



Brain Tumor Programs in Asia and Africa: Current Status, Challenges, and Future Perspectives

Shweta Kedia¹, Mabel Banson², Beverly Cheserem⁶, Bipin Chaurasia³, Claire Karekezi⁵, Enoch Uche⁷, Esther Apuahe¹², James A. Balogun⁴, Lynne Lourdes N. Lucena¹⁵, Maguette Mbaye¹¹, Oluwamayowa Opara⁸, M. Eisam Elhaj Mahmoud¹⁰, Priya Singh¹³, Sachin Chemate¹⁴, Santanu Kumar Bora¹, Selfy Oswari¹⁶, Teddy Totimeh⁹

■ **OBJECTIVE:** To assess the status of brain tumor programs in Asia and Africa and propose comprehensive evidence-based short- and long-term measures for improving the existing systems.

■ **METHODS:** A cross-sectional analytical study was conducted in June 2022 by the Asia-Africa Neurosurgery Collaborative. A 27-item questionnaire was designed and distributed to gain insight into the status and future directions of brain tumor programs in Asia and Africa. Six components of brain tumor programs were identified—surgery, oncology, neuropathology, research, training, and finances—and assigned scores of 0–14. The total scores allowed subclassification of each country into levels of brain tumor program from I to VI.

■ **RESULTS:** A total of 110 responses from 92 countries were received. These were subdivided into 3 groups: group 1, countries with response from neurosurgeons (73 countries); group 2, countries with no neurosurgeons (19 countries); and group 3, countries without a neurosurgeon response (16 countries). The components associated with the highest level of brain tumor program were surgery, neuropathology, and oncology. Most countries in both

continents had level III brain tumor programs with a mean surgical score of 2.24. The major lag between each group was with respect to the advances in neuropathology and financial support.

■ **CONCLUSIONS:** There is an urgent need to improve and develop existing and nonexistent neuro-oncology infrastructure, personnel, and logistics in countries across the continents, especially for the countries with no neurosurgeons.

INTRODUCTION

There has been an increase in the incidence of central nervous system tumors predominantly in the South East Asian population and Europe. In a report published in *The Lancet Neurology* in 2019, the growth in 2016 was 17.3%.¹ Interestingly, the same report indicated the lowest incidence rate was in Africa, although the incidence was increasing.¹ An article published in 2022 in **WORLD NEUROSURGERY** on epidemiology of central nervous system tumors in North Africa showed increasing incidence of tumors in this region over

Key words

- ASAFRIN
- Asia-Africa
- Brain tumor program
- Neuro-oncology

Abbreviations and Acronyms

ASAFRIN: Asia-Africa Neurosurgery Collaborative Group

ASNO: Asian Society for Neuro-Oncology

BTP: Brain tumor program

EANO: European Association of Neuro-Oncology

HIC: High-income country

LMICs: Low- and middle-income countries

SNO: Society of Neuro-Oncology

SNOSSA: Society of Neuro-Oncology sub-Saharan Africa

From the ¹Department of Neurosurgery, All India Institute of Medical Sciences, New Delhi, India; ²Neurosurgery Unit, Department of Surgery, Korle-Bu Teaching Hospital, Accra, Ghana; ³Department of Neurosurgery, Neurosurgery Clinic, Birgunj, Nepal; ⁴Division of Neurosurgery, Department of Surgery, College of Medicine, University of Ibadan, University College Hospital, Ibadan, Nigeria; ⁵Neurosurgery Unit, Department of Surgery, Rwanda

Military Hospital, Kigali, Rwanda; ⁶Neurosurgery Unit, Aga Khan University Hospital, Nairobi, Kenya; ⁷Department of Surgery, University of Nigeria Teaching Hospital, Ituku, Ozaia Enugu State, Nigeria; ⁸Neurosurgery Unit, Imo State Specialist Hospital Owerri, Owerri, Nigeria; ⁹Neurosurgery Unit, University of Ghana Medical Centre, Accra, Ghana; ¹⁰Neurosurgery Unit, Omdurman Teaching Hospital, Khartoum, Sudan; ¹¹Department of Neurosurgery, Fann Teaching Hospital, Dakar, Senegal; ¹²Neurosurgery Unit, Port Moresby General Hospital and National Department of Health, Port Moresby, Papua New Guinea; ¹³Indian Council of Medical Research, All India Institute of Medical Sciences, New Delhi, India; ¹⁴Department of Neurosurgery, Noble Hospitals & Research Centre, Pune, India; ¹⁵Neurosurgery Division, Bicol Regional Hospital and Medical Centre, Legazpi City, Philippines; and ¹⁶Department of Neurosurgery, Indonesia National Brain Center, Faculty of Medicine Universitas Padjadjaran, Sumedang, Indonesia

To whom correspondence should be addressed: Shweta Kedia, M.B.B.S., M.Ch.
[E-mail: drshwetakedia@gmail.com]

Citation: *World Neurosurg.* (2023) 175:e1041-e1048.
<https://doi.org/10.1016/j.wneu.2023.04.067>

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

Available online: www.sciencedirect.com

1878-8750/\$ - see front matter © 2023 Elsevier Inc. All rights reserved.

decades.² Over the last few decades, neuro-oncology has become a well-established subspecialty within the broad field of clinical neuroscience.^{3,4} There have also been significant advances in molecular diagnostics and therapeutic approaches.^{3,4} However, there are visible disparities in neuro-oncology services across the globe,¹ which result from deficits in availability of expertise, infrastructure, resources, innovation, research, and financing.^{5,6} The nuances of providing standardized care to different regions of the world need to be understood to facilitate planned strategies aimed at overcoming region-specific challenges.⁷⁻⁹ The purpose of this study was to assess the status of brain tumor programs (BTPs) in Asia and Africa and to propose comprehensive evidence-based short- and long-term measures for improving the quality of care delivered through existing care systems.

MATERIALS AND METHODS

This analytical cross-sectional study was carried out by a collaborative group of neurosurgeons across Asia and Africa, the Asia-Africa Neurosurgery Collaborative Group (ASAFRIN). ASAFRIN is an informal group of neurosurgeons who came together to address the topic of BTPs at a conference and then studied the topic further to assess existing BTPs in Asia and Africa. Using Google Forms (Google LLC, Mountain View, California, USA), an online 27-item questionnaire pertaining to the current status and future directions of BTPs was created in June 2022 and circulated for 1 month from June 15 to July 15, 2022 (<https://forms.gle/ydeZFfeWLiAkugVB8>). All the countries and territories in Asia and Africa were included, and the questionnaire was circulated using different social media platforms, including WhatsApp groups, Twitter, Facebook, LinkedIn, and Telegram, to obtain 1 response for each country. The list of countries was prepared from the United Nations list (<https://www.un.org/en/about-us/member-states>). Ethics committee approval and patient consent were not required as this was an anonymized survey and did not include any personal data of any institution or patient.

Survey variables were designed to collect data on the nature of training programs available in the representative institution of the country, patient load, services being provided, recent advances, and financial assistance received for overseeing the program including patient care. Additional data on demographics of each country, including the gross domestic product, population density, and level of education, were collected from publicly available data sources such as Worldometer (<https://www.worldometers.info/>) and International Monetary Fund (<https://www.imf.org/>). For this study, we defined the BTP and identified the salient components for successful management of the BTP.

Defining Brain Tumor Program

A BTP is a care system that provides personalized, comprehensive, cutting-edge, multidisciplinary clinical care for patients with brain tumor, anchored on a strong research program.^{10,11} The program enables precise diagnosis, translation of research findings from the bench to the clinic, and optimization of the quality of life of the patient during treatment. Expertise in multidisciplinary care for brain tumor patients is germane to the success of a BTP. Available equipment for diagnostic imaging and intraoperative equipment to ensure safe surgery as well as facilities for

Table 1. Categorization of Levels of Brain Tumor Programs

Levels	Categories							
	Surgery with Intraoperative Adjuncts	Neuropathology with Advanced Molecular Diagnostic Facilities	Medical and Radiation Oncology	Dedicated Neuro-Oncology Multidisciplinary Team	Advanced Imaging Facilities	Resident Training Program	Fellowship Training Program	Neuro-Oncology Research Insurance
V	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IV	Yes	No (molecular diagnosis not routinely done)	Yes	Yes	Yes	Yes	Yes	Most patients
III	Yes	No (basic only)	Yes	Available on ad hoc basis	Basic	Yes	Yes	Some patients
II	Surgery without intraoperative adjuncts	No (basic only)	Yes	Available on ad hoc basis	Basic	Yes	No	No
I	Surgery without intraoperative adjuncts	No (basic only)	Yes	Available on ad hoc basis	Basic	No	No	No
0	No	No	No	No	No	No	No	No

adjuvant care such as radiotherapy, chemotherapy, and rehabilitation are indispensable cornerstones of a BTP.

Proposed Neurosurgical Centers Classification

We categorized countries into 6 levels depending on quality of available BTP in each country (Table 1). The factors that influence practice in the geographical regions were assessed and documented. We analyzed the following covariates in this study: country population, per capita gross domestic product, literacy rate, and number of neurosurgeons per capita.

Components

We identified 6 components of BTPs. These components were extracted from the literature and from the exposure and practice of the authors with respect to the management of BTPs and placed in mutually exclusive categories using indicator variables by assigning scores based on their extent of availability in a program by consensus (Table 2).

Statistical Analysis

We assigned countries into different categories of BTP based on the status of the components available in each country. The components were assigned scores, and each level of BTP was classified based on these scores using mean and standard errors; 95% confidence interval estimates were used to define the upper and lower boundaries of the components at each level of BTP.

We built a multivariate linear regression model, the ASAFRIN brain tumor model, because there was correlation between the level of brain tumor and the different components in our model and applied it to predict the country level of BTP while adjusting for covariates. Statistical analysis was performed using IBM SPSS version 26.0 (IBM Corp., Armonk, New York, USA). The 95% confidence interval and *P* value for each component were tabulated with significance set at $P < 0.05$. A postestimation test, the variance inflation factor, was performed to determine if there was multicollinearity among covariates in our model. Further, we evaluated for effect modification between literacy rate, gross

domestic product, and health expenditure per capita on the level of BTP.

RESULTS

A total of 109 countries and independent states in Asia (48 countries and 3 territories) and Africa (54 countries and 4 territories) were identified (Supplementary Table 1). We received no responses from any neurosurgeon in 15 countries, and 18 countries did not have a neurosurgeon (based on World Federation of Neurosurgical Societies and updated with current articles found online (Supplementary Table 2). The response rate from Asia was 73% and from Africa was 98%.

Most of the countries in both continents fell within level III with a mean surgical score of 2.24. A total of 110 responses from 94 countries were subdivided into 3 subgroups. Group 1 ($n = 73$) included countries with neurosurgeons who had responded (Supplementary Table 1 shows the ratio of population to neurosurgeons), group 2 included countries with no neurosurgeons, and group 3 included countries that provided no response as shown in Figure 1.

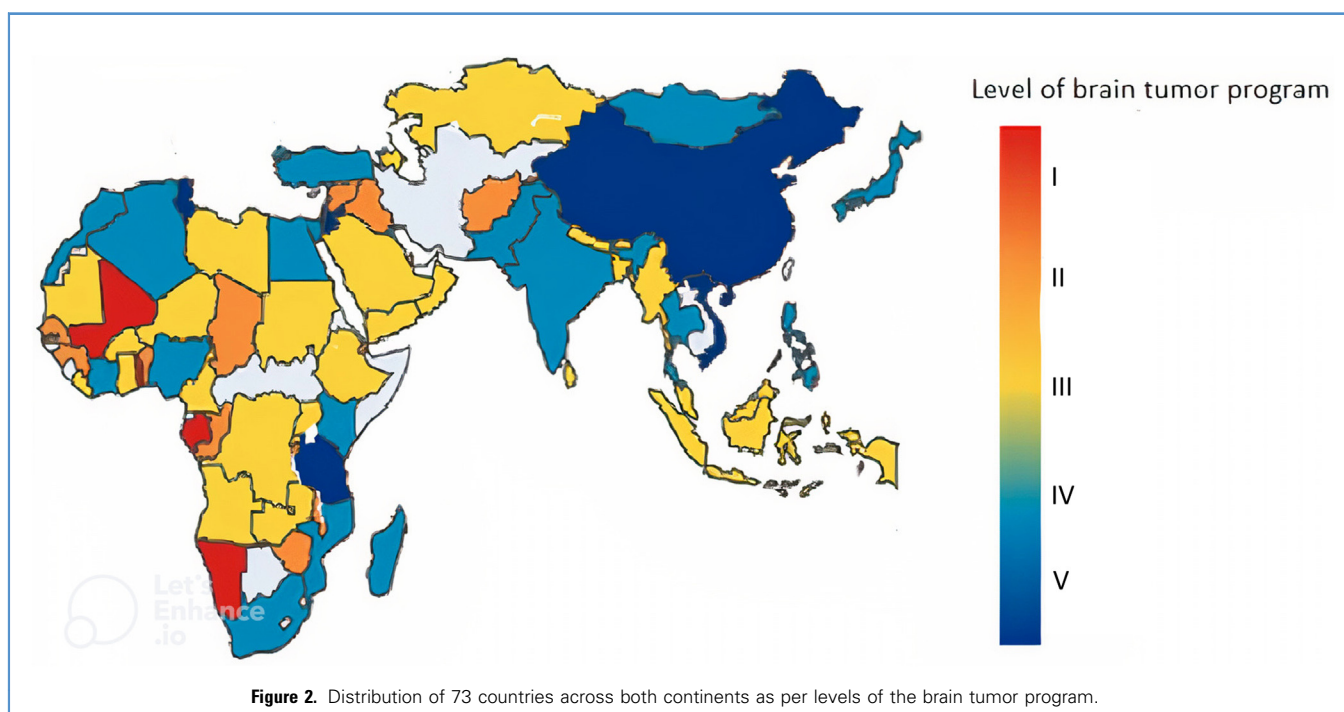
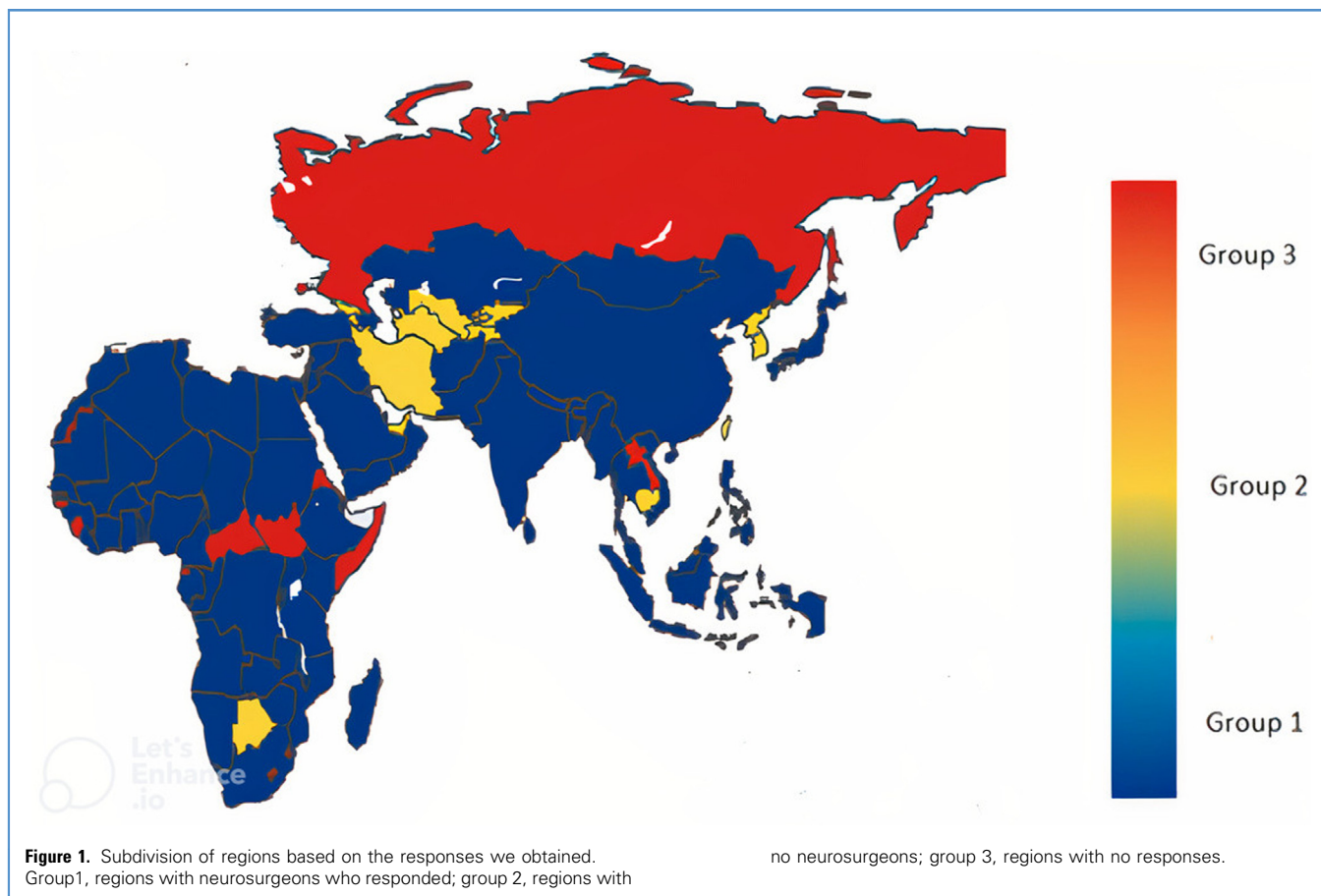
Each country in group 1 was assigned to levels as per scores shown in Figure 2, and countries in group 2 were assigned level 0. We observed within-continent and between-continent geographical differences in the level of BTPs shown in Figure 3. The mean scores of the components for each level of program and the number of countries in each region were calculated and are presented in Table 3. The mean score of each component is represented by the maximum score at the highest level (level V) of the BTP. As the mean component score decreases, the level of the BTP decreases simultaneously.

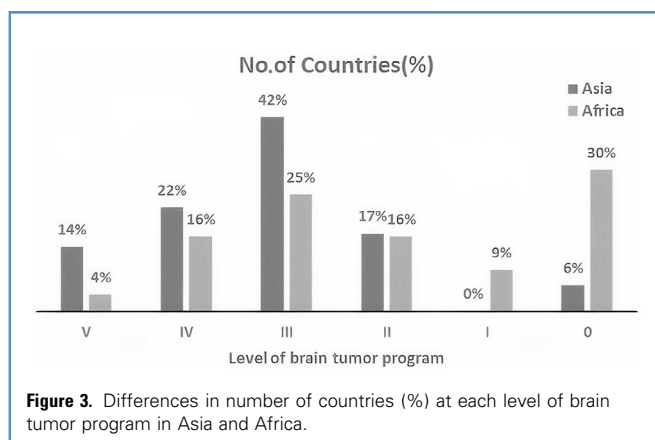
From our analysis, the components with the highest influence on the level of BTP were surgery, neuropathology, and oncology (Table 4 and Supplementary Table 3). A multivariable linear model was built to predict the relationship between components (predictors) and the level of BTP. All the independent variables had a statistically significant relationship with the level of BTP ($P < 0.05$) (Supplementary Table 4 shows the use of this equation in some of the countries).

Table 2. Six Components of Neuro-Oncological Care

Components	Factors Taken into Consideration	Score
Surgery	Number of cases per annum >50, availability of gadgets (microscope, CUSA) (yes, no), intraoperative neuromonitoring, USG, neuronavigation, time to surgery from diagnosis (as early as possible vs. months)	0–3
Oncology	Radiation oncology facility, newer RT and CT drugs	0–2
Neuropathology	Histopathology, IHC for molecular markers as per latest WHO classification	0–3
Research activity	Basic sciences research to advanced state, collaborations with multiple institutes, tumor registry (trials, collaborations)	0–2
Training and education	Resident/fellow training; tumor board, CME, JC, publications	0–3
Finances	Optimization of quality of care based on financial assistance, NGO, insurance	0–1

Minimum score = 0., and maximum score = 14. The total scores were subclassified into levels of brain tumor programs as follows. V, 13–14; IV, 11–12; III, 9–10; II, 7–8; I, 5–6; 0, <5. CUSA, Cavitron ultrasonic aspirator; USG, ultrasonography; RT, radiotherapy; CT, computed tomography; IHC, immunohistochemistry; WHO, World Health Organization; CME, continuing medical education; JC, journal club; NGO, nongovernmental organization.





The prediction equation from our linear model is the statistical basis of our proposed ASAFRIN brain tumor model:

$$\begin{aligned} \text{Level of BTP} = & -1.623 + (0.445 \times \text{surgery}) \\ & + (0.524 \times \text{oncology}) \\ & + (0.402 \times \text{neuropathology}) \\ & + (0.693 \times \text{research}) + (0.492 \times \text{training}) \\ & + (0.475 \times \text{finances}) \end{aligned}$$

From the prediction equation, the β coefficients for all the independent variables—surgery, oncology, neuropathology, research, training, and finances—show a positive linear relationship with BTP indicating that an increase in the value of any of the covariates leads to an increase in level of BTP determined by the corresponding β value (slope of the regression curve). Among the predictors, research, oncology, and training in decreasing order having the highest slopes, followed by finances, surgery, and neuropathology.

A low variance inflation factor (lower than 4) and high tolerance confirm the absence of multicollinearity among the covariates. The major lag between each group was with respect to neuropathology and financial support. For every 0.402 change in

neuropathology, an increment of 1 unit in the level of BTP was observed, holding other parameters constant. Likewise, for financial support, for every 0.475 change, an increment of 1 unit in level of BTP is expected ([Supplementary Table 5](#)).

A decreasing trend was observed in average literacy rate and gross domestic product with decreasing levels of BTP. However, health expenditure per capita did not reflect the same ([Figure 4](#)).

DISCUSSION

This novel study attempted to highlight the resources, care capacity, and challenges encountered in delivering surgical neuro-oncological care in Asia and Africa. The core idea to formulate covariates (components) of a BTP in our study was to identify the country level profiles as well as deficiencies associated with the existing care systems that need to be addressed.

Asia and Africa together account for 77% of the global population, and both are resource-rich continents, although almost two thirds of the population of these continents are unable to access essential neurosurgical care.¹² In this scenario, neuro-oncology, which demands expert neurosurgical care, is bound to suffer.^{13,14} Moreover, few data exist on the true incidence of these pathologies in both continents.^{9,15} Insufficient dedicated specialists, facilities such as for advanced imaging and molecular oncology, economic resources, education, and research capacity pose a huge barrier to successful neuro-oncological management to achieve clinical results equivalent to those achieved in most high-income countries (HICs).^{7,11,16,17}

The challenges and opportunities faced by Asia and Africa are not the same. We observed that 90% of countries without a neurosurgeon were in Africa. The main focus in these countries should be building human resources. The majority of low- and middle-income countries (LMICs) have <1 neurosurgeon per 200,000 population.¹⁸ Moreover, there is an uneven distribution of neurosurgeons within most countries. With shortages of resources and health care workforce for routine medical care, it is certainly more challenging for neurosurgeons to develop and maintain the more complex surgical skills required for neuro-oncology.¹⁹⁻²²

The availability of radiological imaging, in-house radiation and medical oncologists, and modern molecular studies for the comprehensive treatment of the patients is also not uniform

Table 3. Value of Each Component at Each Level of Brain Tumor Program

Level of BTP (Number of Countries)	Components (Scores)					
	Surgery (0–3)	Oncology (0–2)	Neuropathology (0–3)	Research (0–2)	Training (0–3)	Finances (0–1)
V (7)	2.86	2.00	2.86	1.86	2.57	1.00
IV (17)	2.71	1.94	2.71	1.00	2.18	0.88
III (29)	2.24	1.45	2.00	1.07	2.10	0.72
II (15)	0.93	1.07	2.00	1.00	1.80	0.80
I (5)	0.00	0.40	1.20	1.00	1.40	1.00

Mean score of components at levels of BTP. There is a gradual drop in the mean score of component values in accordance with the levels of BTP.
BTP, brain tumor program.

Table 4. Pearson Correlation Matrix Showing the Relationships of Components

Components (Scores)	Standard Error (Between Scores)	95% CI for Score	
		Lower	Upper
Surgery (0–3)	0.49	0.78	2.72
Oncology (0–2)	0.27	0.85	1.89
Neuropathology (0–3)	0.27	1.63	2.67
Research (0–2)	0.15	0.89	1.48
Training (0–3)	0.18	1.67	2.35
Finances (0–1)	0.05	0.79	0.98

CI, confidence interval.

across Asia and Africa.^{23–25} No formal health insurance or other national financial support is available to most patients. An estimated 33 million people worldwide bear catastrophic health expenses for surgeries.²⁶ The majority of the countries fall within the level III category of BTP with inadequate availability of surgeons, poor infrastructure, and lack of other support services including adjuvant therapy, constituting a serious limitation to the delivery of optimal brain tumor care. The lack of adjuvant chemotherapy and radiation therapy is reported to be associated with poor outcomes.²⁷

Our study is the first to our knowledge to build a prediction model for the determinants of brain tumor care services globally. Our model, described as the ASAFRIN brain tumor model, is highlighted by an identifiable contribution of each determinant or component in a multivariable linear prediction relationship. The strongest determinants are surgery, neuropathology, and oncology. Our ASAFRIN model is associated with a high R value of 0.969, suggesting that each component is essential to a successful BTP. We believe that any improvement in these factors will translate to an upgrade in the BTP. We further opine that comprehensive strategies targeted at the 3 above-mentioned components are likely to produce the most desirable changes.

Based on our index study, we hereby propose short- and long-term corrective measures to improve the status of BTPs in a particular region. For the immediate steps, we advocate improving the existing neuro-oncological capacity in Asia and Africa by developing a 3-fold approach of technology, twinning, and training. Technology has revolutionized the capacity to provide optimal neurosurgical care by providing an armamentarium to surgeons to precisely operate on brain tumors with minimal morbidity and mortality. It is imperative that LMICs embrace these technological advancements; this can be helped through a concerted effort by various manufacturers and organized bodies to make this equipment available in LMICs. The use of lower-cost technologies such as intraoperative ultrasound should be a major focus among surgeons practicing in LMICs. Twinning means developing a collaborative effort between a developed academic medical center in an HIC and a practice or training location in an LMIC, which will enable a surgeon from an LMIC to visit a developed facility or a surgeon from an HIC to work with and

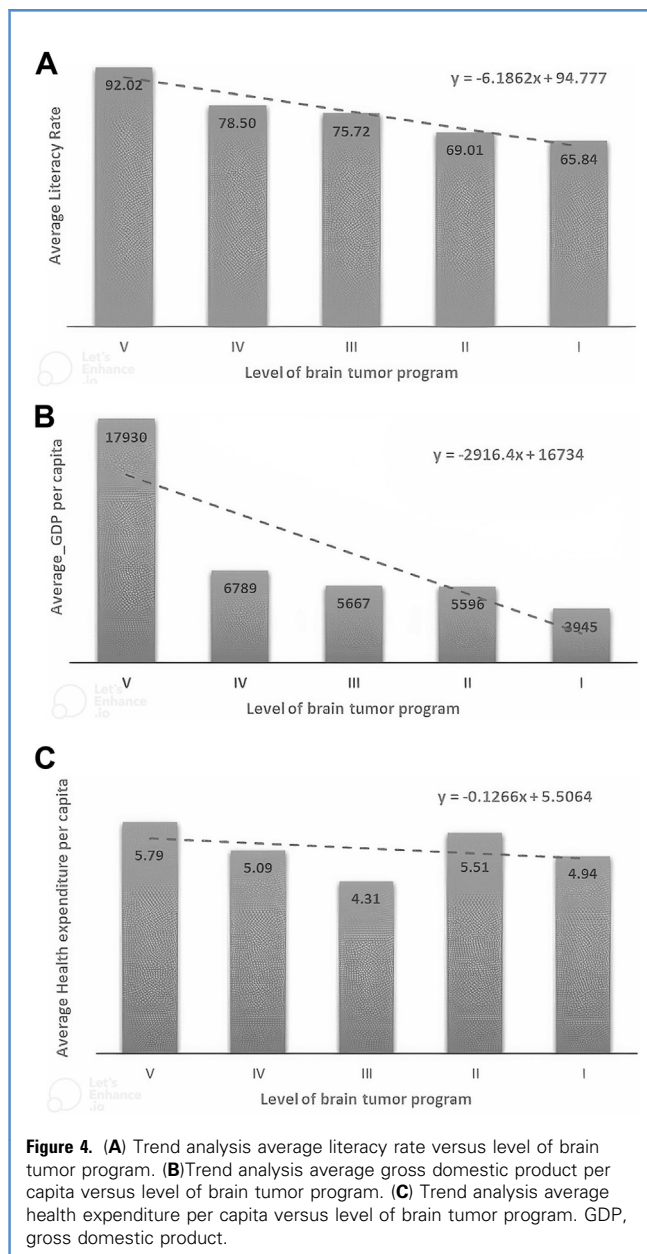


Figure 4. (A) Trend analysis average literacy rate versus level of brain tumor program. (B) Trend analysis average gross domestic product per capita versus level of brain tumor program. (C) Trend analysis average health expenditure per capita versus level of brain tumor program. GDP, gross domestic product.

teach local surgeons and other members of the surgical team during a surgical camp. Upgrading of the training of more neurosurgeons is critical to bridge the care gap in brain tumor care in both continents.

Long-term measures should focus on social advocacy particularly aimed at influencing government policies. Neurosurgeons should adopt strategies to attract government funding as well as private donors and venture funds for neuro-oncology programs.^{19,28,29} Establishment of continuing medical education programs, multidisciplinary teams, and research projects in neuro-oncology is important. Moreover, creation of organized neuro-oncology groups such as the Asian Society for Neuro-

Oncology (ASNO) and the Society of Neuro-Oncology sub-Saharan Africa (SNOSSA) similar to groups in HICs such as the Society of Neuro-Oncology (SNO) and European Association of Neuro-Oncology (EANO) will help to leverage relationships and perform identical activities to improve expertise in neuro-oncology practice and research.^{9,30} In terms of research, LMICs offer an attractive setting for clinical trials because they offer larger treatment-naïve populations with comparatively higher incidence rates of central nervous system tumors.^{11,31}

Limitations

The available information used to categorize each country may not have been a true representation of the country. Country-level brain tumor status may not accurately depict local or regional status. We adopted a parametric model in our index study to obtain baseline estimates of BTPs among our study populations. However, knowing the inherent limitations of parametric models, including their weakness for making future projections for the source population, we plan to perform a follow-up longitudinal study on this subject, for which we shall apply a hierarchical model to properly account for unequal variances among the different populations under study. Finally, it will be worthwhile to compare our 2 highly populated continents with other continents and learn from the successful BTPs adopted by countries in these continents.

CONCLUSIONS

This study represents a first step toward bridging the existing gaps in neuro-oncological services in Asia and Africa. We successfully

mapped 86% of the countries in both continents and categorized them into levels of BTP. The ASAFRIN brain tumor model, a multivariable prediction model that was developed and applied for the first time in our study, has demonstrated a high value in modeling the effect of salient determinants or predictors on BTPs.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Shweta Kedia: Conceptualization, Methodology, Investigation, Project administration, Writing – original draft. **Mabel Banson:** Conceptualization, Methodology, Investigation, Project administration, Writing – original draft. **Beverly Cheserem:** Conceptualization, Methodology. **Bipin Chaurasia:** Conceptualization, Methodology. **Claire Karekezi:** Conceptualization, Methodology, Investigation, Writing – original draft. **Enoch Uche:** Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft. **James A. Balogun:** Conceptualization, Methodology, Investigation, Writing – original draft. **Lynne Lourdes N. Lucena:** Investigation, Data curation. **M. Eisah Elhaj Mahmoud:** Methodology. **Priya Singh:** Investigation, Formal analysis. **Sachin Chemate:** Investigation, Data curation. **Santanu Kumar Bora:** Conceptualization, Methodology. **Teddy Totimeh:** Methodology, Investigation.

ACKNOWLEDGMENTS

We acknowledge all the participants of the survey.

REFERENCES

- Patel AP, Fisher JL, Nichols E, et al. Global, regional, and national burden of brain and other CNS cancer, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet Neurol.* 2019;18:376–393.
- Mohammadi E, Moghaddam SS, Azadnadjafabadi S, et al. Epidemiology of brain and other central nervous system cancers in the North Africa and Middle East region: a systematic analysis of the global burden of disease study 1990–2019. *World Neurosurg.* 2023;171:e796–e819.
- Louis DN, Perry A, Reifenberger G, et al. The 2016 World Health Organization classification of tumors of the central nervous system: a summary. *Acta Neuropathol.* 2016;131:803–820.
- Louis DN, Perry A, Wesseling P, et al. The 2021 WHO classification of tumors of the central nervous system: a summary. *Neuro Oncol.* 2021;23:1231–1251.
- de Robles P, Fiest KM, Frolkis AD, et al. The worldwide incidence and prevalence of primary brain tumors: a systematic review and meta-analysis. *Neuro Oncol.* 2015;17:776–783.
- Bell JS, Koffie RM, Rattani A, et al. Global incidence of brain and spinal tumors by geographic region and income level based on cancer registry data. *J Clin Neurosci.* 2019;66:121–127.
- Chan MH, Boop F, Qaddoumi I. Challenges and opportunities to advance pediatric neuro-oncology care in the developing world. *Childs Nerv Syst.* 2015;31:1227–1237.
- Piñeros M, Sierra MS, Izarzugaza MI, Forman D. Descriptive epidemiology of brain and central nervous system cancers in Central and South America. *Cancer Epidemiol.* 2016;44:S141–S149.
- Kanmounye US, Karekezi C, Nyalundja AD, Awad AK, Lacke T, Balogun JA. Adult brain tumors in Sub-Saharan Africa: a scoping review. *Neuro Oncol.* 2022;24:1799–1806.
- Levin VA. Neuro-oncology: an overview. *Arch Neurol.* 1999;56:401–404.
- Karekezi C, Yamaguchi F, Francesco DM, Maldaun M, Nduom EK. The role of neurosurgery in global health oncology. In: Germano IM, ed. *Neurosurgery and Global Health*. Berlin, Germany: Springer International Publishing; 2022:67–85.
- Meara JG, Leather AJM, Hagander L, et al. Global surgery 2030: evidence and solutions for achieving health, welfare, and economic development. *Lancet.* 2015;386:569–624.
- Mathers C, Fat DM, Boerma JT, World Health Organization, eds. *The Global Burden of Disease: 2004 Update*. Geneva, Switzerland: World Health Organization; 2008.
- Leece R, Xu J, Ostrom QT, Chen Y, Kruchko C, Barnholtz-Sloan JS. Global incidence of malignant brain and other central nervous system tumors by histology, 2003–2007. *Neuro Oncol.* 2017;19:1553–1564.
- Katsura S, Suzuki J, Wada T. A statistical study of brain tumors in the neurosurgical clinics in Japan. *J Neurosurg.* 1959;16:570–580.
- Bailey S, Parkes J, Davidson A. Global challenges in pediatric neuro-oncology. In: *Brain Tumors in Children*. Berlin, Germany: Springer; 2018:403–426.
- Gyorki DE, Muyco A, Kushner AL, Brennan MF, Kingham TP. Cancer surgery in low-income countries: an unmet need. *Arch Surg.* 2012;147:1135–1140.
- Mukhopadhyay S, Punchak M, Rattani A, et al. The global neurosurgical workforce: a mixed-methods assessment of density and growth. *J Neurosurg.* 2019;130:1142–1148.
- Norton R, Kobusingye O. Injuries. *N Engl J Med.* 2013;368:1723–1730.
- Hyder AA, Wunderlich CA, Puvanachandra P, Gururaj G, Kobusingye OC. The impact of traumatic brain injuries: A global perspective. *Neurol.* 2007;22:341–353.
- Hyder A. Global childhood unintentional injury surveillance in four cities in developing countries: a pilot study. *Bull World Health Organ.* 2009;87:345–352.
- World Health Organization. *WHO Global Status Report on Road Safety 2013: Supporting a Decade*

- of Action. World Health Organization <https://apps.who.int/iris/handle/10665/78256>; 2013. Accessed October 2, 2022.
23. Awake surgery with continuous motor testing for resection of brain tumors in the primary motor area - ScienceDirect. <https://www.sciencedirect.com/science/article/abs/pii/S0967586808001070>. Accessed October 18, 2020.
 24. Terao H, Nishikawa H, Oishi H, Endo T, Kaneko I, Kogure T. A new principle and device for radiosurgery using a linear accelerator; its principle, devices and clinical trials. *No Shinkei Geka*. 1992;20:583-592.
 25. Fukaya C, Katayama Y, Yoshino A, Kobayashi K, Kasai M, Yamamoto T. Intraoperative wake-up procedure with propofol and laryngeal mask for optimal excision of brain tumour in eloquent areas. *J Clin Neurosci*. 2001;8:253-255.
 26. Shrome MG, Dare AJ, Alkire BC, O'Neill K, Meara JG. Catastrophic expenditure to pay for surgery worldwide: a modelling study. *Lancet Glob Health*. 2015;3:S38-S44.
 27. Stupp R, Mason WP, van den Bent MJ, et al. Radiotherapy plus concomitant and adjuvant temozolomide for glioblastoma. *N Engl J Med*. 2005;352:987-996.
 28. Kamdem F, Ngatchou W, Hamadou B, et al. Cardiac surgery in sub-saharan Africa: a report of 3-year experience at the douala general hospital. *J Xiangya Med*. 2017;2:67.
 29. Vargas J, Mayegga E, Nuwas E, Ellegala DB, Kucia EJ, Nicholas J. Brain surgery in the bush: adapting techniques and technology to Fit the developing world. *World Neurosurg*. 2013;80:e91-e94.
 30. Osorio DS, Lassaletta A, la Madrid AEM, et al. DEV-14. Impact of a Latin America-wide Teleconferenced brain tumor board. *Neuro Oncol*. 2018;20(Suppl 2):i47.
 31. Khoja A, Kazim F, Ali NA. Barriers to conducting clinical trials in developing countries. *Ochsner J*. 2019;19:294-295.

Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Received 25 February 2023; accepted 15 April 2023

Citation: World Neurosurg. (2023) 175:e1041-e1048. <https://doi.org/10.1016/j.wneu.2023.04.067>

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

Available online: www.sciencedirect.com

1878-8750/\$ - see front matter © 2023 Elsevier Inc. All rights reserved.