severity, progression, and remission.

Characteristic	Value
Numeric rating scale (NRS)*	8 (6–9)
Verbal rating scale (VRS)—*n* (%)	
Mild	12 (12.1)
Moderate	16 (16.2)
Severe	71 (71.7)
Barrow Neurological Institute pain scale—*n* (%)	
I—No pain, no medication required	0 (0)
II—Occasional pain, no medication required	7 (9.3)
III—Some pain, adequately controlled by medication	50 (51.5)
IV—Some pain, not adequately controlled by medication	33 (34)
V—Severe pain or no pain relief with medication	7 (7.2)
Increasing pain frequency—*n* (%)	75 (76.5)
Increasing pain severity—*n* (%)	74 (74.7)
Persistent pain location—*n* (%)	76 (80)
Period of remission†–*n* (%)	40 (40.4)

*Median (1st quartile to 3rd quartile).
†Period of complete remission for at least 2 weeks in duration.

TABLE 4 | Previous history of medical consultation.

Characteristic	Value
Previous history of consultation with—*n* (%)	
Neurology specialist	71 (71)
Dentist and oral-maxillofacial surgeon	69 (69)
General practitioner	56 (56)
Neurosurgeon	43 (43)
Acupuncture specialist	13 (13)
Otorhinolaryngology specialist	12 (12)
Herbal medicine	9 (9)
Others*	5 (5)
Number of previous consultations—*n* (%)	
≤5	56 (64.4)
6–10	8 (9.2)
11–20	8 (9.2)
21–30	5 (5.7)
>30	10 (11.5)
Diagnosed as trigeminal neuralgia by—*n* (%)	
Neurology specialist	85 (85)
Neurosurgeon	8 (8)
Dentist and oral-maxillofacial surgeon	4 (4)
General practitioner	1 (1)
Orthopedic surgeon	1 (1)
Duration from onset to referral†–year	4.7 ± 5.1

*Others, ophthalmology specialist; dermatovenereology specialist; internal medicine specialist; orthopedic surgeon.
†Mean ± SD.

consultations with a healthcare professional. Even though, 43 patients ($n = 43/100$, 43%) of the cohort had a previous visit with a neurosurgeon and none of them were immediately referred to a

TABLE 5 | Previous treatment history.

Characteristic	Value
Previously consumed drug—*n* (%)	
Carbamazepine	75 (75)
Gabapentin	25 (25)
NSAID	5 (5)
Paracetamol	4 (4)
Opiate analgesic	3 (3)
Amitriptyline	3 (3)
Others*	8 (8)
No previous drug consumption	5 (5)
Experiencing drug related side effect—*n* (%)	25 (25.5)
Previous invasive procedure for pain relief—*n* (%)	
Percutaneous RF rhizotomy†	8 (8)
Tooth extraction	6 (6)
Peripheral block	5 (5)
Acupuncture	3 (3)
MVD‡	2 (2)
No previous invasive procedure	76 (76)

*Others, oxcarbamazepine; methylcobalamin; phenytoin; oral corticosteroid; lamotrigine; valproic acid.
†RF, radiofrequency.
‡Microvascular decompression.

neurosurgeon upon diagnosis (**Table 4**). The mean duration (SD) from the onset to referral to our clinic was 4.7 (5.1) years. Ten of them ($n = 10/99$, 10.1%) were referred 10 years or longer after the pain onset. In total, 37 of our patients ($n = 37/100$, 37%) who had $\geq$ 20 years of life expectancy ($\leq$51 years) had a mean duration of 5.6 years from onset to first contact with our clinic, which is 0.9 years longer than the entire cohort, although it is not statistically significant.

At the first contact in our neurosurgery clinic, as much as 21.9% ($n = 21/96$) of the cohort did not know their diagnosis. The logistic regression analysis was performed to ascertain the effects of demography, clinical characteristics, and previous consultation factors. The model was statistically significant ($\chi^2 = 20.754$, $p = 0.008$, Nagelkerke $R^2 = 32.7\%$) and increasing age was significantly associated ($p = 0.018$) with an increased likelihood of not knowing their diagnosis.

Previous History of Pain-Related Treatment and Its Outcome

Carbamazepine was the most prescribed drug among the patients initially treated with medication ($n = 95/100$, 95%). Five patients ($n = 5/100$, 5%) had no previous history of medication for pain relief. More than a quarter patients (26.3%, $n = 25/95$) had already experienced drug-related side effects upon referral. In total, 24 patients ($n = 24/100$, 24%) had a previous history of invasive procedures, with percutaneous radiofrequency rhizotomy being the most frequent (33.3%, $n = 8/24$). Previously prescribed drugs and invasive procedures performed for pain relief are given in **Table 5**. Only six patients ($n = 6/99$, 6.1%) reported complete relief of pain from previous treatment. Most of them only had partial pain relief ($n = 58/99$, 58.6%), while 22 patients ($n = 22/99$, 22.2%) had no resolution and 13 patients ($n = 13/99$, 13.1%) experienced worsening of pain.

Social and Economic Impact of TN in Indonesia

A total of 13 patients ($n = 13/91$, 14.4%) reported significant disturbance in work productivity, with 11 patients ($n = 11/91$, 12.2%) losing jobs due to the facial pain. In total, 52 patients ($n = 52/91$, 57%) reported no effect on working productivity, while 26 patients ($n = 26/91$, 28.6%) complained of decreased work productivity. Effect of pain on work was significantly associated with the previous treatment outcome (chi-squared test, $p = 0.0155$). Five patients ($n = 5/11$, 45.5%) who lost their jobs reported pain worsening as previous treatment outcomes.

The coverage ratio by the Indonesia UHC scheme was only 50% ($n = 48/96$) in our cohort. Among the UHC-uncovered patients, 31 patients ($n = 31/48$, 64.6%) had spent more than 5 million rupiahs (in Indonesian Rupiah—IDR, 1 US dollar equals to 14,495 IDR) and 7 patients ($n = 7/48$, 14.6%) spent more than 50 million rupiahs (3,490.66 USD) for their treatment. There was a moderate, positive correlation between health expenditure and duration from onset to referral, which was statistically significant (Pearson's test, $r = 0.4927$, $n = 46$, $p = 0.0005$).

DISCUSSION

This study revealed identical clinical characteristics of patients with TN with those outsides of Indonesia (1, 15, 16), except for some differences that will be discussed below.

A low prevalence of bilateral involvement was noted in this study (2.1%). This difference may be related to the low prevalence of multiple sclerosis (MS) in Indonesia and other Asian populations compared to the Caucasian population (17). Bilateral TN has been implicated previously in up to 30% of patients with MS in the literature (18–20). The low prevalence of MS in Indonesia may be related to the low number of bilateral patients with TN in our cohort.

Involvement of all the trigeminal nerve branches was distinctly the most common presentation. It is contradictory to many previous findings, which stated that only the second and third trigeminal nerve branches were affected in most cases (1, 15, 16, 21, 22). It is possibly caused by the late referral to our center, allowing the disease to progress. Extension to the first division of the trigeminal nerve has been reported as a manifestation of progression of TN (15, 16, 21).

Moreover, we encountered a surprisingly high proportion (29%) of patients who complained of numbness in the sensory area of the trigeminal nerve. It was presumably another sign of progression of TN observed in our cohort. Numbness has been previously depicted as a sign of deteriorated TN in several studies (23–26). With only two patients having a previous history of either percutaneous rhizotomy or MVD, the association between invasive procedures and numbness that has been previously reported was not seen in this study (24). Numbness, however, was linked to late referrals that led to disease progression.

Furthermore, paroxysmal pain lasting more than 2 mins was documented in 35.7% of patients. Haviv et al. postulated that more prolonged paroxysmal pain is related to the duration of the illness (27), a pattern we also similarly had in our cohort. In our opinion, patients with TN should be referred to a neurosurgeon at the early stage, before the illness progresses, as they can be benefited from a variety of therapeutic choices, including MVD.

Poor recognition of TN among patients and physicians is an issue that we faced in supporting an ideal healthcare system. Poor recognition of their illness from the side of patient is a barrier for medical practitioners in providing the necessary medical services at proper timing. Almost a quarter of our patients did not recognize their illness at the first contact in our neurosurgery clinic. Older age was identified as an independent risk factor for lack of recognition of their disease in this study. Previous studies have shown that literacy of a person on their disease is crucially determining how they cope with pain and affecting their treatment outcome (28–31). Our observation encourages the medical practitioners to inform a comprehensive knowledge of patient about TN. On the other hand, only one patient was diagnosed by a GP, amidst more than half of the cohort had previous consultations with one. Despite the difficulty in recognizing TN among GPs has been previously reported (32–34), TN can be clinically diagnosed with careful history taking even considering its variability in presentation. Thus, our epidemiological study revealed a poor understanding of the illness on both the patients and the medical professionals. Early contact between patients and neurosurgeons is essential in achieving excellent care for potentially debilitating TN and for preventing further socioeconomical loss at individual and public health levels. We believe that it is crucial to make a prompt diagnosis at first contact of patient with GPs in the primary healthcare facility and enhance community knowledge with respect to TN to improve its treatment in Indonesia.

The financial aspect of managing TN is remarkably worrisome in our country. In our cohort, the UHC covered only 50% of patients. This finding was contradictory with the national data of coverage of the system, which has been reported to reach 82.51%. We found no explanation for this matter, as all the expenditures were supposed to be covered, including dental and oral-maxillofacial surgery treatment (35). Since 14.6% of patients not covered by the UHC spent more than 50 million rupiahs in a country with a GDP per capita of 56.9 million rupiahs (in 2020), further study is needed to dwell deep on this matter (36). The Indonesian National Brain Center has provided excellent neurosurgical services covered by the UHC since its establishment in 2014. However, this study revealed that most patients were referred at the later stage of the illness. We were not able to estimate the social loss from prolonged ineffective medications for medically intractable patients with TN. However, numerous patients in our cohort suffered socioeconomically from decreased productivity at work and even lost their jobs besides suffering from the pain itself.

All of the issues we encountered here, namely, advanced TN at initial presentation, underdiagnosis by GPs at primary healthcare facilities, poor disease knowledge among patients, and high socioeconomic burden, points to ineffective management of TN at a public health level. The shortage of neurosurgeons and an unequal geographical distribution are issues that limit neurosurgical access for patients with TN. According to the Indonesian College of Neurosurgeons, our country has a ratio of one neurosurgeon for every 687.5 thousand people, compared to one for every 60–80 thousand people in developed nations (37). More than 15% are concentrated within capital city of Indonesia and almost one-third provinces of Indonesia do not have access to neurosurgical services. Early contact with a neurosurgeon in rural areas is almost impossible and geographical barriers between islands make referrals to our center difficult and expensive. Thus, it is not surprising that only 10% of patients with TN were from outside the island.

The UHC stakeholders must provide at least one comprehensive consultation with a neurosurgeon upon diagnosis. A consensus when to perform an MVD must also be reached. According to a study by Linskey et al., we advocate that all the patients with TN should immediately be referred to a neurosurgeon upon diagnosis. This would allow for judicious surgical decision-making including considerations on risks and appropriate timing (38). We believe that this is feasible under the current UHC system in Indonesia.

Complex MVD surgery, such as in cases such as vertebrobasilar dolichoectasia, must be conducted centrally at a national referral center such as ours and a clear referral pathway must be constructed by the UHC stakeholders. The current system seems to underutilize our resources to perform complex MVD surgeries. Regionalization for simple MVD cases is ideal, but an unequal distribution of neurosurgeons, surgical instruments, and MRI facility prevents the realization of such schemes (39). We believe that implementation of such systems would improve national outcomes of TN, both clinically and socioeconomically.

In this study, we present a clinical and socioeconomical landscape of patients with TN in a developing country, with unusual features of disease progression and a high socioeconomic burden. The challenges and lessons learned at a public health level can be applied to other developing countries, allowing them to design effective healthcare schemes for comprehensive management of TN. However, differences in geographical barriers and healthcare systems must be considered while interpreting our results and opinions.

CONCLUSION

In conclusion, we presented the characterization of TN in Indonesia including the impact and challenges we faced at social, economic, and healthcare system aspects. However, it was only conducted in a tertiary healthcare setting, making our findings may not be representable to all the populations with TN in Indonesia. Our sample size was also limited. A further study was conducted at every healthcare facility level, with larger sample size, using validated instruments, assessing deeply on its health economy domain, including follow-up until the postoperative period is still needed. Current system in Indonesia has enabled an ideal scheme for management of TN to be applied, yet its realization remains a challenge to be addressed.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Indonesia National Brain Center Ethical Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MP, AS, and PA contributed to the conception, design, and acquisition of the study. MP, PA, and TI conducted the data analysis and wrote the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version of the manuscript.

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Neurosurgical Equipment Donations: A Qualitative Study

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Introduction: Neurosurgical equipment donation from high-income countries (HICs) to low-and-middle income countries (LMICs) exists. However, there is currently no published literature on whether there is a need for neurosurgical equipment donations or how to design equipment donation programmes that meet the needs of LMIC neurosurgeons. The primary aims of this study were to explore: (1) the need for the donation of neurosurgical equipment from the UK and Ireland to LMICs within the African continent, and (2) the ways through which neurosurgical equipment donations could meet the needs of LMIC neurosurgeons.

Methods: This was a qualitative study using semi-structured, one-on-one, audio-recorded interviews. Purposive sampling was used to recruit and interview consultants or attending neurosurgeons from Ireland, the UK and LMICs in Africa in a continuous process until data saturation. Interviews were conducted by members of the Association of Future African Neurosurgeons during March 2021. Qualitative analysis used a thematic approach using open and axial coding.

Results: Five HIC and 3 LMIC neurosurgeons were interviewed. Five overarching themes were identified: (1) inequality of access to neurosurgical equipment, (2) identifying specific neurosurgical equipment needs, (3) importance of organisations, (4) partnerships between LMIC and HIC centres, and (5) donations are insufficient in isolation.

Conclusion: There is a need for greater access to neurosurgical equipment in LMICs. It is unclear if neurosurgical equipment donations are the optimal solution to this issue. Other solutions that are not linked to dependency need to be explored and executed. Collaborative relationships between LMICs and HICs better ensures that neurosurgical equipment donations meet the needs of the recipients. These relationships may be best created within an organisation framework that has the logistical capabilities of coordinating international equipment donation and providing a quality control measure.

Keywords: neurosurgical, equipment, donations, donor, developing countries, UK, low-and-middle income countries (LMICs)

INTRODUCTION

Of the 13.8 million individuals requiring neurosurgical care each year, more than 80% are located in low-and-middle-income countries (LMICs) (1). Despite their disproportionate neurosurgical needs, LMICs have significantly fewer human resources, funding and infrastructure to meet them compared to high-income countries (HICs) (2, 3). The World Federation of Neurosurgical Societies' Global Neurosurgery Committee (WFNS GNC) recommends countries should have at least 1 neurosurgeon per 200,000 inhabitants, universal health coverage for all neurosurgical emergencies, and universal 2-h access to a facility that provides basic macroneurosurgery (4). While there have been considerable improvements in neurosurgical workforce and universal health coverage for neurosurgical emergencies, most LMICs face significant infrastructural challenges (5, 6). The WFNS GNC mapped global access to neurosurgical infrastructure using a three-tier categorisation and geographic information systems: Level 1 facilities have the resources to provide basic macroneurosurgery; especially emergency neurotrauma care; Level 2 facilities provide basic microneurosurgery in addition to macroneurosurgery; and Level 3 facilities provide advanced microneurosurgery in addition to basic microneurosurgery and macroneurosurgery (7). This mapping project revealed that most LMICs do not have enough neurosurgical facilities to cover their entire population (7). Similarly, LMIC centres have limited access to neuro-intensive care units, microsurgery equipment, and intraoperative guidance, resulting in LMICs being less likely to provide Level 2 and 3 care (8). Karekezi et al. evaluated the impact of African neurosurgeons whose training had been sponsored by the WFNS and found that restricted access to neurosurgical equipment limited the neurosurgeons' service delivery in their home countries (9).

Mindful of these challenges, strategies of neurosurgical equipment donation from HICs to LMICs have been implemented (10, 11). These initiatives were largely created to tackle the health inequity mentioned above and advance the agenda for social justice for LMIC neurosurgical patients. Social justice in the realms of healthcare can be thought broadly as advocating for individuals' ability to receive timely and adequate treatment independent of their background characteristics, including geographical location (12). Despite neurosurgical equipment donation programmes being set up with the best of intentions, there exists no literature establishing whether neurosurgery equipment donations programmes were needed. The existing literature on neurosurgical equipment donations are sparse, quantitative, and from the lens of HIC authors (10, 11). They solely focus on the impact of a neurosurgery equipment donation initiative. Whilst quantitative methods can be used to assess the impact of a neurosurgical equipment donation, they impose a predetermined metric through which to measure impact based on predetermined beliefs. Therefore, a quantitative methodological approach is too rigid to deeply explore the need for neurosurgical equipment donations or design effective equipment donation programmes that meet the needs of LMIC neurosurgeons (13).

Given the relation of the above to social justice, it is important that the research method used acts as a vehicle through which social justice can be enacted. Qualitative research shares several elements that are in keeping with the pursuit of social justice (14, 15). Primarily, there is a recognition that context is critical (16–18). Secondly, great emphasis is placed on creating a reciprocal relationship between the researchers and research participants, and reflecting on the effect this relationship might have had on the results (17, 19). By enabling this focus on equity, access, participation and harmony, qualitative research allows researchers to assist the people participating in the study in a socially just manner (15, 20). For the purpose of this study, qualitative research design was utilised through the contextualised study of individuals through interviews. Interviews are a means through which both the participants' words and the meaning behind those words can be captured (21). This enabled for more detailed answers, freedom in discussion, and participants to expand on their thoughts and experiences in their own words (22). This in turn allowed for topic areas to be brought up by participants that were not directly asked about by the interviewer. Given the time- and resource-intensive nature of qualitative research, it is important to state that the study design lends itself to small sample sizes. The rigour of qualitative research depends on reflexivity rather than recruiting a predetermined number of participants (23), and recruiting more participants to increase the size of the dataset would do as much to compromise the depth of the analysis as to increase its breadth (24).

Given the researchers conducting this study were affiliated with the Association of Future African Neurosurgeons, it was determined that the focus of this study would be within the geographical areas that the researchers were located in. Therefore, the study focussed on the perspectives of HIC neurosurgeons in the United Kingdom (UK) and Ireland, as well LMIC neurosurgeons in Benin, Cameroon and Zimbabwe. The primary aims of this study were to explore (1) the need for the donation of neurosurgical equipment from the UK and Ireland to LMICs within the African continent, and (2) the ways through which neurosurgical equipment donations could meet the needs of LMIC neurosurgeons. The secondary aims of this study were to identify (1) the views of attending or consultant neurosurgeons regarding the topic of neurosurgical equipment donations, (2) the barriers to donating neurosurgical equipment, and (3) the factors that could motivate neurosurgical equipment donation.

METHODS

Study Design

This study was designed by authors who all met and connected online via social media channels. The authors connected over their shared interest of neurosurgery and equipment donations. This was a qualitative study using semi-structured one-on-one audio-recorded interviews (25). A participatory approach was taken. Participants were actively involved in the research process and the co-creation of understandings. This study received ethical approval by the University of Oxford Medical Sciences

Inter-Divisional Research Ethics Committee (Ethics Approval Reference: R74097/RE001) on 15th February 2021. Participation was voluntary and informed consent was obtained from each participant before embarking on this study.

Participants

Unlike sampling in quantitative studies where the goal is to randomly sample a population with the intention of making inferences from that sample to the population in general, qualitative research requires purposive sampling that focuses on particular characteristics of the population of interest. As such, purposive sampling was used to recruit consultants or attending neurosurgeons from Ireland, the UK and LMICs in Africa, as defined by the World Bank criteria (26). A non-probability sampling technique was used as the aim of qualitative research is not to produce a statistically representative sample or draw statistical inference, but to have an appropriate group of individuals that reflects the diversity and breadth of the sample population (27). Indeed, an idea needed to only appear once to be deemed of value. The specific form of purposive sampling used was theoretical sampling, where recruitment and interviewing were done in a continuous process until both a suitably varied group of participants had been interviewed and when the data was deemed to have no further interpretive value, often termed data saturation (28, 29).

Data Collection

Written informed consent was sought from all participants including for audio-recording and anonymous quotations. Demographic information was gathered from all participants including ethnicity and geographic location. Interviews were conducted using a semi-structured approach. The interviews were conducted using a topic schedule (**Appendix S1**). This started with specific questions but as themes arose these were followed. All interviews were conducted one-on-one with each participant over Zoom over a 4-week period in March 2021. Each interview was audio-recorded and transcribed. Audio records and anonymised transcripts were encrypted and stored in a secure location.

Data Analysis

Qualitative data coding, management, and analysis was conducted. Identifiers were removed from transcripts to preserve anonymity. Qualitative analysis used a thematic approach using open and axial coding (28). Open coding involved deconstructing participant responses into common groupings based on shared ideas. Dominant ideas that emerged were then organised into overarching themes through axial coding. Each author independently reviewed and coded the data. Any conflicts in coding were resolved by mutual agreement. Participant data were interpreted and summarised. Codes of similar information were merged leading to a series of phenomena that appeared increasingly representative of the participants perspectives. Data gathering ceased when collecting more data was deemed to have no further interpretive value. To reduce researcher bias, we discussed and maintained an awareness of preconceptions and constantly linked the emergent themes to the interview data.

RESULTS

Participants

Eight neurosurgeons participated in this study. There was a wide spectrum of experience with neurosurgical equipment donations, with some individuals having no experience and others having extensive experience. Similarly, individuals belonged to a wide spectrum of neurosurgical centres, in which some centres had never been involved in neurosurgical equipment donations, some centres had previously been involved in neurosurgical equipment donation, and some centres were currently involved in neurosurgical equipment donation. The participants represented the diversity and breadth of the sample population.

Thematic Analysis

Analysis of the interviews resulted in five overarching themes. These are described in greater detail below and supported with verbatim quotes from study participants (**Appendix S1**).

Inequality in Access to Neurosurgical Equipment

All individuals recognised that LMICs did not have access to certain types of neurosurgical equipment, and this was a need that should be addressed.

There was diversity of thought on how best to meet this need. Some believed that donations were the best way forward. Others believed that donations created a dependency relationship, and the way forward was through the creation of an exchange system.

Identifying Specific Neurosurgical Equipment Needs

Neurosurgeons in HICs felt a barrier to donation was lack of knowledge about what was needed. They believed that the needs of one country did not map onto the needs of another. They agreed that neurosurgery equipment donations were only useful if the equipment donated matched the demands of the recipient centre.

This discrepancy in need was evident in the fact that some LMICs were recognised to have facilities that were comparable to those present in neurosurgical centres in HIC countries, whilst others were struggling to acquire common consumables used in neurosurgery.

Despite differences, neurosurgeons based in different LMICs shared some common needs. An equipment that was found to be wanting and in high demand was the neurosurgery operating microscope.

LMIC and HIC neurosurgeons felt the cost and the logistics of transport created a barrier to donating microscopes. These costs were considered to be balanced by some by the longevity of the donation. However, others felt there was a risk that the microscope could break down, and if there was no system in place for servicing the equipment this would lead to a waste of valuable resources.

Importance of Organisations

Given the complexities surrounding equipment donations, the involvement of an organisation in this process was thought to be important. Organisations were believed to be important in dealing with the logistics of collecting equipment from multiple centres in HICs, providing quality-control and infection-control of the equipment being donated, and distributing the equipment to LMIC centres.

Two organisations that were identified to be important in existing equipment donation were the World Health Organisation (WHO) and the WFNS. UK neurosurgeons believed that the Society of British Neurological Surgeons (SBNS), as a member society of the WFNS, were optimally placed to bring together the UK neurosurgical community for the purposes of equipment donation between centres within the UK and abroad. The British Medical Association (BMA) and the Royal College of Surgeons in Ireland (RCSI) were thought to be other organisations who could potentially take up this role in the UK and Ireland, respectively. However, involvement through WFNS was highly favoured by LMIC neurosurgeons.

A concern regarding organisations distributing neurosurgical equipment was the lack of transparency and auditing of where the material had been distributed to. It was theorised that being able to follow up the positive effects of an equipment donation could potentially advertise the benefits of doing so and encourage future equipment donations. It was appreciated that this may be difficult to do so for an organisation dealing with the inflow and outflow of equipment worldwide, and in the long-term having multiple organisations involved could improve the efficiency and transparency of this system. It was also thought to be important for the organisation involved in this process to ensure donating centres were not taking away equipment that would be needed for their own patients, as this could introduce significant opposition to equipment donation. A way to bypass this issue was identified to be for reusable, expensive equipment to be donated when hospitals in HICs were upgrading their equipment.

Partnerships Between LMIC and HIC Centres

The importance of relationships between centres was a key tenet of promoting neurosurgical equipment donations. A HIC neurosurgeon having a personal relationship with another neurosurgeon in a LMIC centre was a key motivator for donating to that centre.

These partnerships also better enabled the equipment donations to match the specific needs of the LMIC centre. Partnerships to establish needs could also be with neurosurgical societies based in different countries.

However, there were some qualms about how partnerships are largely created between people who know each other or where there are historical links between centres. This could place some centres without this network at a disadvantage to receiving equipment from HIC centres. It was thought to be critical to have an organisation act as a mediator to set up partnerships where none exist.

Equipment Donations Are Insufficient in Isolation

Partnerships also enabled training of local neurosurgeons to be performed. The educational side to these international partnerships was thought to be more valuable long-term as it could optimise the usability of current and possibly future neurosurgical equipment donations. There were fears that inadequate training of how to use a neurosurgical equipment could lead to harm being done to the local population or the equipment being broken.

There was a consensus that this training needed to occur in the setting of the LMIC centre, so that the equipment could be taught to be used within the resource constraints and environment of the LMIC that would be using it henceforth. The importance of training LMIC neurosurgeons was also highlighted in the fact that HIC neurosurgeons often came to LMIC countries to perform surgery and then went back home, and there was a need to have a local person trained to look after the patient post-operatively once the HIC neurosurgeon had left the LMIC.

Despite the recognition by HIC neurosurgeons of the need to train individuals within LMIC settings, there was some hesitancy about saying this and frequent unprompted clarifications that this was not related to denying opportunities for LMIC neurosurgeons in HICs or an act of charity. The time commitment required to spend a length of time training individuals in a LMIC away from family was highlighted as a barrier to equipment donation, as were local political situations that made educational endeavours challenging.

DISCUSSION

Summary of Findings

There is inequality in access to neurosurgical equipment between neurosurgical centres, both within the context of LMICs and between LMICs and HICs. Neurosurgical equipment donations were believed to be one method by which to address this inequity. However, there were concerns this could lead to a dependency relationship, and an exchange programme would be preferred. Regardless of the means of providing the equipment to centres, there was a recognition of the importance of first establishing the needs of a centre. This could be done by establishing partnership between centres or through organisations. Bilateral partnerships were highlighted to be key in motivating individuals to continue donating. For this reason, it was suggested that organisations, who are better suited to cope with the logistics of equipment donations on an international scale, should also encourage the creation of these relationships and be transparent about the impact of each donation. Furthermore, partnerships would also encourage an aspect that is critically linked to successful neurosurgical equipment donations: education on how to use the equipment to best serve the needs of the local population. This education and training were thought to be best done within LMIC centres, so that individuals could be trained in how to use the equipment within the context of the local resources available.

Implications

The need for neurosurgical equipment in LMICs has been highlighted in prior literature (10, 30, 31), and our current study suggests this need is still unmet. Unidirectional donation of equipment has traditionally been the approach to address this, and is still supported by some study participants. However, equipment donations were identified as possibly creating a possibly harmful power imbalance between donors and recipients, and the harmful effects of dependency that have been well documented in prior research (32, 33). However, it should be noted that donations are not intrinsically linked to dependency. Studies have shown that dependency is influenced by many factors, some of which do include the length and intensity of a donation period, but are linked to other factors that disincentivise local production and acquisition of skills (34, 35).

Our study also identified the potential for mis-matched donations resulting from a lack of understanding of recipient needs; a phenomenon that has been identified to be an issue in equipment donations for other subspecialties (30). One method to ameliorate this is through a collaborative approach, with reciprocal relationships between HICs and LMICs (30). The importance of bilateral partnerships has been noted previously, but so too have the difficulties in creating such partnerships. The greatest barrier identified in a survey by Davis *et al.* was the identification of potential partners (36). Participants in the current study validated this difficulty in neurosurgery, and called for an organisation to facilitate the equitable formation of partnerships. An example of such an organisation is the InterSurgeon platform, which was developed as a mechanism for promoting international neurosurgical collaboration (37).

The utility of organisational involvement goes beyond this. The WHO highlights how organisations may have the logistical capabilities to tackle some of the barriers to effective donation of neurosurgical equipment that were identified in this study (38, 39). For example, organisations may have the funding and manpower to track and monitor the impact of equipment donations, thereby providing greater transparency and accountability. However, there is a risk that an organisation tasked with this worldwide could grow too large and be less efficient than several smaller organisations (40, 41). A novel approach could be the creation of bilateral partnerships between HIC and LMIC centres within an organisation framework, which would combine the benefits of central organisations coordinating logistical efforts with the reciprocal understandings created through partnerships.

Interestingly, a survey of InterSurgeon members did not rank the physical sharing of equipment as a top priority of collaboration (37). Rather, the greatest importance was placed on the training of neurosurgeons in LMICs, which is in keeping with views expressed by participants in the current study. The importance of training and developing skills within local populations is also a key factor in preventing the deleterious effects of equipment donations (35). The hesitancy of some HIC neurosurgeons to embark on neurosurgical equipment donations due to their knowledge of the need to provide this training and the time commitment this would involve should be applauded, as this prevents the harm caused by short-term endeavours (42, 43). However, geographical displacement and time away from family do not need to be a barrier to providing the education that is critical for successful neurosurgical equipment donations. With the advancement of communication technology applications like Zoom, it is becoming increasingly easier to teach surgical skills through web-based applications without the need for physical travel (44).

It should be noted that neurosurgeons interviewed from HICs in this study were limited to the UK and Ireland only. It is possible that motivating factors and barriers to neurosurgical donations pertinent to neurosurgeons from other HICs were missed. Similarly, this study included neurosurgeons from African LMICs, and it is possible that neurosurgeons in other LMICs had differing opinions on the need for neurosurgical equipment donations. Therefore, the recommendations made from this article should be considered within the context of one of the primary aims of this study, which was to identify if there was need for the donation of neurosurgical equipment from the UK and Ireland to LMICs within the African continent. An additional limitation to this study was that qualitative analysis relies on the quality of the interview and the need for the interviewer not to introduce any biases. Therefore, the interviewers discussed and maintained an awareness of preconceptions and constantly linked the emergent themes to the interview data to minimise bias. In addition, a semi-structured approach was taken to the interview. This may have limited the participants from answering in a more diverse manner about their views on equipment donation, and instead directed them towards areas mentioned in the topic schedule. In order to minimise participants' answers being restricted in their content, it was essential that the interviewers were relatable to the participants. This was done through the interviewers having similar geographical backgrounds to that of the participants.

CONCLUSION

There is a need to reduce the shortage of neurosurgical equipment in LMICs if neurosurgical care is to improve. However, it is unclear if neurosurgical equipment donations provide the best path to meeting these needs, although they have provided a solution to this challenge historically. Other solutions that are not linked to dependency need to be explored and executed. A key factor behind neurosurgical equipment donations that meet the needs of the recipient and the provision of adequate training is the development of collaborative relationships between LMICs and HICs. These relationships may be best created within an organisation framework that has the logistical capabilities of coordinating international equipment donation and providing a standardised, quality control measure.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of Oxford Medical Sciences Inter-Divisional Research Ethics Committee. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DS: conception, design, interviewing, data analysis, writing, reviewing and editing, visual abstract, and project administration. SB: conception, interviewing, data analysis, writing, reviewing and editing, supervision, and project administration. AC, JE, and JK: interviewing, data analysis, writing, reviewing and editing. AE: data analysis, writing, reviewing and editing. NB, GH, and DD: writing, reviewing and editing. UK: writing, reviewing and editing, and supervision. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsurg.2021.690910/full#supplementary-material

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Evaluating the Impact of Neurosurgical Rotation Experience in Africa on the Interest and Perception of Medical Students Towards a Career in Neurosurgery: A Continental, Multi-Centre, Cross-Sectional Study

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Objective: Africa has the second highest neurosurgical workforce deficit globally and many medical students in Africa lack exposure to the field. This study aims to assess the impact of a neurosurgical rotation during medical school in shaping the perception and interest of students toward a career in neurosurgery.

Study Design: Cross-sectional study.

Methods: A Google form e-survey was disseminated to African clinical medical students between February 21st and March 20th, 2021. Data on exposure and length of neurosurgical rotation and perception of, and interest in, neurosurgery were collected. Data was analyzed using descriptive statistics and adjusted logistic regression modeling.

Results: Data was received from 539 students in 30 African countries (30/54, 55.6%). The majority of participants were male and were from Kenya, Nigeria and South Africa. Most students had undertaken a formal neurosurgery rotation, of which the majority reported a rotation length of 4 weeks or less. Students who had more than 4 weeks of neurosurgical exposure were more likely to express a career interest in neurosurgery than those without [odds ratio (OR) = 1.75, $p < 0.04$] and men were more likely to express interest in a neurosurgical career compared to women (OR = 3.22, $p < 0.001$), after adjusting for other factors.

Conclusion: Neurosurgical exposure is a key determinant in shaping the perception and interest of medical students toward a career in neurosurgery. Our findings support the need: i) for a continent-wide, standardized curriculum guide to neurosurgical rotations and ii) to advocate for gender inclusivity in education and policy-making efforts across the African continent.

Keywords: global neurosurgery, clinical rotation, medical students, medical education, training, Africa, interest, perception

INTRODUCTION

According to the Lancet Commission for Global Surgery, an estimated five billion people worldwide do not have access to safe, affordable surgical and anesthetic care, with most of these people residing in low- and middle-income countries (LMICs) (1). This health disparity phenomenon is particularly apparent in the neurosurgical landscape seen in Africa.

In recent years, Africa has begun to experience an emerging transformation in the availability of neurosurgical care through an increase in the number of training centers and increased collaboration with international neurosurgical foundations and neurosurgery departments from developed countries (2). However, despite these advances, the continent still has the second highest neurosurgical workforce deficit reported globally (3). This deficit has impacted surgical capacity negatively, with an estimated 1,877,568 surgical case deficit annually (3). Resolving this deficit is critical to ensuring timely access to high-quality neurosurgical care, reducing complication rates, and ultimately improving quality of life.

Interestingly, a recent survey among aspiring African neurosurgeons showed that the vast majority of students have little or no exposure to neurosurgical procedures (4). This highlights the scarcity of avenues for students to gain exposure and nurture their interest in the field. Published literature has shown that an essential long-term strategy in reducing this workforce deficit would include providing medical students with educational and career development opportunities related to the field of neurosurgery (3). This would be a key step in helping students gain an insight into a neurosurgical career and its demands, as well as to identify potential areas of interest.

To date, there has been a paucity of studies appraising the presence of a dedicated neurosurgical rotation in the curriculum delivered in African medical schools. Its impact on the perceptions and interest of medical students toward neurosurgery as a potential career has also yet to be evaluated.

In this prospective cross-sectional study, we aim to assess the role of a defined neurosurgical rotation during medical school and its impact on shaping perceptions and interest toward a neurosurgical career. We also aim to identify the features of a neurosurgical rotation that are associated with positive perception and interest toward a career in neurosurgery. We hypothesize that students with experience of a formal rotation in neurosurgery will have a more positive perception toward a career in neurosurgery.

This is the first study of its kind, addressing a key issue relevant to the whole African continent. Our findings aim to inform the ongoing progressive development of medical curricula, policy, and guidelines in medical schools across Africa.

METHODS

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement was used to guide this study report (5).

Study Design

A prospective analytical cross-sectional survey of African medical students was carried out using a self-administered electronic questionnaire. The criteria for the survey eligibility were current medical students studying in Africa and who are in their clinical years (4th to 6th, or higher year of study).

Data Collection

A 27-item, electronic survey (e-survey) was developed by medical students and a neurosurgery resident using Google Forms (Google, USA). The questionnaire was categorized into four sections: socio-demographic background, neurosurgical experience, perception toward neurosurgical career, and interest in a neurosurgical career. Questions under the perception toward a neurosurgical career category were adapted from Zuckerman et al. (6). The questionnaire included a five-point Likert scale, multiple-choice and free-text questions to improve the granularity of the data collected. All initial questions in the survey required a response to minimize any potential missing data at submission. A pilot survey was distributed to 15 randomly selected clinical medical students in Africa, who were not involved in the conception or design of the study, to seek feedback, improve clarity, and ensure objectivity.

The questionnaire was distributed to clinical medical students in the African continent between February 21st and March 20th, 2021. The questionnaire was available in the English and French language to facilitate broad coverage. The questionnaire in the English language was designed by three authors (OD, EO, OR) and translated to a French version by one author (OD) with the help of a deep learning translator [Traduit avec www.DeepL.com/Translator (version gratuite)]. This translated version of the questionnaire was vetted by a native French-speaking author (YK).

The questionnaires were distributed *via* social media platforms (Twitter, Facebook, WhatsApp, and Telegram), emails,

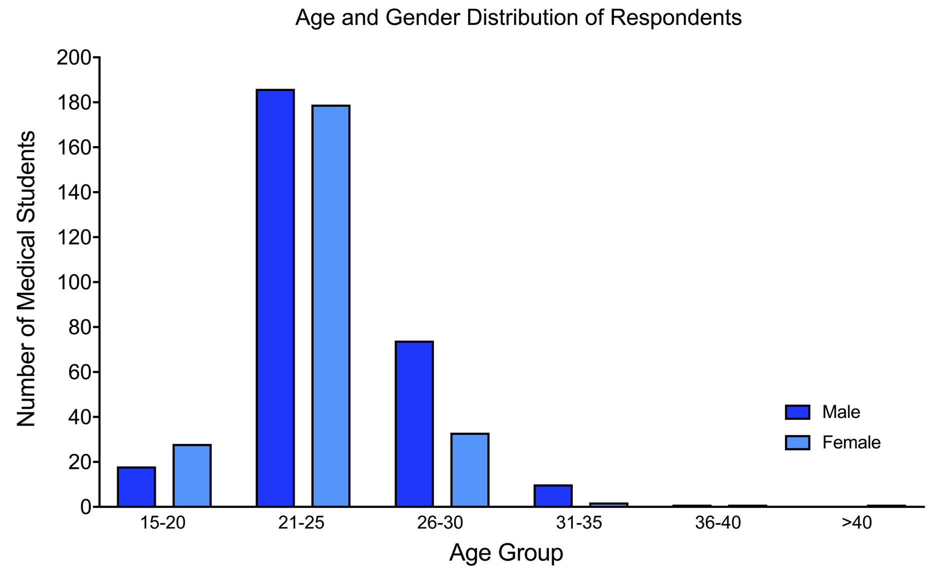

FIGURE 1 | Bar chart showing the age and gender distribution of the participants.

and through executive committee members of medical student associations in some countries. Participation was voluntary, and participants were informed prior to starting the survey that all data collected was non-identifiable and would only be used for the purposes of analysis, distribution and publication. A mandatory selection box consenting to participation and confirming that this was the first time completing this survey was included at the beginning of the survey, ensuring a 100% consent rate. Participants who were unwilling or unable to give consent to the study were excluded. A copy of the final questionnaire can be found in **Appendix 1**.

Definition of Terms Used

Formal neurosurgical exposure was defined as having experienced a neurosurgical clinical rotation regardless whether arranged by the medical school or self, informal exposure was defined as experience sought outside of a clinical rotation, and overseas neurosurgical exposure was defined as having experienced a neurosurgical clinical rotation or elective outside Africa. Formal neurosurgical exposure included clinical rotations that may have other specialties taught alongside neurosurgery during the rotation.

TABLE 1 | Sociodemographic characteristics of surveyed African medical students.

Sociodemographic characteristics	Number of respondents, *n* (%)
Total number of participants	***N* = 539**
Age	
15–20 years	46 (8.5%)
21–25 years	370 (68.6%)
26–30 years	108 (20.0%)
31–35 years	12 (2.2%)
36–40 years	2 (0.4%)
>40 years	1 (0.2%)
Gender	
Male	289 (53.6%)
Female	244 (45.3%)
Non-binary	1 (0.2%)
Prefer not to say	5 (0.9%)
Geographical location of institution/hospital	
Rural	35 (6.5%)
Urban	504 (93.5%)

Statistical Analysis

Descriptive statistics were performed for all variables. Depending on normality, the median and interquartile range or mean and 95% confidence interval (CI) were calculated for each domain of perception toward neurosurgery among rotators (defined as students who have undertaken a formal neurosurgical clinical rotation) and non-rotators. Differences in each domain of perception toward neurosurgery were analyzed using Wilcoxon rank sum test for non-parametric variables and the Welch *t*-test for parametric variables. Adjusted logistic regression models were developed to estimate the odds of definite interest in neurosurgery careers. Sequential addition of covariates (age, gender, and geographical location) and likelihood ratio tests of nested models were conducted to identify the model of best fit. The model examined previous formal neurosurgery rotation and length of formal neurosurgery exposure (more than 4 weeks vs. 4 weeks or less). The 4-week cut-off was common practice for the minimum length of clinical rotations in medical schools worldwide (7). The final models were adjusted for gender. The interaction between geographical location and formal rotation experience was detected and included. Statistical significance was

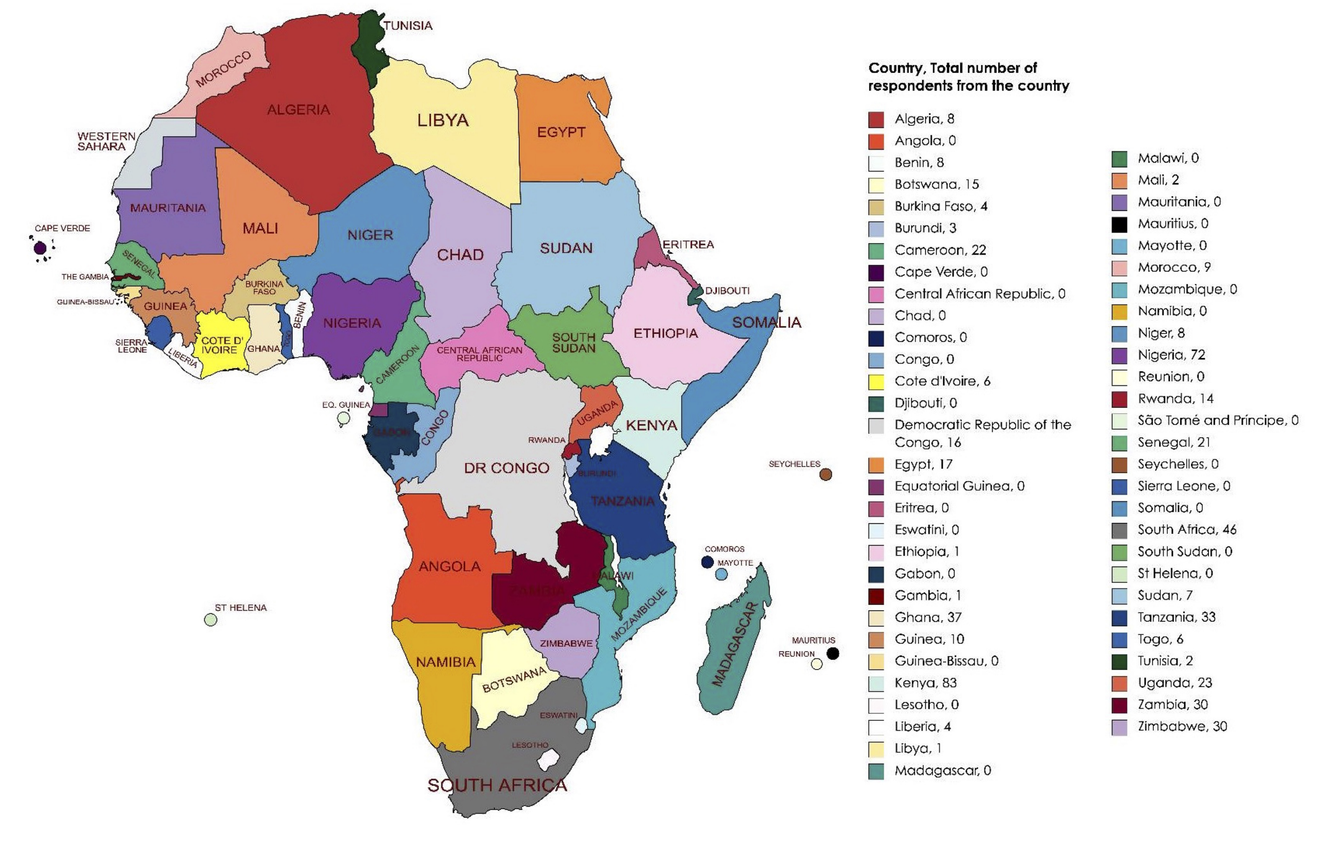

FIGURE 2 | Continental heat map of African countries and number of students that responded to the survey.

accepted at $p < 0.05$. All analyses were conducted on STATA 16.1 (Stata, Version 16.1, StataCorp, USA).

RESULTS

Sociodemographic Characteristics

Data was provided from 539 medical students from 30 African countries, which represents 55.6% ($n = 30/54$) of all African countries. The majority of respondents were aged between 21 and 25 years old ($n = 370/539$, 68.6%; **Figure 1**) and a slight majority were male ($n = 289/539$, 53.6%; **Table 1**). Of the 30 African countries surveyed, the country with the highest number of respondents was Kenya ($n = 83/539$, 15.4%), followed by Nigeria ($n = 72/539$, 13.4%), and South Africa ($n = 46/539$, 8.6%; **Figure 2**). Most students (504/539, 93.5%) self-reported that they were from medical schools located in urban areas, while the rest stated that their medical schools were in rural areas (**Table 1**).

No data was missing even though questions 7, 8, and 9 in the questionnaire was dependent on the response to question 6 (**Appendix 1**).

Medical Students' Exposure to Neurosurgery

Importantly, 312 (57.8%) students reported a lack of a neurosurgery training program at their base institution (**Table 2**). A total of 278 (51.6%) medical students had participated in a formal neurosurgery rotation. Of these 278 students, the majority of students had participated in rotations lasting 4 weeks or less ($n = 181/278$, 65.1%), while 33 students (11.8%) had between 4 and 8 (defined as more than four but less than eight) weeks experience, and 52 students (18.2%) had 8 weeks or longer experience on neurosurgical rotation (**Figure 3**). Twelve students (4.3%) did not report the duration length of their rotation. Only 113 (40.6%) students had a dedicated neurosurgery rotation, while 165 (59.4%) reported a mixed rotation with other specialties.

Among 278 students, 227 (81.7%) of students were exposed to inpatient care management, while 153 (55.0%) had participated in outpatient care. In addition, 179 (64.4%) students received teaching through neurosurgery lectures ($n = 179/278$, 64.4%), and 174 (62.5%) had bedside tutorials for neurosurgery (**Table 2**). In terms of operating room exposure, a more significant proportion of students reported observing or participating in elective neurosurgery cases ($n = 146/278$; 52.5%) than emergency cases ($n = 92/278$; 33.1%). Only 15 (5.4%) students also had exposure to neurosurgery outside of Africa (**Table 2**). When asked to compare their experiences abroad against those in their home countries, the general consensus among students was the differences between the quality of neurosurgical care

TABLE 2 | Characteristics of neurosurgery experience among African medical students.

Neurosurgery experience characteristics	Number of respondents, *n* (%)
Total number of participants	***N* = 539**
Formal neurosurgery rotation	278 (51.6%)
Exposure to inpatient care	227 (42.1%)
Exposure to outpatient care	153 (28.4%)
Elective surgery	146 (27.1%)
Emergency surgery	92 (17.1%)
Academic meetings	131 (24.3%)
Morbidity and mortality meetings	45 (8.3%)
Ward rounds	201 (37.3%)
Lectures	179 (33.2%)
Bedside tutorials	174 (32.3%)
Informal neurosurgery exposure	160 (29.7%)
Webinar	68 (12.6%)
Research	63 (11.7%)
Workshop	36 (6.7%)
Conference	36 (6.7%)
Elective	15 (2.8%)
Other	4 (0.7%)
Neurosurgery experience outside Africa	15 (2.8%)
Presence of home institution's neurosurgery program	
Yes	227 (42.1%)
No	175 (32.5%)
Unsure	137 (25.4%)

delivered. This includes "access to better equipment" and "more neurosurgeons in the workforce" abroad.

Among all 539 students, 160 (29.7%) students reported to have had informal neurosurgery exposure (**Table 2**). The most common form of informal exposure to neurosurgery were through webinars (n = 68/539, 12.6%), followed by research (n = 63/539, 11.7%), workshops (n = 36/539, 6.7%), and conferences (6.7%).

Perception of Neurosurgery

Some perceptions of neurosurgery differed between medical students with and without formal neurosurgery rotation experience (**Table 3**). Of note, students with neurosurgery rotation experience reported a stronger agreement that it is more difficult for women to pursue a career in neurosurgery than those with no neurosurgery rotation experience ($p = 0.0001$). Students with neurosurgery rotation experience also showed stronger agreement that the clinical experience influenced their perception of a neurosurgical career, when compared to non-rotators ($p = 0.03$). Perception of neurosurgery training as emotionally draining was significantly different between the two groups ($p = 0.001$). Students with neurosurgery rotation experience also reported a stronger agreement with the perception of pleasant personalities in the field of neurosurgery, than non-rotators ($p = 0.04$). Interestingly, students with previous formal clinical rotation experience expressed a lower likelihood of pursuing a career in neurosurgery than those without ($p = 0.02$).

Interest in a Neurosurgical Career

Among 278 medical students with formal neurosurgery experience, 88 (31.7%) expressed definite interest in a neurosurgical career, while 190 (68.3%) reported no or possible interest. Of 261 medical students without formal rotation experience, 109 (41.8%) reported clear interest in pursuing neurosurgery, and 152 (58.2%) declared no or possible interests.

Considering students attending medical schools in perceived urban settings, the odds of having an interest in a career in neurosurgery were 60% lower in rotators in comparison to non-rotators (OR = 0.40, 95% CI = 0.25–0.64, $p < 0.001$; **Table 4**) after adjusting for gender. In contrast, this adjusted association was not observed in medical students who attend medical schools in rural areas (OR = 2.28, 95% CI = 0.51–10.18, $p = 0.278$). This analysis is, however, potentially limited by the relatively low number of medical students situated in rural areas (35, 6.5%). Additionally, the interaction between geographical location and formal neurosurgery rotation experience was statistically significant ($p = 0.02$). Importantly, students who had more than 4 weeks of neurosurgical exposure were 1.75 times more likely to express a career interest in neurosurgery than those without (OR = 1.75, 95% CI = 1.02–3.01, $p < 0.04$) when previous rotation experience, gender, and urban/rural location were controlled. Men were 3.22 times more likely than women to express interest in a neurosurgical career (OR = 3.22, 95% CI = 2.18–4.76, $p < 0.001$) after adjusting for previous formal rotation, neurosurgical experience of more than 4 weeks, and urban/rural location.

DISCUSSION

Summary of Findings

In this study, we assess the perception and interest of clinical medical students in Africa toward a career in neurosurgery. The majority of participants were within the 21–25-year-old age group and there was a slight male preponderance. Regarding neurosurgery exposure, more than half of the students surveyed have had experience of a formal clinical rotation in neurosurgery. Of the students with neurosurgery rotation experience, the majority had a rotation lasting 4 weeks or less. Inpatient care was the most commonly reported form of teaching in a clinical rotation. In terms of operating room exposure, more students had participated or observed elective neurosurgical cases as opposed to emergency cases.

The majority of students are of the perception that it is more difficult for women to pursue a career in neurosurgery, compared to men, and that neurosurgical training is emotionally draining. Indeed, this may, at least partially, explain why collectively students with experience of a formal clinical rotation in neurosurgery of all durations are less likely to demonstrate an interest in pursuing a career in neurosurgery. Students who have gained both local and international perspectives in the field of neurosurgery highlight the under-resourced nature of the specialty in Africa. This provides insight into potentially concerning findings regarding the perception of neurosurgery

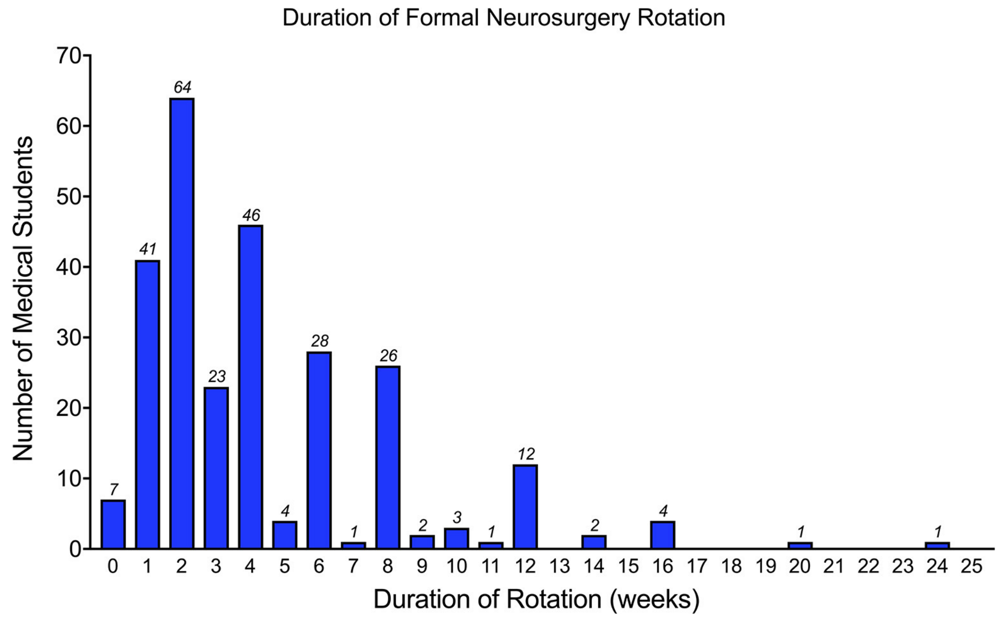

FIGURE 3 | Bar chart showing the duration of clinical neurosurgical rotation, in weeks, of the respondents.

TABLE 3 | Perception of neurosurgery by formal neurosurgery clinical rotation experience.

Perception of neurosurgery (1 = strongly disagree, 5 = strongly agree)	Rotators		Non-rotators		*p*-value
Number of participants	*N* = 278		*N* = 261		
	Mean (SD)	Median (IQR)[a]	Mean (SD)	Median (IQR)[a]	
The range of operations performed by neurosurgeons is highly diverse	3.69 (1.09)	4 (3–5)	3.84 (1.15)	4 (3–5)	0.08
The future of neurosurgery is bright	4.04 (1.04)	4 (3–5)	4.01 (1.12)	4 (3–5)	0.98
Neurosurgery is emotionally draining for residents and attendings	3.97 (1.13)	4 (3–5)	3.70 (1.07)	4 (3–5)	0.001*
Neurosurgery residency training is very difficult	3.93 (1.08)	4 (3–5)	3.80 (1.10)	4 (3–5)	0.14
Neurosurgeons are financially secured	3.58 (1.16)	4 (3–5)	3.69 (1.13)	4 (3–5)	0.34
Becoming a neurosurgeon and having a family is achievable	3.65 (1.09)	4 (3–5)	3.70 (1.15)	4 (3–5)	0.46
It is more difficult for women to pursue a career in neurosurgery	3.46 (1.29)	4 (3–5)	2.99 (1.43)	3 (2–4)	0.0001*
I agree that exposure to neurosurgery (or lack thereof) has influenced your perception about a neurosurgical career	4.08 (1.06)	4 (4–5)	3.79 (1.31)	4 (3–5)	0.03*
You are likely to pursue a career in neurosurgery	3.03 (1.45)	3 (2–4)	3.32 (1.34)	3 (3–5)	0.02*
The outcome of neurosurgical patients is excellent	3.01 (1.02)		3.07 (1.01)		0.47[b]
In the field of neurosurgery, the personalities of attendings and collegiality between faculty is very pleasant and collegial	3.37 (1.05)		3.18 (0.97)		0.04*,[b]
Neurosurgeons have a high quality of life	3.13 (1.04)		3.15 (1.00)		0.79[b]

[a] *Median and interquartile range (IQR) are reported and p-value were obtained from Wilcoxon rank-sum test due to non-normality.*
[b] *Obtained from two-sample t-test.*
**p-value < 0.05.*

amongst medical students in Africa. Nevertheless, our finding that students with >4 weeks formal exposure to neurosurgery, either during dedicated or mixed speciality placements, are more likely to express a career interest in neurosurgery highlights an opportunity for future evidence-based curriculum modifications to help inspire the next generation of neurosurgeons and begin tackling the continental workforce deficit.

Implications

The presence of a neurosurgical rotation or the lack thereof can inevitably impact students' decisions on whether they should pursue a career in neurosurgery. In our survey, respondents who had a formal rotation in neurosurgery agreed that the experience influenced their perception of a neurosurgical career. This is expected when one has been exposed to a clinical specialty. The

TABLE 4 | Neurosurgical career interest based on adjusted logistic regression model.

Factors	OR	95% CI	Adjusted *p*-value
Urban medical students with formal neurosurgery rotation vs. without	0.40	0.25–0.64	< 0.001*
Rural medical students with formal neurosurgery rotation vs. without	2.28	0.51–10.18	0.278
Formal neurosurgical exposure for more than 4 weeks vs. 4 weeks or less	1.75	1.02–3.01	0.04*
Male vs. female	3.22	2.18–4.76	< 0.001*

**p-value < 0.05.*

clinical experience exposes students to the intimacies of this field, allowing students to either nurture a willingness to pursue a career in this field or dismiss the profession on an informed basis. Conversely, students who lack prior exposure may consider pursuit of a neurosurgical career based predominantly on societal views or presumed prestige, whilst failing to appreciate potential sacrifices common in the profession. In a survey of third-year, fourth-year, and fifth-year medical students from the Royal College of Surgeons in Ireland on their perception of a neurosurgical career, 92% acknowledged high prestige and income attached to neurosurgery as positives (8). However, the pitfalls of a career in neurosurgery included 98% of respondents feeling that the training was too long, 97% feeling that the operations were too long, and 87% feeling that a neurosurgical career impeded on the quality of a family life (8). Although our study did not specifically examine the perception of prestige, most students responding to our survey agreed that neurosurgeons are financially secure and that the future of neurosurgery is bright. This can be related to a study conducted among 256 Nigerian final-year medical students at a single institution. Balogun et al. reported in the study that perception of prestige and high-income potential was associated with increased interest toward a neurosurgical career (9). Akhigbe et al., also reported that the neurosurgery's high-income and perceived prestige were driving factors for medical students' interest in neurosurgery (8). These results highlight the importance of a neurosurgical clinical rotation in medical school, to ensure that any aspiring neurosurgeon is provided with the opportunity to gain a clear, truthful appreciation of the specialty before making a decision on which specialty to pursue. The lack of medical student exposure to neurosurgery is likely contributed to by many factors. However, only 42.1% of students we surveyed were able to confirm the presence of a neurosurgical programme at their base institution highlighting a fundamental lack of opportunity. This suggests that many medical institutions may need to partner with external neurosurgical centres to provide their students with opportunities for exposure to this speciality.

A key finding in our study was that students with formal neurosurgical exposure had a stronger consensus, than those without, that it is more difficult for women to pursue neurosurgery as a career. Such views may be influenced by students having witnessed, first-hand, the lack of female representation in neurosurgical departments at almost all levels, from the head of departments to trainees. This creates a void of potential mentors, guidance, and role models for aspiring female neurosurgeons and perpetuates the barriers to women considering a career in neurosurgery (10). Although there are increasing numbers of female neurosurgeons and trainees globally, stark gender inequalities still exist and this is even more apparent in developing countries (11). Throughout Africa, the issue of the lack of female representation in neurosurgery is attributed to many deep-seated factors, such as the inequality of access to education for women. In recent years, work has begun to educate and empower women who wish to pursue a career in the health sector, and specifically, surgical fields. However, the issue within neurosurgery persists as there is a paucity of representation of current female neurosurgeons in academia and leadership positions (12). Notwithstanding, it is important to recognize that the issue goes beyond providing female neurosurgeons equal opportunities. Currently, there are no potential training arrangements for neurosurgeons to undertake less than full-time training (LTFT)-a policy implemented in countries such as the United Kingdom (13). Given the demanding nature of neurosurgery, the lack of LTFT opportunities may be a barrier to perceived feasibility of pursuing the field, especially if one wishes to allocate more time for family whilst continuing their progression in training. Moreover, there is also no easily accessible data on the impact of maternity leave on a neurosurgeon's salary. The uncertainty that comes with the lack of transparency and/or lack of attention given to discussions about remuneration during maternity leave could also be a potential barrier to women pursuing neurosurgery. A reform of local policies by national governments and stakeholders addressing these issues would be a critical step to improve the perception of neurosurgery to women and to level the playing field for them with the flexibility they may need during their training. Furthermore, a potential focus for future research would include detailed evaluation of the attitudes and perceptions of aspiring female neurosurgeons in Africa toward pursuing a career in the specialty. This would be crucial in gaining in-depth understanding of the relevant perceived barriers, and thus, providing valuable data to the literature that may be useful in influencing change to neurosurgery programs in Africa.

Perception of neurosurgical training as emotionally draining was significantly different between those who had a rotation and those who did not. It is well known that neurosurgical training is time-consuming and demanding, and when students have had some exposure to this, their perceptions may become more grounded and realistic. The perception that neurosurgery is emotionally draining may be associated with a perceived lack of work-life balance, which is a vital factor deterring medical students from a career in neurosurgery consistent with previous surveys completed in the West (14, 15). For students who have not had a formal rotation, the demands of the career can be underestimated or glamorized by the media and perceived prestige.

Another factor influencing the diminished interest of students with neurosurgery rotation experience compared to students without neurosurgery rotation experience may include the reduced surgical and practical nature of the rotation. In a study of 76 students, Burford et al., reported that the most influential factor in attracting medical students to neurosurgical careers was the surgical approaches (14). Of the 278 students who were able to complete a formal neurosurgical rotation, only 44.2% reported having any surgical exposure. This low exposure to practical neurosurgery could contribute to diminished interest. Improving the practical aspect of these rotations could foster more interest and support budding African neurosurgeons.

A positive finding of our study was that respondents who had a neurosurgical rotation reported higher agreement that pleasant personalities and collegiality within the field of neurosurgery were prevalent. This demonstrates the positive impact rotations could have on dismantling the societally imposed negative stereotypes that have plagued neurosurgery. It is often assumed that the neurosurgical specialty is impossibly challenging, devoid of life, and can damage family life (8). These sentiments keep away potentially strong candidates, and without personable exposure, these inaccurate stereotypes may otherwise be held as universal truths. The results of the study observed are encouraging as an increased perception of pleasant personalities and collegiality within the field may facilitate students interested in entering the field to reach out and seek guidance and mentorship. This is key as strong mentorship is associated with a more successful matching of medical students into neurosurgical residency programs (16). Mentorship is also a significant factor influencing sub-specialty choice among medical students in general (17). This perception may also influence the pursuit of academic interests, collaboration, and career opportunities which are significant factors influencing specialty choice among medical students (17).

Overall, in contrast to our central hypothesis, students with formal clinical rotation experience of any length in neurosurgery were less likely to pursue a career in neurosurgery than those with no formal neurosurgical experience. This might reflect more students with a predetermined interest in other career paths in larger medical schools where students are more likely to gain exposure to a broader range of specialties, in addition to neurosurgery. This also highlights how career path selection amongst medical students is multifactorial and interdependent between the various specialities available (16).

Interestingly, our analysis demonstrated that students with more than 4 weeks of experience in a formal neurosurgical rotation were 1.75 times more likely to pursue a career in neurosurgery than those with exposure lasting 4 weeks or less. This highlights the importance of lengthened exposure to this field to medical students as the added time allows students to gain greater experience within the specialty and to seek opportunities that may maintain their interest in the long term. These opportunities could be in the form of establishing mentorship, conducting a research project with the local department and observing/assisting in more neurosurgical cases. Similar to our work, Balogun et al. observed only 64.5% of students on clinical rotations felt they received adequate neurosurgical teaching, and 47% of students felt they did not spend enough valuable time with the neurosurgical consultants (9). This may, at least in part, explain our findings that a shorter clinical rotation is associated with decreased interest in neurosurgery. Although it is possible that some students with a strong pre-existing interest in neurosurgery may have been able to self-arrange longer formal rotations in neurosurgery, it is unlikely to have been common since internal student selected components are not available within the curricula of many medical schools across Africa. Therefore, it is imperative that medical schools in Africa review their curricula and consider lengthening exposure to neurosurgical rotations as appropriate, even if this is within the context of mixed rotations. Stakeholders and national organizations could also play a part in offering bursaries for African medical students to undertake neurosurgical clinical electives during term time and/or holiday periods as a means to provide students with the opportunity to expand and consolidate their knowledge and skills and to promote continuity in their learning in the specialty.

CHALLENGES AND LIMITATIONS

Although our study analyses the responses of 539 medical students across 30 nations within Africa, there was a preponderance of responses from students based in Kenya, Nigeria, and South Africa. Therefore, our sample distribution and size may reflect a degree of underrepresentation of clinical medical students within some nations across Africa. Additionally, the survey was only provided in English or French. Distribution of the survey in other languages, such as Portuguese and Arabic, might have helped enhance the diversity of representation and reach a larger population of students. However, due to resource constraints, this was not possible. Also, given the mode of data collection for the survey, some preclinical (ineligible) medical students may have responded. Additionally, students in rural areas or areas with an unstable internet connection or poor access to the internet may have been disproportionately unable to participate in the survey.

RECOMMENDATIONS

The expansion of neurosurgical training is required to tackle the current workforce deficit throughout the continent of Africa and provide safe, timely neurosurgical care. The deficit in neurosurgical training, education, and exposure is contributed to by a lack of resources, infrastructure, and governance within the medical school curriculum. Following the results of our study, we have compiled a list of recommendations that can be implemented to increase interest in neurosurgery within Africa.

The emphasis on increasing diversity and inclusion within the neurosurgical field was strongly suggested throughout our data collection. The lack of female representation within the neurosurgical field has been a great detriment toward the progression of inclusivity and the expansion of neurosurgical availability in general. To help overcome this hurdle, we recommend increasing the number of students with a formal rotation over 4 weeks duration in clinical neurosurgery, in addition to increasing the number of female students rotating within these programs. Where feasible, resources to provide rotation-specific mentorship could be prioritized toward female medical students and, ideally, delivered by female trainees or consultants-even if greater implementation of virtual/distance mentorship programs is required to ensure this is achievable. Similar to the beneficial effects of neurosurgery interest groups throughout the global West including the UK (18) and US (19), the establishment and promotion of neurosurgery interest groups within and between medical schools throughout Africa could help enhance more equitable neurosurgical exposure and opportunities for mentorship. Initiatives such as the Association of Future African Neurosurgeons (AFAN) may play a key role in this respect and should be supported (20).

In addition to increasing diversity within neurosurgery rotations, we propose offering a dedicated neurosurgical rotation that does not intertwine with other surgical specialties. Often, neurosurgical rotations are intertwined with other surgical rotations such as obstetrics and gynecology, general surgery, and orthopedics (21). The lack of dedicated time within the neurosurgical field fails to allow for the complete acclimation into the neurosurgery specialty and may reduce student's ability to gain broader appreciation of what is required of a neurosurgeon during training. Therefore, having a dedicated neurosurgical rotation could potentially increase neurosurgical interest and help debunk any myths surrounding the neurosurgical specialty, allowing students to make well-informed decisions about future specialty choices. Nevertheless, our data suggests that even mixed speciality placements which incorporate neurosurgical exposure are still likely to be beneficial in nurturing career interest in neurosurgery, so long as these rotations last >4 weeks.

Collaboration is recommended between institutions within Africa and larger institutions in the global West as the sharing of education resources, funding, and training opportunities will increase the number of students that show interest in the neurosurgical field. For example, partnerships include the Duke Global Neurosurgery and Neurosciences (DGNN) working at Mulago Hospital in Uganda and organizations such as Global Partners in Anesthesia and Surgery (GPAS), which are great examples of collaborations that have helped continue to broaden, improve, and diversify the field of neurosurgery within Africa (22).

CONCLUSION

Neurosurgical exposure is a vital determinant in the perception and interest of African medical students toward pursuing a career in neurosurgery. Our study has identified the most relevant factors responsible for interest or lack of such interest in a neurosurgical career. A large majority of African medical students do not have optimal exposure to neurosurgical rotations. Of those students who have neurosurgical exposure, there is often an inadequacy in the inpatient and outpatient exposure during rotations. The perceived gender inequality in most neurosurgical centers in Africa is also a deterring factor as females in neurosurgery are exquisitely underrepresented, and this may discourage female medical students from pursuing neurosurgery as a career. These findings and our recommendations can help inform more standardized and equitable access to neurosurgical rotations in medical training centers across Africa, with greater gender inclusion in advocacy, education, and policy development for neurosurgical training in Africa.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

OD: conceptualization, data analysis, writing, editing, and critical revisions of the manuscript. SO: data analysis, data visualization, writing, editing, and critical revisions of the manuscript. GB, YK, EO, EA, KN, AA, OO, LK, AO, UB, MB, and DO: writing, editing, and critical revisions of the manuscript. CL: writing, data analysis, editing, and critical revisions of the manuscript. OR: conceptualization, writing, editing, and critical revisions of the manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsurg.2022.766325/full#supplementary-material

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Identifying Barriers and Facilitators to the Improvement of Healthcare Delivery and Ethics in Two Cameroonian Neurosurgical Centers

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Background: Low-and middle-income countries (LMICs) are disproportionately affected by neurosurgical burden of disease. This health inequity causes constraints in decision-making. Neurosurgical ethics helps us to assess the moral acceptability and effectiveness of clinical decisions. We aimed to assess ethical neurosurgical care and its effect on patient satisfaction in Cameroon.

Methods: Two questionnaires hosted on Google Forms were administered among inpatients and staff at two Cameroonian neurosurgery centers. The questionnaires covered the factors influencing health outcomes and ethics. Data were collected from November 11, 2020, to March 11, 2021 and analyzed with SPSS v 26 to generate non-parametric tests with a threshold of significance at 0.05.

Results: Seventy patients and twenty healthcare providers responded to the survey. Most patients faced financial hardship (57.1%; 95% CI = 45.7–68.6%), and felt that this affected the care they received ($P = 0.02$). Patients noticed changes in the care plan and care delivery attributable to the neurosurgical units' lack of resources. According to the patients and caregivers, these changes happened 31.0–50.0% of the time (42.9%, 95% CI = 5.7–21.4%). The majority of patients were pleased with their involvement in the decision-making process (58.6%; 95% CI = 47.1–70.0%) and felt their autonomy was respected (87.1%; 95% CI = 78.6–94.3%).

Conclusion: Multiple challenges to neurosurgical ethical care were seen in our study. Multimodal interventions based on the four ethical principles discussed are necessary to improve ethical neurosurgical decision-making in this low resource setting.

Keywords: Cameroon, ethics, neurosurgery, barriers, health outcomes, facilitators

INTRODUCTION

The majority of low- and middle-income countries (LMICs) currently struggle to provide adequate neurosurgical services, with African countries disproportionately affected due to factors such as an insufficient number of neurosurgeons, inadequate healthcare infrastructure, and a paucity of equipment and funding (1). The neurosurgical workforce density in Africa is 1: 4,000,000 (2–4), while the average percentage of the population with access to neurosurgical services within a 2-h window is 25.3% in sub-Saharan Africa (5). These factors complicate the delivery of neurosurgical services to already underserved populations (6).

Challenges in decision-making arise due to a lack of standardized guidelines for neurosurgical techniques and management protocols, limited knowledge of surgical techniques, limited exposure to real time intraoperative decision making, and lack of guidelines regarding best practices for postoperative care (7, 8). Consideration of the ethical dimensions of decision-making is necessary to evaluate both the effectiveness and equitability of neurosurgical decisions, particularly as technology and care paradigms advance. Traditionally, ethical analyses are based on four key principles: respect for patient autonomy, beneficence, non-maleficence, and justice according to Beauchamp and Childress (9). Respect for patient autonomy refers to the right of the patient to make informed decisions about their medical care. The principle of beneficence is the obligation of physicians to act for the benefit of the patient, while non-maleficence involves avoiding the causation of harm. Justice refers to the balancing risks and benefits, ranging from the fair treatment of individuals to equitable allocation of healthcare resources (9).

To the best of our knowledge, no existing study has examined ethical decision-making within neurosurgery in an under-resourced setting. This study aims to assess ethical dimensions in the delivery of neurosurgical care in Cameroon and their relationship with patient satisfaction and outcomes. Our study will inform strategies for optimizing ethical decision-making in the delivery of neurosurgical care within the constraints of LMICs.

METHODS

Study Setting

This study was carried out in two Cameroonian neurosurgical centers—Laquintinie Hospital (LH) and Douala General Hospital (DGH). **Figure 1** demonstrates the neurosurgical centers in Cameroon by region. In descending order, the Center Region has three: Yaounde General Hospital, Central Hospital Yaounde and Center Emergency Yaounde; Littoral Region:DGH and LH; North West Region: Bamenda General Hospital; North Region: Garoua Regional Hospital. The distance between Douala and Garoua, Bamenda and Yaounde in descending order is 1,338.4, 321.2, and 232.7 km, respectively. **Figure 2** illustrates a pictorial representation of DGH and LH. The distance between DGH and LH is 10.2 km. Health facilities in Cameroon are organized according to categories, with category one as most well-equipped and category seven as least equipped. The level of equipment of each of these neurosurgical centers was based on the availability and maintenance of the equipment used to manage the neurosurgical pathologies common in this setting. Douala General Hospital is a category one hospital, while Laquintinie Hospital is a category 2 facility (10).

Study Design

We conducted a cross-sectional survey among LH and DGH neurosurgery inpatients and personnel. This included patients who came to the surgical outpatient department for follow-up consultations after benefitting from surgical management of their neurosurgical disease and hospitalized patients in the postoperative period following a neurosurgical intervention. We did not include patients who were managed conservatively and medically for their neurosurgical diseases.

Study Period and Duration

Data were collected from November 11, 2020, to March 11, 2021.

Data Collection

Data were collected using Google Forms (Google LLC, California, USA) from November 11, 2020, to March 11, 2021.

Self-administered questionnaires designed in French and English were distributed among patients and healthcare workers who met the inclusion criteria. The patient questionnaire had six categories: sociodemographics (age, gender, level of education), resource allocation, variations in the standard of care, levels of satisfaction with the continuity of care and follow-up, cultural awareness, and disclosure of informed consent. The healthcare worker questionnaire had six categories: clinical roles, resource allocation, availability of resources, variations in the standard of care intraoperatively and postoperatively, continuity of care and follow-up, patient and procedure selection, cultural awareness, and disclosure and informed consent. The healthcare providers were also prompted to indicate other barriers and facilitators not mentioned in the questionnaire. Below is the patient and care provider's survey.

With respect to the ethical principles by Beauchamp and Childress, the survey was structured as follows: the third and fourth parts of the patient's survey evaluated maleficence and beneficence in neurosurgical care and the fifth part of the patient's survey measured autonomy. Justice was evaluated in parts of the second and third sections of the provider's survey.

Frequency, importance, and satisfaction were evaluated using Likert scales. Frequency was subdivided into: never (i.e., 0.0% of the time), occasionally (i.e., 1–30.0% of the time), sometimes (i.e., 31.0–50.0% of the time), usually (i.e., 51.0–80.0% of the time), and always (i.e., 81.0–100.0% of the time). Importance was subdivided into: very unimportant (0.0% importance), somewhat unimportant (1.0–30.0% importance), neutral (31.0–50.0% importance), somewhat important (51.0–80.0% importance), and very important (81.0–100.0% importance). Similarly, satisfaction was divided into very unsatisfied (0.0% satisfaction), unsatisfied (1–30% satisfaction), neutral (31–50% satisfaction), satisfied (51–80% satisfaction)n and very satisfied (81–100% satisfaction).

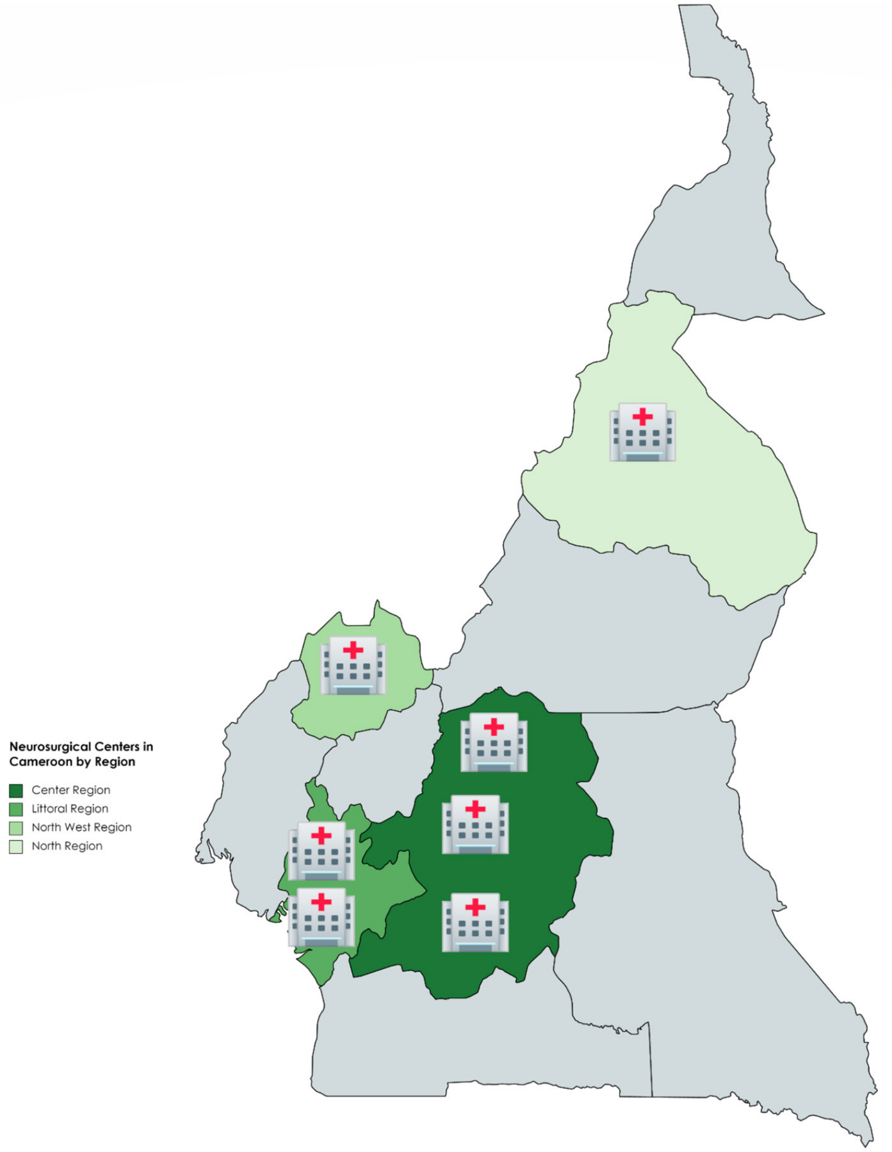

FIGURE 1 | Neurosurgical Centers in Cameroon by Region.

Data Analysis

Data were analyzed with SPSS v 26 to generate non-parametric tests with a threshold of significance at 0.05. Categorical quantitative sociodemographic data and responses were computed as frequencies and percentages, while age was computed as a mean with a 95% confidence interval. Data regarding patient information, resource availability, service delivery, and patient satisfaction were compared between the hospitals (DGH vs. LH) and healthcare provider roles (physician vs. nursing and operating room staff). Responses to the open-ended questions were organized into themes by the first and senior authors. The interrater reliability (96.0%) was calculated using Cohen's kappa.

Ethical Approval

The institutional review boards approved this study of DGH and LH (Ref 19AR/MINSANTE/HGD/DM/01/21 and 06394/AS/MINSANTE/DHL/CM). Patient consent for participation was obtained.

RESULTS

Seventy patients and twenty healthcare providers responded to the survey. This corresponds to response rates of 31.8 and 71.4%, respectively. The mean age of the patients was 40.6 (95% CI = 36.2–45.3) years. Most of them were male (74.3%; 95% CI = 64.3–84.3%), and few had attained tertiary education (17.1%; 95% CI =

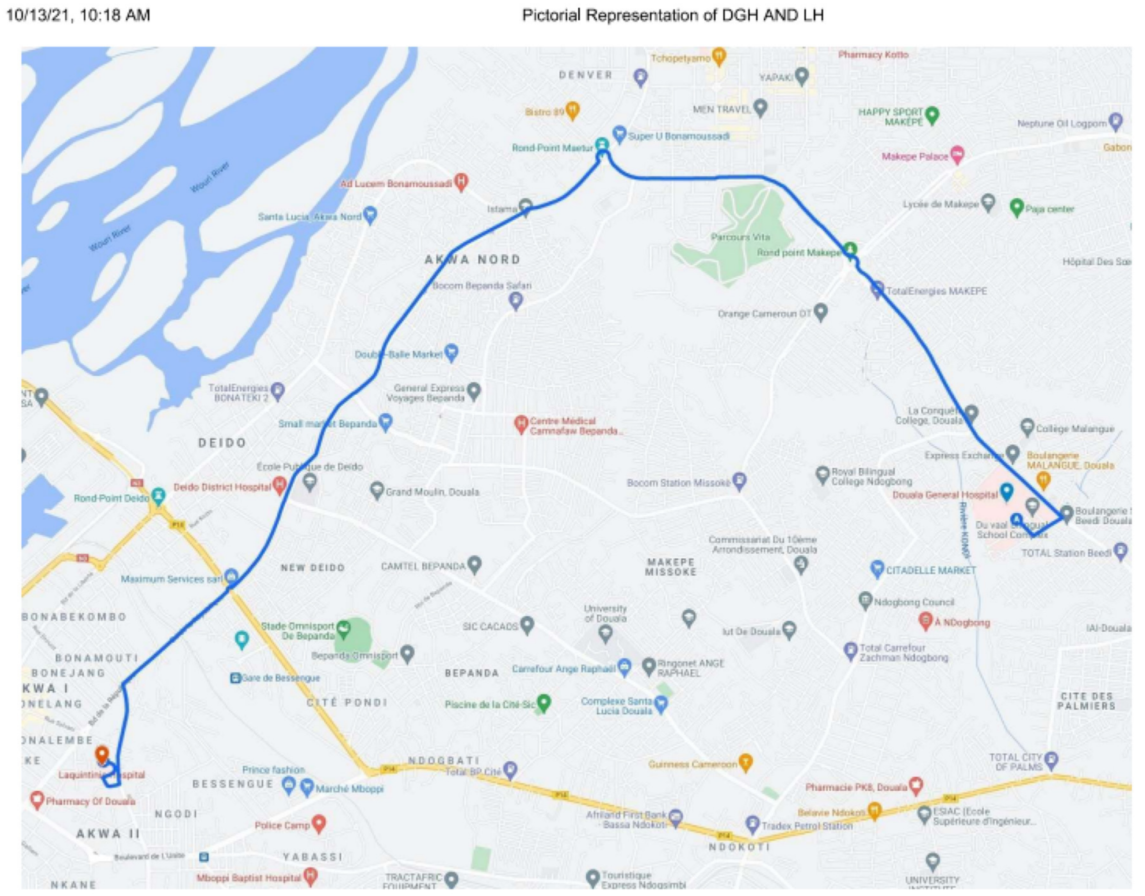

FIGURE 2 | Pictorial Representation of DGH and LH.

8.6–27.1%). Half of the healthcare providers were nurses (50.0%; 95% CI = 30.0–70.0%) (**Table 1**).

Barriers to Care—Patient Perspective

Most patients faced financial hardship (57.1%; 95% CI = 45.7–68.6%), and they felt this stress affected the care they received ($P = 0.02$). Similarly, more than half of the patients spent between 80 and 99% of their annual household income on neurosurgical care-related expenses (54.3%; 95% CI = 42.9–65.7%) (**Figure 3**). As a result, 82.9% (95% CI = 72.9–91.4%) had to borrow or crowdfund money for their neurosurgical care expenses. Patients at LH were less likely to face financial hardship (OR = 5.33; 95% CI = 1.16–18.04; $P = 0.03$) and to borrow or crowdfund for their health expenses (OR = 6.15; 95% CI = 1.48–21.00; $P = 0.02$).

The patients noticed changes in the care plan and care delivery attributable to the neurosurgical units' lack of resources. These changes referred to alterations in the initial care plan midway its execution due to a discovery that some resources were not there and an initial divergence from a preferred plan because of lack of resources. According to the patients and caregivers, these changes happened 31.0–50.0% of the time (42.9%, 95% CI = 5.7–21.4%). Only 20 patients (28.6%, 95% CI = 18.0–39.2%) got all the needed services at one of the study sites. The other patients had to go to another facility to get care. DGH patients were less likely to move from one hospital to another because of a lack of resources (25.0 vs. 32.4%; $P = 0.01$).

Barriers to Care—Provider Perspective

Healthcare providers felt the greatest barriers to equitable access to care at the system level were lack of infrastructure ($n = 13$; 65.0%; 95% CI = 45.0–85.0%) and funding ($n = 9$; 45.0%; 95% CI = 25.0–65.0%) (**Table 2**).

Suboptimal infrastructures influenced their decision-making by relegating their expertise and implementing the standard of care guidelines after resource availability considerations (80.0%; 95% CI = 62.5–97.5%). Other significant determinants of care delivery included: case type and experience (**Figure 4**).

Patient Information

The majority of patients were pleased with their involvement in the decision-making process (58.6%; 95% CI = 47.1–70.0%) and felt their autonomy was respected (87.1%; 95% CI = 78.6–94.3%). Unfortunately, 51.4% (95% CI = 41.4–64.3%) did not receive enough information about the role and side effects of their prescribed medications. At discharge, only 70.0% (95% CI = 58.6–80.0%) of patients felt they had received comprehensive and digestible information on their management's next steps. Providers reported communicating information about the disease, therapeutic options, and therapy goals with patients and caregivers (85.0%; 95% CI = 70.0–100.0%). Despite sharing information with the patients and caregivers, healthcare providers reported communication challenges. These included fear of the unknown for patients and caregivers due to the uncertainty of the eventual outcome (55.0%; 95% CI = 35.0–75.0%), an inability for patients and caregivers to understand explanations (5.0%; 95% CI = 0.0–15.0%), and disagreements about the best course of action between patients and their families (5.0%; 95% CI = 0.0–15.0%).

TABLE 1 | Sociodemographic characteristics of patients and healthcare providers that responded to the survey.

Characteristics	Frequency (percentage; 95% confidence interval)
Patients (*N* = 70)	
Sex	
Male	52 (74.3%; 64.3–84.3%)
Female	18 (25.7%; 15.7–35.7%)
Education	
Tertiary	12 (17.1%; 8.6–27.1%)
Secondary	34 (48.6%; 35.7–60.0%)
Primary	21 (30.0%; 20.0–41.4%)
No formal education	3 (4.3%; 0.0–10.0%)
Healthcare providers (*N* = 20)	
Nurse	10 (50.0%; 30.0–70.0%)
Neurosurgeon	5 (25.0%; 10.0–45.0%)
General practitioner	2 (10.0%; 0.0–25.0%)
Anesthetist	1 (10.0%; 0.0–15.0%)
Nurse assistant	1 (10.0%; 0.0–15.0%)
Operating room technician	1 (10.0%; 0.0–15.0%)

TABLE 2 | Barriers to equitable neurosurgical care.

Characteristics	Frequency (percentage; 95% confidence interval)
Patient perspective	
How often did lack of resources affect patient care?	28 (40.0%, 28.5–51.5%)
Never	4 (5.7%; 31.4–54.3%)
Usually	30 (42.9%; 5.7–21.4%)
Sometimes	4 (5.7%; 1.4–11.4%)
Occasionally	4 (5.7%; 1.4–11.4%)
Always	
How often did you have to go to another health facility to get care?	
Never	20 (28.6%, 18.0–39.2%)
Usually	10 (14.3%; 7.1–22.9%)
Sometimes	18 (25.7%; 15.7–35.7%)
Occasionally	12 (17.1%; 10.0–25.7%)
Always	10 (14.3%; 5.7–22.9%)
Provider perspective	
Which of the following components of the neurosurgical system are barriers to equitable care?	
Infrastructure	13 (65.0%; 45.0–85.0%)
Funding	9 (45.0%; 25.0–65.0%)
Workforce	6 (30.0; 9.9–50.0%)
Service delivery	4 (20.0; 2.5–37.5%)
Governance	4 (20.0; 2.5–37.5%)
Information management	1 (5.0%; 0.0–15.0%)

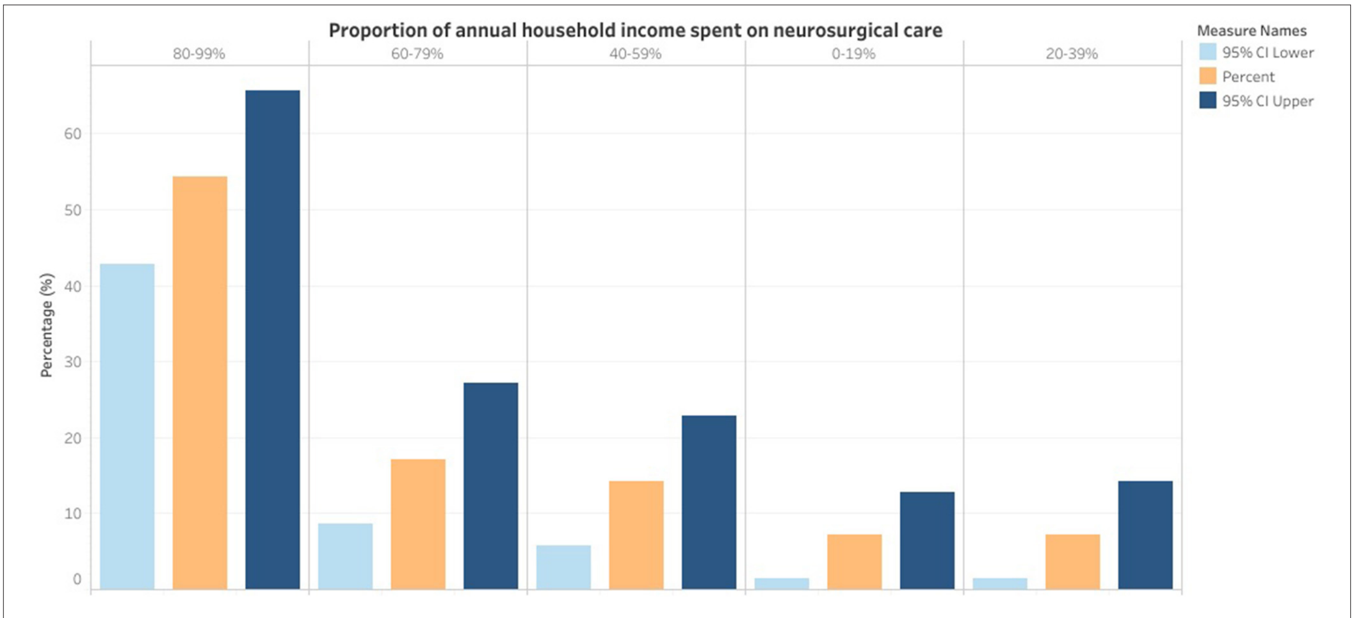

FIGURE 3 | Proportion of the annual household income spent on neurosurgical care.

FIGURE 4 | Factors influencing the quality of care and service delivery.

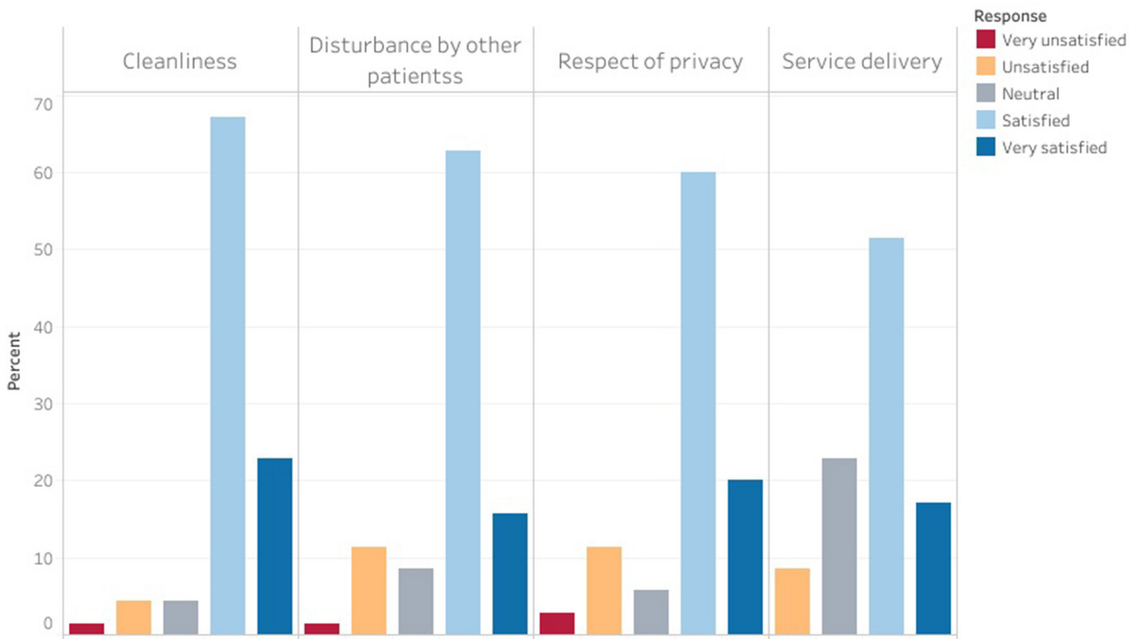

FIGURE 5 | Neurosurgery patient satisfaction with service delivery and the care environment.

Patient Satisfaction

Patients and caregivers were generally satisfied with the service delivery and hospital environment (**Figure 5**).

Most providers reported regularly evaluating their patients (85.0%; 95% CI = 65.0–100.0%) especially in the postoperative period (90.0%; 95% CI = 75.0–100.0%). Also, they felt confident in their ability to recognize postoperative complications (95.0%; 95% CI = 85.0–100.0%).

With respect to the ethical principles by Beauchamp and Childress, we found that the principles of beneficence and maleficence were respected because most of the patients were satisfied with the service delivery and hospital environment.

However, a good number of them felt their financial hardship affected the care they received. The principle of autonomy was respected as most of the patients were pleased with their involvement in the decision making process and most felt that their autonomy was respected.

Care providers had difficulties implementing the principle of Justice due to a lack of infrastructure and funding. In spite of this, they reported regularly communicating with their patients and following them up.

DGH patients were less likely to move from one hospital to another because most of the infrastructure and resources needed by the care providers were more available in DGH.

DISCUSSION

In this study, we identified the determinants of ethical service delivery in two Cameroonian neurosurgery centers. To the best of our knowledge, this is the first study examining ethical dimensions of neurosurgical care in LMICs. Some patients observed changes in the care plan and services delivered due to a lack of resources. As a result, a quarter of patients transferred from one health facility to another when imaging services and medications were unavailable at one of the two neurosurgical centers. The proportion of patients who were required to transfer was lower among patients at DGH than those at LH. This is because most of the infrastructure and resources needed by the care providers were more available in DGH.

Healthcare providers equally reported that lack of infrastructure and funding adversely impacted neurosurgical care.

Information Provision and Informed Consent

Most patients did not understand the information they were given. This contrasted with the perception of healthcare providers, who reported communicating adequate information on the disease, therapeutic options, and treatment goals to patients and caregivers. Healthcare workers attributed unmet patient information needs to a lack of understanding on the part of patients. However, poor patient comprehension and low recall, accentuated further by low educational attainment, are likely responsible for this discrepancy (11, 12). Patient informational needs are frequently unmet, particularly regarding prognosis and follow-up after surgery and surgeon experience (13, 14). These findings highlight the need for neurosurgeons to remain aware of the discrepancy between their conceptualization of patient understanding and actual patient understanding, recognize common barriers to patient understanding, and attempt to minimize the effect of these barriers within the context of a patient encounter (11, 15).

Most patients reported their autonomy was respected, and were satisfied with their involvement in the decision-making process. Greater patient involvement in decision-making decreases patient anxiety and increases patient satisfaction (15). Current paradigms of patient involvement in neurosurgical decision-making focus on communication within consultations and the utilization of information conveyed by providers to decide regarding care (16). The informed consent process involves presenting the patient with information regarding their condition, possible treatments with associated risks and benefits, alternatives, and the risks and benefits of pursuing no treatment (17). Baseline patient health literacy and informational needs should guide discussions (17). Specialized interventions, such as specialized checklists for consent forms, question prompts, educational and interactive websites, and visual aids, are also necessary to facilitate patient understanding during the informed consent process (17). Augmented communication strategies, including providing quantifiable measures of success and risk, organizing the decision into a simple visual algorithm, utilizing methods to assess patient understanding such as teach-backs, and ensuring enough time for questions will optimize the informed consent process (17–19).

Together, these factors may improve patient understanding of their condition and treatment options, promoting patient-centered care and greater patient satisfaction. Importantly, informed consent is a continual process that requires continual information provision, assessment of patient understanding, and correction of misconceptions across the duration of care (17, 20, 21).

Ethical Decision-Making in Low Resource Settings

Numerous strategies exist for improving ethical decision-making in low resource settings. Institutions in low resource settings can employ a series of simple yet far-reaching interventions. These include creating a set of ethical standards with clear guidelines regarding best practices, increasing awareness regarding common ethical issues, analyzing ethical examples and employing counterexamples to train trainees and neurosurgeons in how to conceptualize ethical decisions, basing the discussions of cases on objective information rather than value judgments, and using cases to continually refine the approach of neurosurgeons to ethical decision-making (22–24). A novel concept is appointing "ethical champions," who are individuals in institutions who are responsible for creating ethical standards and maintaining ethical oversight of care practices, to actively guide ethical decision-making while maintaining consideration of limited resources (21). Ethical champions use "ethical frames" to increase team ethical awareness and reduce moral disengagement and "business frames" depending on the perceived effect of the ethical decision on factors such as resource allocation (21). In any case, ethical decision-making must hold principles of respect for patient autonomy, beneficence, non-maleficence, and justice as foundational.

Limitations

This study had limitations. First, the study was conducted at the height of the COVID-19 pandemic, perhaps positively skewing patient responses given they received medical care during a challenging time. Second, we used a convenience sampling method which led to a small sample size, perhaps leading to excessive variability in survey responses. We also reported 95% confidence intervals to account for potential variability. Medical staff who did not respond were neuro-nurses and neuro anesthetists and patient caregivers may have been unwilling to participate given emotional stress, perhaps introducing non-response bias. In an effort to increase the response rate, we tried contacting the staff in person and on the phone at presumably convenient times and attempted to communicate clearly with caregivers and patients when they were visibly less stressed. Despite the aforementioned limitations, this study provides novel insight into ethical neurosurgical decision-making in Cameroon that may inform practices in other similar contexts.

CONCLUSION

We identified multiple challenges to ethical neurosurgical care in two Cameroonian centers. Lack of resources affected service delivery, and patients had poor comprehension and recall of information conveyed to them by neurosurgeons. Specialized interventions are necessary to improve the informed consent process, while comprehensive measures to expand the application of ethical thinking to clinical encounters may improve ethical neurosurgical decision-making in low resource settings. These measures should be instituted across all levels of care delivery. Given the ethical challenges faced by providers in low-resource settings exhibit substantial overlap, our findings may guide best practices for ethical decision-making in LMICs.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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