Infrastructural Barriers to Neurosurgical Care of Brain Tumors in Low- and Middle-Income Countries: A Systematic Review

Muhammad Shakir[1,2], Aly Hamza Khowaja[3], Hammad Atif Irshad[3], Izza Tahir[3], Syeda Fatima Shariq[3], Ali I. Rae[4], Radzi Hamzah[4], Saksham Gupta[4], Kee B. Park[4], Syed Ather Enam[1,2]

Key words
- Neurosurgical Care
- Infrastructure
- Low and Middle Income Countries
- Brain Tumors

Abbreviations and Acronyms
HIC: High-income country
LMIC: Low- and middle-income country
MRI: Magnetic resonance imaging
NSOAP: National Surgical, Obstetric, and Anesthesia Plan
OR: Operating room

From the [1]Section of Neurosurgery, Department of Surgery, Aga Khan University Hospital, Karachi, Pakistan; [2]Centre of Oncological Research in Surgery (COORS), Juma Research Laboratories, Aga Khan University, Karachi, Pakistan; [3]Medical College, Aga Khan University, Karachi, Pakistan; and [4]Department of Global Health and Social Medicine, Program in Global Surgery and Social Change (PGSSC), Harvard Medical School, Boston, Massachusetts

To whom correspondence should be addressed: Syed Ather Enam, M.D., Ph.D. [E-mail: ather.enam@aku.edu]

Citation: World Neurosurg. (2025) 194:123375. https://doi.org/10.1016/j.wneu.2024.10.104

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

Available online: www.sciencedirect.com

BACKGROUND: **Appropriate surgical infrastructure is important for improving patient outcomes. However, low- and middle-income countries (LMICs) often struggle to provide adequate brain tumor surgery due to fractured infrastructure. This study aims to identify and evaluate barriers to surgical care infrastructure for brain tumors in LMICs.**

METHODS: **A comprehensive literature search was conducted from inception to October 20, 2022, using PubMed, Scopus, CINAHL, and Google Scholar. Inclusion criteria were studies that focused on surgical care of brain tumors in terms of infrastructure in low-resource settings. Studies were excluded if they did not focus on surgical care or were not conducted in LMIC. Data was extracted and analyzed qualitatively.**

RESULTS: **A final analysis of 39 studies showed significant barriers: 66% had poor operating room infrastructure, 32% lacked specialized care centers and imaging facilities, 26% faced long-distance travel issues, 13% had poor public health infrastructure, and 11% had poor referral pathways and lacked advanced diagnostic facilities. Additionally, 3% had an uneven distribution of quality centers and inadequate ward capacity. Proposed strategies include cross-border collaboration (29%), optimizing existing resources (29%), improving referral pathways (7%), resource sharing within hospitals, and acquiring surgical devices through donations (7%).**

CONCLUSIONS: **The review highlights key barriers in infrastructure while providing effective neurosurgical care to brain tumors in LMICs. To overcome these challenges, targeted strategies need to be implemented by stakeholders, policymakers, and health ministries.**

INTRODUCTION

Brain tumors are a serious global health concern and rank as the 10th leading cause of death worldwide. In 2020, 308,102 new cases of central nervous system tumors were diagnosed, resulting in 251,329 deaths. Affecting individuals of all ages, these tumors place a substantial burden on healthcare systems due to their high mortality rates, significant impairments, and severe impact on quality of life.[1,2]

The epidemiology of brain tumors varies widely around the world, and information on brain tumors in low- and middle-income countries (LMICs) is frequently limited due to the dearth of population-based cancer registries. As a result, it can be difficult to predict the prognosis of brain tumors in these settings. However, compared to LMICs (around 4.81 instances per 100,000 person-years), high-income countries (HICs) appear to have a greater incidence of brain tumors (6.29 cases per 100,000 person-years), which may be due to case ascertainment bias.[3]

There is a significant healthcare disparity between HICs and LMICs. Five-year survival rates have been reported to be more than 80% for 45,000 children with brain tumors in HICs versus less than 30% for 384,000 in LMICs.[4] Treatment failure rates in the pediatric population with brain tumors range from 37% to 83% in developing countries, owing partially to a lack of resources and infrastructure.[5]

In developing countries, the provision of surgical care to brain tumors is hindered by numerous factors, including limited workforce, service delivery, information management, governance, financing, and infrastructure. Among these, infrastructure is considered the most critical aspect of establishing successful surgical programs in developing nations. Unfortunately, inadequate

infrastructure, including a lack of necessary medical equipment, can impede healthcare delivery and ultimately result in poor patient outcomes.[6]

This systematic review aims to uncover the challenges related to infrastructure of brain tumors surgical management in LMICs and provide recommendations for future policies to address these issues. To our knowledge, no similar study has been conducted to highlight these shortcomings in neurosurgical care in LMICs with evidence from the literature.

MATERIALS AND METHODS

The systematic review of literature on barriers and potential strategies for neurosurgical care of brain tumors was conducted according to best practices and guidelines, including the population, intervention, control, and outcome framework and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines.[7,8] The study protocol was registered on PROSPERO (CRD 42023395882).

Search Strategy

A comprehensive search strategy was used to identify relevant studies, including the use of multiple databases such as Scopus, PubMed, Google Scholar, and CINAHL without any language restrictions. The Medical Subject Headings database and specific keywords (Neurosurgery OR "Neurosurgical Procedures" AND "Capacity Building" OR Infrastructure OR "Health Resources" AND "Brain Neoplasms" OR "Brain Tumors" AND "Developing Countries" OR "low- and Middle-income Countries") were used to ensure that the most up-to-date and relevant literature was captured. Furthermore, additional sources such as the World Health Organization Library, ResearchGate, World Health Organization, United Nations High Commissioner for Refugees, and Gray Literature Report were searched to include gray literature and unpublished studies. The search was conducted from inception to October 20, 2022, and backward referencing from search results was also done to ensure that a maximum number of articles were screened. The detailed search strategy for each database is available in the **Supplementary Data**.

Study Selection

This study is a part of comprehensive reviews on the barriers and strategies to the surgical care of brain tumors in low-resource settings. The review uses the National Surgical, Obstetric, and Anesthesia Plan (NSOAP) framework to identify the domains of workforce, infrastructure, service delivery, financing, information management, and governance.[9] This review focuses on infrastructure-related barriers to brain tumor care. Only articles from countries identified as LMICs in data provided by The World Bank (D.C., USA).[10] Different study designs, including epidemiological studies, qualitative studies, cross-sectional studies, cohort studies, randomized or nonrandomized controlled trials, commentary, and author/expert opinions, were included. Both population-based and hospital-based studies were included in the analysis, and articles without full text, review articles, editorials, letters to the editor, meeting abstracts, case reports, case series ($n < 10$), book chapters, guidelines, animal testing, and biological studies were excluded.

Screening of Studies

Two authors independently screened the titles and abstracts of each article to exclude studies that did not meet the inclusion criteria. The final selection of studies included in this review was determined through independent full-text reviews of the remaining articles.

Data Extraction

The data from the included studies were extracted onto an Excel sheet (Microsoft Excel) and independently verified by 2 authors (M. S. and A. H. K.). The reviewers resolved their disagreements through discussion and consensus. In the study, the primary objective was to identify the barriers and challenges to surgical treatment of brain tumors in terms of infrastructure in LMICs. Based on the inclusion of the primary outcome in the studies included, the authors assessed study-level bias.

The following variables were collected from the included studies: publication year, study design, study setting, sample size, barriers and challenges to brain tumor surgical care, the strategies/recommendations suggested by the authors, the study objective, and outcome.

Data Analysis

For data processing and organization, Microsoft Excel was used. The extracted data was sorted using the NSOAP framework.[9] Following the data extraction process, we conducted a thematic analysis, which allowed us to identify and categorize themes. These themes were subsequently presented, quantified, and reported as percentages to provide a comprehensive overview of the findings.

RESULTS

39 studies were included in our final analysis.[5,11-48] The kappa score for the full-text review stage between M. S. and A. H. K. was 0.79, and for the title and abstract screening was 0.82.[49] A detailed of screening can be found in **Figure 1**. No studies have specifically explored the barriers and challenges to infrastructure of surgical care of brain tumors in LMICs using the NSOAP framework. However, the authors of the included studies have reported potential barriers and strategies to address them based on their experience with patients, their medical records, and their knowledge of backgrounds. The details are outlined in **Table 1**.

We found some barriers to the provision of effective neurosurgical care, 66% of the included studies reported poor infrastructure of operating rooms (ORs),[5,11-15,18,19,23,27,28,30,32-36,39,42-44,46-48] 32% reported lack of specialized centers to provide care, 32% lack of imaging facilities,[5,11,15,18,19,21-26,33,34,38,39,41,43-45,48] 26% long-distance travel,[15,16,21,29,31,32,34,37,42,44] 11% poor referral pathways,[15,20,21,46] 13% poor public health infrastructure,[15,21,31,34,37] 3% uneven distribution and disparity in quality of centers across the country,[16] 11% lack of advanced diagnostic facilities,[5,17,25,46] and 3% insufficient capacity in wards and hospital units.[34] Additionally, poor availability of surgical equipment, shortage of anesthesia medications, lack of uninterrupted power supply in ORs, and unavailable blood bank services. These challenges can make it difficult for patients to access specialized care and for healthcare

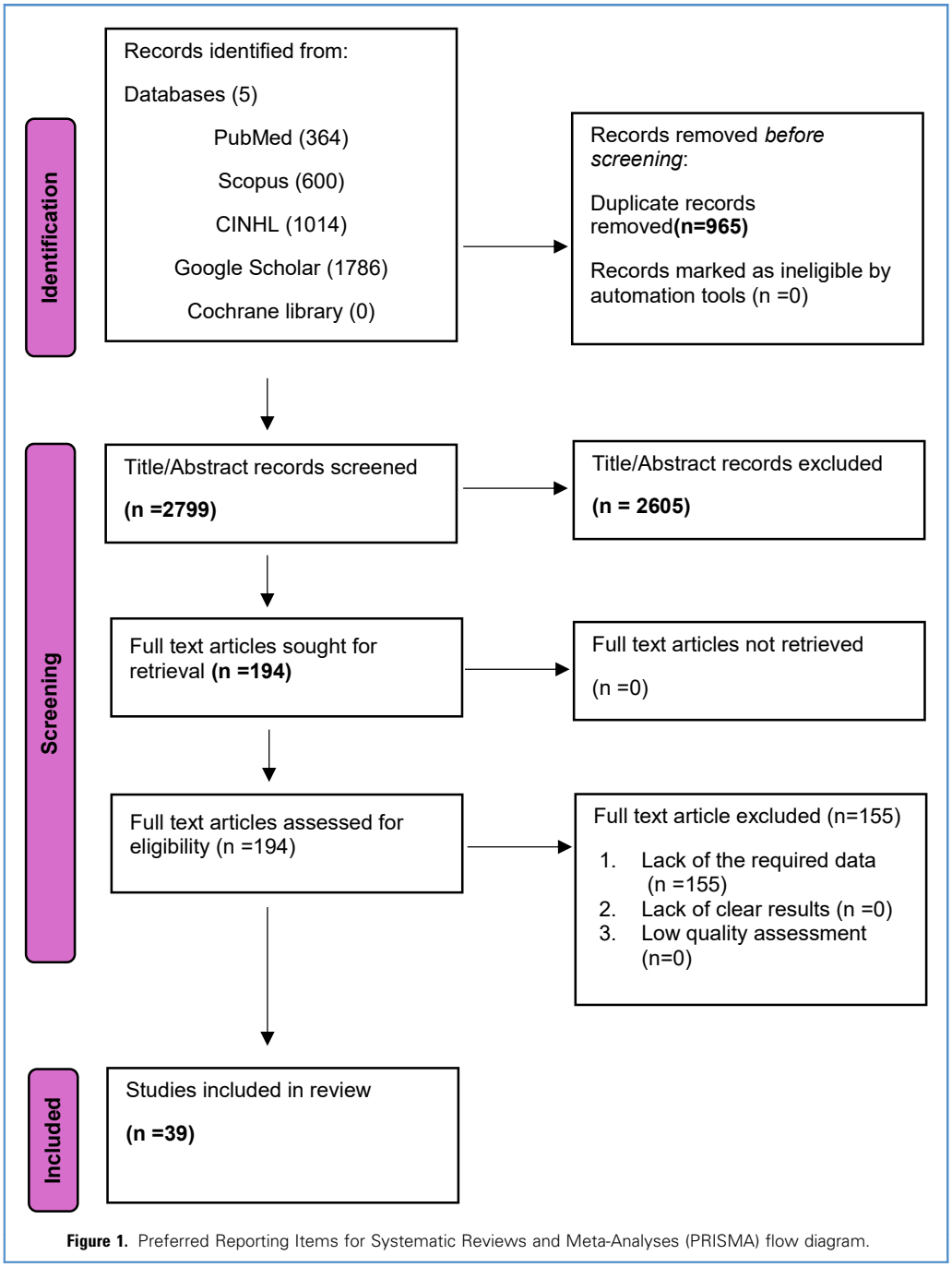

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram.

providers to perform these complex procedures effectively. The details are outlined in **Table 2** and **Figure 2A** .

To improve the provision of neurosurgical care in low-income settings, we identified various strategies. These include collaboration with other institutions and healthcare centers across the borders (29%),[14,25,41,46] optimization of existing resources and sharing (29%),[15,35,36,46] the use of awake craniotomy instead of craniotomy under general anesthesia (29%),[26,32,36,43] and the use of thin-slice computed tomography as an alternative when magnetic resonance imaging (MRI) is unavailable and using intraoperative ultrasound as a neuronavigation alternative to MRI (14%).[28,48] Additionally, improving referral pathways (7%),[33] addressing healthcare infrastructural issues (7%),[40] and exploring acquisition

Table 1. Baseline Characteristics of included studies

Study Name	Country	Study Design	Sample Size	Population
Abdelgadir et al. 2017[11]	Uganda	Retrospectively chart review	11/1440	Mixed
Abdelhameed et al. 2021[12]	Egypt	Retrospective series	20	Adult
Adeleye et al. 2012[13]	Nigeria	Prospective, descriptive survey	51	Adult
Aristizabal et al. 2020[14]	Mexico-United States	Prospective	60	Mixed
Ashraf et al. 2022[15]	Pakistan	Prospective audit	37/148	-
Bajwa et al. 2022[16]	Pakistan	Retrospective cross-sectional	2366	Mixed
Baskin et al. 2013[5]	Paraguay	Mixed methods	-	Healthcare professional
Benyaich 2020[43]	Morocco	Retrospective review	20	Adult
Beygi et al. 2013[17]	Iran	Retrospective review (National Cancer Registry)	2052	Mixed
Dewan et al. 2018[42]	Global survey	Mixed-question survey	459	Pediatric surgeons
Dwarakanath et al. 2007[18]	India	Prospective nonrandomized study	37	Adult
Elhassan et al. 2019[44]	Sudan	Retrospective review	62	Pediatric
Elkady et al. 2020[19]	Egypt	Retrospective cohort	101	Adult
Elmezughi et al. 2017[20]	Africa	Retrospective chart review	70	Adult
Filho et al. 2019[21]	Brazil	Retrospective (descriptive, longitudinal)	742	Mixed
Gandaho et al. 2016[45]	Nigeria	Retrospective analysis	38	Mixed
Govindan et al. 2018[22]	India	Retrospective descriptive	71	Pediatric
Hamid et al. 2022[23]	Pakistan	Retrospective chart review	518	Pediatric
Hammad et al. 2021[24]	Egypt	Retrospective cohort	47	Pediatric
Hatef et al. 2014[25]	Uganda	Retrospective cohort	411	Mixed
Helal et al. 2018[26]	Egypt	Retrospective chart review	193	Mixed
Howe et al. 2013[27]	Indochina and Africa: Ghana, Nigeria, Indonesia, China	Retrospective cohort	38	Mixed
Ibrahim et al. 2018[28]	Egypt	Prospective cohort	30	Adult
Jaju et al. 2014[29]	India	Commentary	-	-
Kaale et al. 2021[30]	Tanzania	Prospective	24	Mixed
Kakusa et al. 2019[31]	Uganda	Retrospective	112	Mixed
Mansur et al. 2018[32]	Indonesia	Prospective mixed method	88	Neurosurgeons
Moiyadi et al. 2012[33]	India	Prospective	196	Mixed
Moreira et al. 2020[46]	LMIC	Commentary	-	Pediatric
Tran 2019[34]	Vietnam	-	-	Mixed
Tesfaye Abebe 2022[47]	Ethiopia	Prospective study	239	Adult
Pant 2004[35]	Nepal	Commentary	-	-
Pascual 2021[36]	Philippines	Retrospective analysis	65	Adult
Qaddoumi 2011[37]	Developing countries	Online survey/cross-sectional	151	Pediatric Neurosurgeons
Riaz 2019[38]	Pakistan	Retrospective observational study	175	Pediatric

Continues

Table 1. Continued

Study Name	Country	Study Design	Sample Size	Population
Sahlu 2019[48]	Ethiopia	Retrospective analysis	100	Adult
Shamim 2011[39]	Pakistan	Survey	36	Neurosurgery trainees and neurosurgeons
Nyeko 2022[40]	Uganda	Retrospective analysis	35	Pediatric
Stagno 2014[41]	Uganda	Retrospective analysis	172	Pediatric

LMIC, low- and middle-income country.

of surgical devices through donations (7%).[41] The details are outlined in Table 3 and Figure 2B.

DISCUSSION

Neurosurgical care of brain tumors in settings with limited resources is a significant challenge due to a number of barriers. One of the major deterrents identified in the literature is the lack of proper infrastructure to hold up the delivery of care. This includes inadequate facilities, medical equipment, and limited access to technology. These issues can greatly impact healthcare services to patients, ultimately leading to poor patient outcomes. The present study highlights some of the infrastructure-related barriers and potential strategies to improve neurosurgical care of brain tumors.

The provision of brain tumor treatment can pose significant challenge in regions that lack specialized medical centers and healthcare professionals who lack proper training. In South Africa, for instance, one hospital serves a population of 100,000.[50] In many developing countries, there is a shortage of well-trained and motivated healthcare teams. The involvement of a multidisciplinary team, including neurosurgeons, anesthesiologists, neuropsychologists, neurophysiologists, and speech therapists, is essential to achieve better postoperative outcomes and improve the quality of life of patients with brain tumors.[43]

Dell et al. report approximately 4 ORs for a population of 100,000 in South Africa and Brazil. Most LMICs, including Uganda, Zimbabwe, Tanzania, Ethiopia, and Rwanda, had approximately one OR per 100,000 population. On the other hand, HICs such as the United States had approximately 14 ORs per 100,000 population as of 2014.[50] Postoperatively, patients are admitted to wards or intensive care units, and the provision of surgical care has been restricted by a small number of beds.[51] The disparity in hospital bed availability per 100,000 population is notable based on the country's economic status. In low-income countries such as Uganda and Tanzania, the availability of hospital beds is reported to be less than 200 per 100,000 population. In contrast, HICs such as the United Kingdom, the United States, and Australia had a more substantial number of hospital beds, ranging from 294 to 382 per 100,000 population.[50] Given this disparity, it is crucial to increase the number of ORs and hospital beds in LMICs.

Poor infrastructure also refers to an insufficient dispersion of neurological facilities including travel distance. But in connection with it, the travel distance is a significant problem. The average distance for surgical care varies from 20 to 40 km, and even more than 100 km[52] in LMICs compared to 10 km in HICs.[16] Furthermore, due to the poor transport systems often found in the LMICs, the distance to care does not completely depict the inconvenience caused by travel. The traveling distance may be more than 50 km in some LMICs, which is frequently considered as a benchmark for sufficient infrastructure to provide safe surgery.[16] Studies have shown the association of greater travel distance with delayed detection of disease,[53] delayed operative treatment,[54] and the effect on health outcomes has also been heavily studied.[55]

Another critical aspect of poor infrastructure in LMICs is the lack of adequate surgical instrument maintenance and renewal. This is a significant issue affecting the delivery of optimal care. Public sector institutions may have expensive equipment, but due to a lack of funding for consumables, such as drapes and maintenance, these one-time big-ticket item purchases are often wasted. Although specific articles are scarce on this topic, this problem is well recognized in the field.

It is also essential for ORs to be well equipped with safe and effective operating tools to manage patients with brain tumors. According to a review conducted in the Philippines, which included studies from 6 different LMICs, negative pressure ORs were not found in Brazil and Turkey.[56] The shortage of these facilities is further compounded by inadequate sterilization practices in ORs, sterilization equipment, and postanesthesia care units,[51] leading to increased risk of postsurgical complications, including infections.[51,57]

The absence of a stable power source is a significant challenge in low-income countries. Interruptions in electricity or inadequate provision of generators can result in delays in medical procedures and diagnoses. Unfortunately, only two thirds of the 21 LMICs surveyed had access to an uninterrupted power supply.[51] In neurosurgery, where precision and

Table 2. Infrastructure Barriers to Surgical Care of Brain Tumors

	Barriers								
Study Name	Lack of specialized centers to provide care	Poor operating room infrastructure (intraoperative mapping, surgical equipment, power supply, and anesthesia)	Lack of intraoperative and postoperative imaging facilities	Long-distance travel	Poor referral pathways	Poor public health infrastructure	Disparity in the quality of centers	Lack of advanced diagnostic facilities	Inadequate capacity of hospital units
Abdelgadir et al. 2017[11]	✓	✓	✓						
Abdelhameed et al. 2021[12]		✓							
Adeleye et al. 2012[13]		✓							
Aristizabal et al. 2020[14]		✓							
Ashraf et al. 2022[15]	✓	✓		✓	✓	✓			
Bajwa et al. 2022[16]				✓			✓		
Baskin et al. 2013[5]		✓	✓					✓	
Benyaich 2020[43]		✓	✓						
Beygi et al. 2013[17]								✓	
Dewan et al. 2018[42]		✓		✓					
Dwarakanath et al. 2007[18]		✓	✓						
Elhassan et al. 2019[44]		✓	✓	✓					
Elkady et al. 2020[19]		✓	✓						
Elmezughi et al. 2017[20]					✓				
Filho et al. 2019[21]	✓			✓	✓	✓			
Gandaho et al. 2016[45]	✓		✓						
Govindan et al. 2018[22]	✓								
Hamid et al. 2022[23]	✓	✓							
Hammad et al. 2021[24]	✓								
Hatef et al. 2014[25]			✓					✓	

Continues

Table 2. Continued

Study Name	Barriers								
	Lack of specialized centers to provide care	Poor operating room infrastructure (intraoperative mapping, surgical equipment, power supply, and anesthesia)	Lack of intraoperative and postoperative imaging facilities	Long-distance travel	Poor referral pathways	Poor public health infrastructure	Disparity in the quality of centers	Lack of advanced diagnostic facilities	Inadequate capacity of hospital units
Helal et al. 2018[26]	✓	✓							
Howe et al. 2013[27]		✓							
Ibrahim et al. 2018[28]		✓							
Jaju et al. 2014[29]				✓					
Kaale et al. 2021[30]		✓							
Kakusa et al. 2019[31]				✓		✓			
Mansur et al. 2018[32]		✓		✓					
Moiyadi et al. 2012[33]	✓	✓	✓						
Moreira et al. 2020[46]		✓			✓			✓	
Tran 2019[34]		✓	✓	✓		✓			✓
Tesfaye Abebe 2022[47]		✓							
Pant 2004[35]		✓							
Pascual 2021[36]		✓							
Qaddoumi 2011[37]				✓		✓			
Riaz 2019[38]	✓								
Sahlu 2019[48]		✓	✓						
Shamim 2011[39]	✓	✓							
Stagno 2014[41]	✓		✓						

delicacy are crucial, electrical failures can have devastating repercussions during procedures. Adeleye et al. report the use of rechargeable overhead lights to compensate for the lack of overhead OR lights.[13] There is also a lack of functional blood bank services in many LMICs.[51]

Countries that have medical equipment available often cannot use it efficiently[6] due to various reasons, including missing parts and untrained staff, which impair service delivery. About 40% of the medical equipment is found to be out of service in developing countries.[58] Technicians and biomedical staff need to be adequately trained to make full use of the available technology.

Lack of intraoperative imaging, neuronavigation, and mapping facilities is another barrier faced in LMICs.[5,43] These facilities aid in assessing tumor

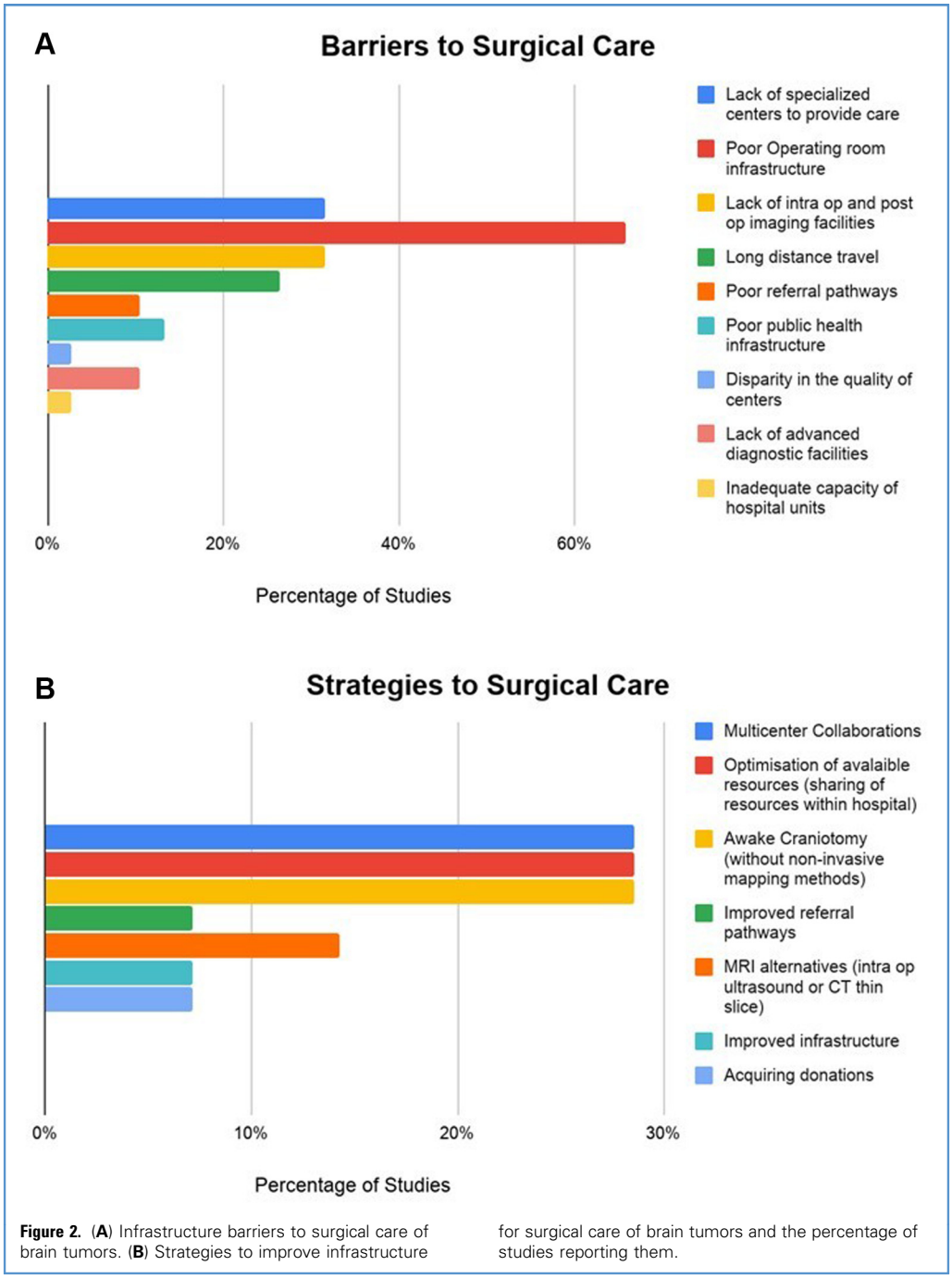

Figure 2. (**A**) Infrastructure barriers to surgical care of brain tumors. (**B**) Strategies to improve infrastructure for surgical care of brain tumors and the percentage of studies reporting them.

extensions to attempt maximum total resection for improved outcomes, and to assess the cognitive function in awake craniotomy for brain tumors. Wu et al. demonstrate a significantly improved extent of resection of gliomas with the use of intraoperative MRI,[59] which subsequently improves outcomes. Where unavailable, intraoperative MRI can be replaced by intraoperative ultrasonography in certain cases to identify the tumor boundaries and achieve maximum safe resection.[43] Pascual et al. have reported their success in performing awake craniotomy for multiple indications including tumor resection in eloquent areas despite the absence of neuronavigation.[36] This work from the Philippines can be replicated in other LMICs and use awake craniotomy as an alternative to neuronavigation, relying on crude intraoperative function rather than intraoperative structural and functional imaging. However, teams

Table 3. Potential strategies to improve infrastructure for surgical care of brain tumors

	Strategies						
Study Name	**Multicenter collaborations**	**Optimization of available resources (sharing of resources within hospitals)**	**Awake craniotomy (without noninvasive mapping methods)**	**Improved referral pathways**	**MRI alternatives (intraoperative ultrasound or CT)**	**Improved infrastructure**	**Acquiring donations**
Aristizabal et al. 2020[14]	✓						
Ashraf et al. 2022[15]		✓					
Benyaich 2020[43]			✓				
Hatef et al. 2014[25]	✓						
Helal et al. 2018[26]			✓				
Ibrahim et al. 2018[28]					✓		
Mansur et al. 2018[32]			✓				
Moiyadi et al. 2012[33]				✓			
Moreira et al. 2020[46]	✓	✓					
Nyeko 2022[40]						✓	
Pant 2004[35]		✓					
Pascual 2021[36]		✓	✓				
Sahlu 2019[48]					✓		
Stagno 2014[41]	✓						✓

MRI, magnetic resonance imaging; CT, computed tomography.

need to be cognizant and prepared for the risk of complications such as intraoperative seizures when performing awake craniotomies.[60]

Moreover, well-trained healthcare providers prefer to reside in big cities as opposed to rural areas. A study revealed that 30% of the neurologists and neurosurgeons in India reside in big cities and capitals.[61] Another example is that of Haiti, where residents train in private setups instead of the educational system because of a poor lack of resources in these setups.[51] This effect training and capacity building for future trainees. Patients are often from rural areas where the level of surgical care required for brain tumors is not available. Long-distance travel[62] and logistics make it difficult for patients to travel from remote areas to the main hospital. Housing options should be provided to these patients and their families. Alternatively, incentives for physicians

and surgeons can be provided to meet the needs of distant cities.

Training programs need to be initiated in all developing countries to increase workforce and train surgeons who understand their own culture and environment. An example is the establishment of the training center in Rabat, which has led to the training of young neurosurgeons in Africa.[61] The formation of local training programs and getting the necessary equipment has been suggested to ensure long-term results in Africa.[63]

Surgical capacity building plays a pertinent role in improving the infrastructure of surgical care in brain tumors. This can be achieved by acquiring surgical equipment as donations[58] and through local, multicenter, and cross-border collaborations. But it should be ensured that expertise, cost, need assessment, and clinical guidelines should be considered while acquiring these devices.[6]

Finances are a major limitation when it comes to improving infrastructure in surgical care for brain tumors. Major investments in facilities and surgical resources are required.[57] Surgical teams from HICs can visit LMICs and train local surgeons to make a sustainable and long-lasting impact.[51] Examples include the establishment of an oncology twinning program in Madrid[5] and between a San Diego hospital and a hospital in Tijuana. Besides the provision of resources, chemotherapy protocols were also tailored according to the local resources.[14] These global partnerships then lead to improved patient outcomes.[51]

Telemedicine is more feasible in today's era to deal with the shortcomings in infrastructure. Teleclinics make remote areas more accessible, reducing travel time and costs. One hundred fifty medical colleges with a high-speed network have been linked to remote areas for teleconsultation in India,[61] and regional satellite clinics are in place in Paraguay.[4] Referral pathways need to be improved, and one way to do so is to refer patients for neurosurgery via teleconsultation. Awareness regarding the brain tumors presentation, treatment, and referral pathway should be raised.[5]

Most infrastructural challenges to neurosurgical care as described in LMICs are too large to be tackled individually. The unavailability of advanced equipment, facilities, personnel, and even nonsurgical infrastructure such as uninterrupted power supply, public transport systems, network connectivity, all require great initial and continued investment, and cannot be feasibly addressed in the short-term period. These are a result of decades of neglect, driven by internal and external political instability, lack of finances in the national health budget, and inappropriate public health policies among other factors.[64] We can only hope and advocate for improved public health policy and global surgical care, while advocating for immunity of healthcare systems to instabilities due to political instability and conflict. Furthermore, the generosity of decision-makers in high-income economies as charitable missions and twinning programs is greatly needed and has already proven to be extremely beneficial for many health systems.[65-69] Such comprehensive efforts have had great impact, such as the revolution in ophthalmic care in Pakistan.[70]

Furthermore, smaller, public-private partnerships in healthcare to provide equitable access to those visiting public setups, such as the Mini-Public-Private Partnerships in Malaysia,[65] have shown immediate improvements in healthcare equity with great return on investment. Global twinning models such as the International Neurosurgical Twinning Modeled for Africa[66,67] have shown improvement in patient care, directly via operative expertise, as well as by donating and servicing equipment to LMICs, addressing challenges of initial investment and maintenance. Such efforts have proven to be financially feasible and sustainable.[69]

Limitations

A comprehensive search strategy was used to collect data on surgical care of brain tumors in LMICs. However, a specific search focused on the infrastructure of brain tumor care was not used as the literature in this area is limited. It is also important to acknowledge that some of the data in this study were based on the observations of the authors of the included studies regarding the surgical care of brain tumors. This could introduce bias into the data and must be considered when interpreting the results. It is also worth mentioning that an assessment of the quality of all studies was performed due to the diverse study designs used in the analysis.

CONCLUSION AND FUTURE DIRECTION

The review highlights some key barriers to providing effective neurosurgical care to brain tumors in LMICs, including long-distance travel, lack of specialized hospitals, inadequate equipment, and poor availability of diagnostic facilities. Strategies to overcome these challenges include collaboration with other institutions, optimization of existing resources, and the use of alternative and cost-effective techniques. The review highlights the need for widespread policy and system change within LMICs, with financial and technical aid from more established health systems. Improving referral pathways, addressing infrastructural limitations, and exploring options such as resource sharing and acquiring equipment through donations will be key in improving patient care. To improve surgical care of brain tumors in settings with limited resources, it is crucial to conduct comprehensive studies that reveal the underlying issues, and potential solutions to address them. This will help in identifying areas that require improvement and provide guidance in developing and implementing effective strategies.

CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Muhammad Shakir: Writing — review & editing, Writing — original draft, Supervision, Methodology, Conceptualization. **Aly Hamza Khowaja:** Writing — original draft, Visualization, Validation. **Hammad Atif Irshad:** Writing — review & editing, Writing — original draft. **Izza Tahir:** Writing — review & editing, Writing — original draft. **Syeda Fatima Shariq:** Writing — review & editing. **Ali I. Rae:** Writing — original draft, Supervision. **Radzi Hamzah:** Writing — review & editing. **Saksham Gupta:** Writing — review & editing, Writing — original draft. **Kee B. Park:** Writing — original draft, Supervision, Conceptualization. **Syed Ather Enam:** Writing — review & editing, Writing — original draft, Supervision, Conceptualization.

ACKNOWLEDGMENTS

The authors would like to thank the Jenabai Hussainali Shariff Family for their generous support for this research.

REFERENCES

1. Dasgupta A, Gupta T, Jalali R. Indian data on central nervous tumors: a summary of published work. *South Asian J Cancer*. 2016;5:147-153.
2. Fan Y, Zhang X, Gao C, et al. Burden and trends of brain and central nervous system cancer from 1990 to 2019 at the global, regional, and country levels. *Arch Publ Health*. 2022;80:1-14.
3. 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.
4. Science and health for all children with cancer - PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/30872518/ . Accessed October 8, 2023.
5. Baskin JL, Lezcano E, Kim BS, et al. Management of children with brain tumors in Paraguay. *Neuro Oncol*. 2013;15:235-241.
6. Diaconu K, Chen YF, Cummins C, Jimenez Moyao G, Manaseki-Holland S, Lilford R. Methods for medical device and equipment procurement and prioritization within low-and middle-income countries: findings of a systematic literature review. *Glob Health*. 2017;13:1-16.
7. Moher D, Liberati A, Tetzlaff J, Altman DG, PRISMA Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Int J Surg*. 2010;8:336-341.
8. McInnes MD, Moher D, Thombs BD, et al. Preferred reporting items for a systematic review and meta-analysis of diagnostic test accuracy studies: the PRISMA-DTA statement. *JAMA*. 2018;319:388-396.
9. Peters AW, Roa L, Rwamasirabo E, et al. National surgical, obstetric, and anesthesia plans supporting the vision of universal health coverage. *Glob Health Sci Pract*. 2020;8:1-9.
10. World Bank Open Data. World Bank open data. Available at: https://data.worldbank.org . Accessed October 17, 2024.
11. Abdelgadir J, Tran T, Muhindo A, et al. Estimating the cost of neurosurgical procedures in a low-income setting: an observational economic analysis. *World Neurosurg*. 2017;101:651-657.
12. Abdelhameed E, Abdelghany MS, Abdelkhalek H, Elatrozy HIS. Awake surgery for lesions near eloquent brain under scalp block and clinical monitoring: experience of single center with limited resources. *Egypt J Neurol Psychiatr Neurosurg*. 2021;57:78.
13. Adeleye AO, Fasunla JA, Young PH. Skull base surgery in a large, resource-poor, developing country with few neurosurgeons: prospects, challenges, and needs. *World Neurosurg*. 2012;78:35-43.
14. Aristizabal P, Burns LP, Kumar NV, et al. Improving pediatric neuro-oncology survival disparities in the United States-Mexico border region: a cross-border initiative between San Diego, California, and Tijuana, Mexico. *JCO Glob Oncol*. 2020;6:1791-1802.
15. Ashraf M, Kamboh UA, Raza MA, et al. Prospective elective neurosurgical Theater utilization audit in Pakistan: problems in a public tertiary care hospital and proposed solutions from lower-middle-income country. *Asian J Neurosurg*. 2022;17:58-67.
16. Bajwa MH, Shah MM, Khalid MU, et al. Distance travelled for brain tumour surgery: an Low and Middle Income Country's perspective. *J Pak Med Assoc*. 2022;72:S25-S33.
17. Beygi S, Saadat S, Jazayeri SB, Rahimi-Movaghar V. Epidemiology of pediatric primary malignant central nervous system tumors in Iran: a 10 year report of National Cancer Registry. *Cancer Epidemiol*. 2013;37:396-401.
18. Dwarakanath S, Suri A, Sharma BS, Mahapatra AK. Neuronavigation in a developing country: a pilot study of efficacy and limitations in intracranial surgery. *Neurol India*. 2007;55:111-116.
19. Elkady A, Soliman MAR, Ali AM. Clinical outcomes of infratentorial Meningioma surgery in a developing country. *World Neurosurg*. 2020;137:e373-e382.
20. Elmezughi KK, Pirie FJ, Motala AA. Characteristics and outcome of surgically treated pituitary tumours in South Africa: a single-centre experience. *Clin Endocrinol*. 2017;86:534-540.
21. Adriano Filho CE, Pinto LM, Jesus JMD. Epidemiological Profile of Malignant Brain Neoplasms in the Northern Region of Brazil: data from the Cancer Hospital Registry of the Instituto Nacional de Câncer. *Arq Bras Neurocir*. 2019;38:094-101.
22. Govindan A, Parambil RM, Alapatt JP. Pediatric intracranial tumors over a 5-year period in a tertiary care center of north Kerala, India: a retrospective analysis. *Asian J Neurosurg*. 2018;13:1112-1117.
23. Hamid SA, Zia N, Maqsood S, et al. Impact of dedicated pediatric neuro-oncological services in a developing country: a single-institution, Pakistani experience. *Pediatr Blood Cancer*. 2022;69:e29887.
24. Hammad M, Hosny M, Khalil EM, Alfaar AS, Fawzy M. Pediatric ependymoma: a single-center experience from a developing country. *Indian J Cancer*. 2021;58:378-386.
25. Hatef J, Adamson C, Obiga O, et al. Central nervous system tumor distribution at a tertiary referral center in Uganda. *World Neurosurg*. 2014;82:258-265.
26. Helal AE, Abouzahra H, Fayed AA, Rayan T, Abbassy M. Socioeconomic restraints and brain tumor surgery in low-income countries. *Neurosurg Focus*. 2018;45:E11.
27. Howe KL, Zhou G, July J, et al. Teaching and sustainably implementing awake craniotomy in resource-poor settings. *World Neurosurg*. 2013;80:e171-e174.
28. Ibrahim A, Abdel Ghany WA, Elzoghby MA, El-Shazly A, Simry H, Fakhr MA. Ultrasound-guided versus traditional surgical resection of supratentorial gliomas in a limited-resources neurosurgical setting. *Egypt J Neurosurg*. 2018;33:1-11.
29. Skull base surgery. Indian perspective - PubMed. Available at: https://pubmed.ncbi.nlm.nih.gov/25203567/ . Accessed October 7, 2023.
30. Kaale AJ, Rutabasibwa N, Mchome LL, et al. The use of intraoperative neurosurgical ultrasound for surgical navigation in low-and middle-income countries: the initial experience in Tanzania. *J Neurosurg*. 2020;134:630-637.
31. Kakusa BW, Xu LW, Vaca SD, et al. Central nervous system tumors in Uganda: outcomes of surgical treatment and complications assessed through telephone survey. *World Neurosurg*. 2019;129:e866-e880.
32. Mansur A, Oswari S, Wahjoepramono POP, Kusdiansah M, Bernstein M. Awake craniotomy in a low-to middle-income country: a sustainability analysis. *World Neurosurg*. 2018;118:332-341.
33. Moiyadi AV, Shetty P. Feasibility of repeat surgery for pediatric brain tumors: an objective assessment of perioperative outcomes. *J Neurosurg Pediatr*. 2012;10:411-417.
34. Tran HM, Karras CL, Yerneni K, et al. Neurosurgical oncology in vietnam. *World Neurosurg*. 2019;127:541-548.
35. Pant B, Shrestha P. Management of brain tumor in Nepal. *Int Congr*. 2004;1259:149-155.
36. Pascual JSG, Omar AT, Gaddi MJS, et al. Awake craniotomy in low-resource settings: findings from a retrospective cohort in the Philippines. *World Neurosurg*. 2021;145:500-507.e1.
37. Qaddoumi I, Unal E, Diez B, et al. Web-based survey of resources for treatment and long-term follow-up for children with brain tumors in developing countries. *Child's Nerv Syst*. 2011;27:1957-1961.
38. Riaz Q, Naeem E, Fadoo Z, Lohano M, Mushtaq N. Intracranial tumors in children: a 10-year review from a single tertiary health-care center. *Child's Nerv Syst*. 2019;35:2347-2353.
39. Shamim MS, Tahir MZ, Godil SS, Kumar R, Siddiqui AA. A critical analysis of the current state of neurosurgery training in Pakistan. *Surg Neurol Int*. 2011;2:183.
40. Nyeko R, Kambugu JB, Angom R, et al. The clinicopathological profile and value of multidisciplinary management of pediatric brain tumors in a low-income setting. *Pediatr Hematol Oncol*. 2023;40:267-280.
41. Stagno V, Mugamba J, Ssenyonga P, Kaaya BN, Warf BC. Presentation, pathology, and treatment outcome of brain tumors in 172 consecutive children at CURE Children's Hospital of Uganda. The predominance of the visible diagnosis and the uncertainties of epidemiology in sub-Saharan Africa. *Child's Nerv Syst*. 2014;30:137-146.
42. Dewan MC, Baticulon RE, Rattani A, Johnston JM, Warf BC, Harkness W. Pediatric neurosurgical

workforce, access to care, equipment and training needs worldwide. *Neurosurg Focus*. 2018;45:E13.

43. Benyaich Z, Hajhouji F, Laghmari M, et al. Awake craniotomy with functional mapping for glioma resection in a limited-resource-setting: preliminary experience from a lower-middle income country. *World Neurosurg*. 2020;139:200-207.

44. Elhassan MMA, Mohamedani AA, Osman HHM, Yousif NO, Elhaj NM, Qaddoumi I. Patterns, treatments, and outcomes of pediatric central nervous system tumors in Sudan: a single institution experience. *Child's Nerv Syst*. 2019;35:437-444.

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

46. Moreira DC, Rajagopal R, Del Campo RMNM, et al. Bridging the gap in access to care for children with CNS tumors worldwide. *JCO Glob Oncol*. 2020;6:583-584.

47. Tesfaye Abebe F, Biluts Mersha H, Hirbo Guyolla Y. Predictors of early unplanned reoperation after craniotomy for brain tumor, Addis Ababa, Ethiopia: a one-year prospective study. *Interdiscipl Neurosurg*. 2022;30:101602.

48. Sahlu A, Laeke T, Kassahun A, et al. One hundred skull base meningiomas operated at black lion specialized hospital, Addis Ababa, Ethiopia. *World Neurosurg*. 2019;126:e1321-e1329.

49. Kappa coefficient: a popular measure of rater agreement - PMC. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4372765/ . Accessed October 7, 2023.

50. Dell AJ, Kahn D. Surgical resources in South Africa: an international comparison and deficit calculation. *World J Surg*. 2018;42:541-548.

51. DeGennaro V, DeGennaro VA, Bitar M, Bitar J, Thaller S. Building advanced surgical capacity at a hospital in port-au-prince, Haiti. *J Craniofac Surg*. 2015;26:1042-1047.

52. Chao TE, Burdic M, Ganjawalla K, et al. Survey of surgery and anesthesia infrastructure in Ethiopia. *World J Surg*. 2012;36:2545-2553.

53. Shakir M, Shariq SF, Tahir I, et al. Challenges to early detection of brain tumors in low- and middle-income countries: a systematic review. *World Neurosurg*. 2024;191:68-80.

54. Abelson JS, Barron J, Bauer PS, et al. Travel time to a high volume center negatively impacts timing of care in rectal cancer. *J Surg Res*. 2021;266:96-103.

55. Kelly C, Hulme C, Farragher T, Clarke G. Are differences in travel time or distance to healthcare for adults in global north countries associated with an impact on health outcomes? A systematic review. *BMJ Open*. 2016;6:e013059.

56. Pascual JSG, Ignacio KHD, Castillo MRL, Khu KJO. Practice Patterns in surgical neuro-oncology among low- and middle-income countries during the coronavirus disease 2019 pandemic: a scoping review and situational report from the Philippines. *World Neurosurg*. 2022;159:189-197.e7.

57. Prinja S, Nandi A, Horton S, Levin C, Laxminarayan R. *Costs, effectiveness, and cost-effectiveness of selected surgical procedures and platforms*. In: *Essential Surgery Disease Control Priorities*. Third Edition. Washington (DC): The International Bank for Reconstruction and Development / The World Bank; 2015.

58. Perry L, Malkin R. Effectiveness of medical equipment donations to improve health systems: how much medical equipment is broken in the developing world? *Med Biol Eng Comput*. 2011;49:719-722.

59. Wu JS, Gong X, Song YY, et al. 3.0-T intraoperative magnetic resonance imaging-guided resection in cerebral glioma surgery: interim analysis of a prospective, randomized, triple-blind, parallel-controlled trial. *Neurosurgery*. 2014;61(Suppl 1):145-154.

60. Shakir M, Khowaja AH, Altaf A, Tameezuddin A, Bukhari SS, Enam SA. Risk factors and predictors of intraoperative seizures during awake craniotomy: a systematic review and meta-analysis. *Surg Neurol Int*. 2023;14:195.

61. Misra BK. Neurosurgery in countries with limited resources. *World Neurosurg*. 2018;114:111-112.

62. Hong MAC, Omar AT, Khu KJO. Socioeconomic factors affecting survivorship of glioblastoma patients in the Philippines. *J Clin Neurosci*. 2022;98:89-95.

63. El Khamlichi A. African neurosurgery: current situation, priorities, and needs. *Neurosurgery*. 2001;48:1344-1347.

64. Shakir M, Shariq SF, Irshad HA, et al. Governance challenges to the neurosurgical care of brain tumors in low- and middle-income countries: a systematic review. *World Neurosurg*. 2024;190:399-407.e3.

65. Waran V, Thillainathan R, Karuppiah R, Pickard JD. Equitable access to state-of-the-art medical technology-a Malaysian mini-public-private partnership case study. *World Neurosurg*. 2022;157:135-142.

66. Corell A, Jabang JN, Manneh J, et al. Successful adaptation of twinning concept for global neurosurgery collaborations-a validation study. *Acta Neurochir (Wien)*. 2024;166:174.

67. Uche EO, Mezue WC, Ajuzieogu O, et al. Improving capacity and access to neurosurgery in sub-Saharan Africa using a twinning paradigm pioneered by the Swedish African Neurosurgical Collaboration. *Acta Neurochir (Wien)*. 2020;162:973-981.

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

69. Chu QD, Nguyen T, Nguyen P, Ho HS. Cost analysis of establishing a relationship between a surgical program in the US and vietnam. *Int Surg*. 2012;97:155.

70. Khan MD. The Duke Elder Lecture: the challenge of equitable eye care in Pakistan. *Eye (Lond)*. 2011;25:415. https://doi.org/10.1038/eye.2010.186.

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 14 July 2024; accepted 25 October 2024

Citation: World Neurosurg. (2025) 194:123375. https://doi.org/10.1016/j.wneu.2024.10.104

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

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

SUPPLEMENTARY DATA

Search Strategy:

Concept# 01: (Surgical Care). ("Neurosurgery"[Mesh] OR "Neurosurgical Procedures"[Mesh] OR "Craniotomy"[Mesh] OR "Radiosurgery"[Mesh] OR "Perioperative Care"[Mesh] OR "Preoperative Care"[Mesh] OR "Intraoperative Care"[Mesh] OR "Postoperative Care"[Mesh] OR "Neurosurgical management" OR "Neurosurgical Intervention" OR "Neurosurgical care" OR "Surgical Management" OR "Awake craniotomy"

OR "Perioperative Nursing"[Mesh] OR "Operating Room Nursing"[Mesh] OR "Postanesthesia Nursing"[Mesh] OR "Post Surgical Nursing" OR "Recovery Room Nursing"

OR "Capacity Building"[Mesh] OR "Health Resources"[Mesh] OR "Health Care Facilities, Manpower, and Services"[Mesh] OR "Workforce"[Mesh] OR "Health Workforce"[Mesh]OR "Personnel, Hospital"[Mesh] OR "Health Personnel"[Mesh] OR "Personnel, Hospital"[Mesh] OR "Health Personnel"[Mesh] OR "Operating Room Technicians"[Mesh] OR "Operating Room Information Systems"[Mesh] OR "Operating Tables"[Mesh])

Concept# 02: (Brain Tumors). "Brain Neoplasms"[Mesh] OR "Central Nervous System Neoplasms"[Mesh] OR "Brain tumor*" OR "brain cancer*" OR "CNS tumor*" OR "Nervous system tumor*" OR "Neuro-Oncology" OR "Intracranial neoplasm*" OR "Primary brain tumor*" OR "Skull Base Neoplasms"[Mesh] OR "Meningioma"[Mesh] OR "Glioma"[Mesh] OR "Chordoma"[Mesh] OR "Craniopharyngioma"[Mesh] OR "Glomus Jugulare"[Mesh] OR "Glomus Jugulare Tumor"[Mesh] OR "Pinealoma"[Mesh] OR "Pituitary Neoplasms"[Mesh] OR "Prolactinoma"[Mesh] OR "Neuroma, Acoustic"[Mesh] OR "Astrocytoma"[Mesh] OR "Glioma, Subependymal"[Mesh] OR "Oligodendroglioma"[Mesh] OR "Glioblastoma"[Mesh] OR "Ependymoma"[Mesh] OR "Medulloblastoma"[Mesh] OR "Cerebellar Neoplasms"[Mesh] OR "Infratentorial Neoplasms"[Mesh] OR "Supratentorial Neoplasms"[Mesh] OR "Brain Stem Neoplasms"[Mesh] OR "Diffuse Intrinsic Pontine Glioma"[Mesh] OR "Pituitary Neoplasms"[Mesh] OR "Schwannomas" OR "Pediatric brain tumor*" OR "Adult brain tumor*"

Concept# 03: (LMICs). ("Developing Countries"[MeSh] OR "Low-and Middle-income countries" OR LMIC OR "afghanistan"[MeSH] OR "guinea-bissau"[MeSH] OR "somalia"[MeSH] OR "burkina faso"[MeSH] OR "korea"[MeSH] OR "south sudan"[MeSH] OR "burundi"[MeSH] OR "liberia"[MeSH] OR "sudan"[MeSH] OR "central african republic"[MeSH] OR "madagascar"[MeSH] OR "syria"[MeSH] OR "chad"[MeSH] OR "malawi"[MeSH] OR "togo"[MeSH] OR "congo"[MeSH] OR "mali"[MeSH] OR "uganda"[MeSH] OR "eritrea"[MeSH] OR "mozambique"[MeSH] OR "yemen"[MeSH] OR "ethiopia"[MeSH] OR "niger"[MeSH] OR "gambia"[MeSH] OR "rwanda"[MeSH] OR "guinea"[MeSH] OR "sierra leone"[MeSH] OR "angola"[MeSH] OR "honduras"[MeSH] OR "algeria"[MeSH] OR "india"[MeSH] OR "samoa"[MeSH] OR "bangladesh"[MeSH] OR "indonesia"[MeSH] OR "sao tome and principe"[MeSH] OR "belize"[MeSH] OR "iran"[MeSH] OR "senegal"[MeSH] OR "benin"[MeSH] OR "kenya"[MeSH] OR "bhutan"[MeSH] OR "sri lanka"[MeSH] OR "bolivia"[MeSH] OR "kyrgyzstan"[MeSH] OR "tanzania"[MeSH] OR "cabo verde"[MeSH] OR "tajikistan"[MeSH] OR "cambodia"[MeSH] OR "lesotho"[MeSH] OR "timor-leste"[MeSH] OR "cameroon"[MeSH] OR "mauritania"[MeSH] OR "tunisia"[MeSH] OR "comoros"[MeSH] OR "micronesia"[MeSH] OR "ukraine"[MeSH] OR "congo"[MeSH] OR "mongolia"[MeSH] OR "uzbekistan"[MeSH] OR "cote d'ivoire"[MeSH] OR "morocco"[MeSH] OR "vanuatu"[MeSH] OR "djibouti"[MeSH] OR "myanmar"[MeSH] OR "vietnam"[MeSH] OR "egypt"[MeSH] OR "nepal"[MeSH] OR "el salvador"[MeSH] OR "nicaragua"[MeSH] OR "zambia"[MeSH] OR "eswatini"[MeSH] OR "nigeria"[MeSH] OR "zimbabwe"[MeSH] OR "ghana"[MeSH] OR "pakistan"[MeSH] OR "haiti"[MeSH] OR "Papua new guinea"[MeSH] OR "Africa"[MeSh] OR "Africa, Eastern"[MeSh] OR "Africa, Central"[MeSh] OR "Africa South of the Sahara"[MeSh] OR "Asia, Southeastern"[MeSh])

PubMed: (No of articles retrieved, 364). (("Neurosurgery"[Mesh] OR "Neurosurgical Procedures"[Mesh] OR "Craniotomy"[Mesh] OR "Radiosurgery"[Mesh] OR "Perioperative Care"[Mesh] OR "Preoperative Care"[Mesh] OR "Intraoperative Care"[Mesh] OR "Postoperative Care"[Mesh] OR "Neurosurgical management" OR "Neurosurgical Intervention" OR "Neurosurgical care" OR "Surgical Management" OR "Perioperative Nursing"[Mesh] OR "Operating Room Nursing"[Mesh] OR "Postanesthesia Nursing"[Mesh] OR "Post Surgical Nursing" OR "Recovery Room Nursing" OR "Capacity Building"[Mesh] OR "Health Resources"[Mesh] OR "Health Care Facilities, Manpower, and Services"[Mesh] OR "Workforce"[Mesh] OR "Health Workforce"[Mesh]OR "Personnel, Hospital"[Mesh] OR "Health Personnel"[Mesh] OR "Personnel, Hospital"[Mesh] OR "Health Personnel"[Mesh] OR "Operating Room Technicians"[Mesh] OR "Operating Room Information Systems"[Mesh] OR "Operating Tables"[Mesh]) AND ("Brain Neoplasms"[Mesh] OR "Central Nervous System Neoplasms"[Mesh] OR "Brain tumor*" OR "brain cancer*" OR "CNS tumor*" OR "Nervous system tumor*" OR "Neuro-Oncology" OR "Intracranial neoplasm*" OR "Primary brain tumor*" OR "Skull Base Neoplasms"[Mesh] OR "Meningioma"[Mesh] OR "Glioma"[Mesh] OR "Chordoma"[Mesh] OR "Craniopharyngioma"[Mesh] OR "Glomus Jugulare"[Mesh] OR "Glomus Jugulare Tumor"[Mesh] OR "Pinealoma"[Mesh] OR "Pituitary Neoplasms"[Mesh] OR "Prolactinoma"[Mesh] OR "Neuroma, Acoustic"[Mesh] OR "Astrocytoma"[Mesh] OR "Glioma, Subependymal"[Mesh] OR "Oligodendroglioma"[Mesh] OR "Glioblastoma"[Mesh] OR "Ependymoma"[Mesh] OR "Medulloblastoma"[Mesh] OR "Cerebellar Neoplasms"[Mesh] OR "Infratentorial Neoplasms"[Mesh] OR "Supratentorial Neoplasms"[Mesh] OR "Brain Stem Neoplasms"[Mesh] OR "Diffuse Intrinsic Pontine Glioma"[Mesh] OR "Pituitary Neoplasms"[Mesh] OR "Schwannomas" OR "Pediatric brain tumor*" OR "Adult brain tumor*") AND ("Developing Countries"[MeSh] OR "Low-and Middle-income countries" OR LMIC OR "afghanistan"[MeSH] OR "guinea-bissau"[MeSH] OR "somalia"[MeSH] OR

"burkina faso"[MeSH] OR "korea"[MeSH] OR "south sudan"[MeSH] OR "burundi"[MeSH] OR "liberia"[MeSH] OR "sudan"[MeSH] OR "central african republic"[MeSH] OR "madagascar"[MeSH] OR "syria"[MeSH] OR "chad"[MeSH] OR "malawi"[MeSH] OR "togo"[MeSH] OR "congo"[MeSH] OR "mali"[MeSH] OR "uganda"[MeSH] OR "eritrea"[MeSH] OR "mozambique"[MeSH] OR "yemen"[MeSH] OR "ethiopia"[MeSH] OR "niger"[MeSH] OR "gambia"[MeSH] OR "rwanda"[MeSH] OR "guinea"[MeSH] OR "sierra leone"[MeSH] OR "angola"[MeSH] OR "honduras"[MeSH] OR "algeria"[MeSH] OR "india"[MeSH] OR "samoa"[MeSH] OR "bangladesh"[MeSH] OR "indonesia"[MeSH] OR "sao tome and principe"[MeSH] OR "belize"[MeSH] OR "iran"[MeSH] OR "senegal"[MeSH] OR "benin"[MeSH] OR "kenya"[MeSH] OR "bhutan"[MeSH] OR "sri lanka"[MeSH] OR "bolivia"[MeSH] OR "kyrgyzstan"[MeSH] OR "tanzania"[MeSH] OR "cabo verde"[MeSH] OR "tajikistan"[MeSH] OR "cambodia"[MeSH] OR "lesotho"[MeSH] OR "timor-leste"[MeSH] OR "cameroon"[MeSH] OR "mauritania"[MeSH] OR "tunisia"[MeSH] OR "comoros"[MeSH] OR "micronesia"[MeSH] OR "ukraine"[MeSH] OR "congo"[MeSH] OR "mongolia"[MeSH] OR "uzbekistan"[MeSH] OR "cote d'ivoire"[MeSH] OR "morocco"[MeSH] OR "vanuatu"[MeSH] OR "djibouti"[MeSH] OR "myanmar"[MeSH] OR "vietnam"[MeSH] OR "egypt"[MeSH] OR "nepal"[MeSH] OR "el salvador"[MeSH] OR "nicaragua"[MeSH] OR "zambia"[MeSH] OR "eswatini"[MeSH] OR "nigeria"[MeSH] OR "zimbabwe"[MeSH] OR "ghana"[MeSH] OR "pakistan"[MeSH] OR "haiti"[MeSH] OR "Papua new guinea"[MeSH] OR "Africa"[MeSh] OR "Africa, Eastern"[MeSh] OR "Africa, Central"[MeSh] OR "Africa South of the Sahara"[MeSh] OR "Asia, Southeastern"[MeSh]))

Scopus: (Number of articles retrieved, 600). (Neurosurgery OR "Neurosurgical Procedures" OR Craniotomy OR Radiosurgery OR "Perioperative Care" OR "Preoperative Care" OR "Intraoperative Care" OR "Postoperative Care" OR "Neurosurgical management" OR "Neurosurgical Intervention" OR "Neurosurgical care" OR "Surgical Management" OR "Awake craniotomy" OR "Perioperative Nursing" OR "Operating Room Nursing" OR "Postanesthesia Nursing" OR "Post Surgical Nursing" OR "Recovery Room Nursing" OR "Capacity Building" OR "Health Resources" OR "Health Care Facilities, Manpower, and Services" OR "Workforce" OR "Health Workforce" OR "Personnel, Hospital" OR "Health Personnel" OR "Personnel, Hospital" OR "Health Personnel" OR "Operating Room Technicians" OR "Operating Room Information Systems" OR "Operating Tables")

AND

("Brain Neoplasms" OR "Central Nervous System Neoplasms" OR "Brain tumor" OR "brain cancer" OR "CNS tumor" OR "Nervous system tumor" OR "Neuro-Oncology" OR "Intracranial neoplasm" OR "Primary brain tumor" OR "Skull Base Neoplasms" OR Meningioma OR Glioma OR Chordoma OR Craniopharyngioma OR "Glomus Jugulare" OR "Glomus Jugulare Tumor" OR Pinealoma OR "Pituitary Neoplasms" OR Prolactinoma OR "Neuroma, Acoustic" OR Astrocytoma OR "Glioma, Subependymal" OR Oligodendroglioma OR Glioblastoma OR Ependymoma OR Medulloblastoma OR "Cerebellar Neoplasms" OR "Infratentorial Neoplasms" OR "Supratentorial Neoplasms" OR "Brain Stem Neoplasms" OR "Diffuse Intrinsic Pontine Glioma" OR "Pituitary Neoplasms" OR Schwannomas OR "Pediatric brain tumor" OR "Adult brain tumor")

AND

("Developing Countries" OR "Low-and Middle-income countries" OR LMIC OR Afghanistan OR "guinea-bissau" OR somalia OR "burkina faso" OR korea OR "south sudan" OR burundi OR liberia OR sudan OR "central african republic" OR Madagascar OR syria OR chad OR malawi OR togo OR congo OR mali OR Uganda OR eritrea OR Mozambique OR yemen OR ethiopia OR niger OR gambia OR rwanda OR guinea OR "sierra leone" OR angola OR Honduras OR algeria OR india OR samoa OR Bangladesh OR indonesia OR "sao tome and principe" OR belize OR iran OR Senegal OR benin OR kenya OR bhutan OR srilanka OR bolivia OR Kyrgyzstan OR tanzania OR "cabo verde" OR Tajikistan OR Cambodia OR Lesotho OR "timor-leste" OR Cameroon OR mauritania OR tunisia OR comoros OR Micronesia OR ukraine OR congo OR Mongolia OR uzbekistan OR "cote d'ivoire" OR morocco OR vanuatu OR djibouti OR myanmar OR vietnam OR egypt OR nepal OR "el salvador" OR Nicaragua OR zambia OR eswatini OR Nigeria OR zimbabwe OR ghana OR pakistan OR haiti OR "Papua new guinea" OR Africa OR "Africa, Eastern" OR "Africa, Central" OR "Africa South of the Sahara" OR "Asia, Southeastern")

CINHAL: (Number of articles retrieved, 1014). ((MH "Perioperative Nursing") OR (MH "Perianesthesia Nursing") OR (MH "Waiting Rooms") OR (MH "Patients' Rooms+") OR (MH "Post Anesthesia Care Units") OR (MH "Operating Room Personnel+") OR (MH "Operating Room Information Systems") OR (MH "Recovery+") OR (MH "Anesthesia Recovery") OR (MH "Operating Room Traffic Patterns") OR (MH "Practical Nurses") OR (MH "Surgery Schedule+") OR (MH "Surgical Technologists") OR (MH "Operating Rooms") OR (MH "Alternative Health Facilities") OR (MH "Surgery, Operative+") OR (MH "Operating Rooms") OR (MH "Operating Systems") OR (MH "Systems Analysis+") OR (MH "Surgery Outside the OR") OR (MH "Management Information Systems+"))

AND

((MH "Neurosurgery+") OR (MH "Brain Neoplasms+") OR (MH "Neuroectodermal Tumors, Primitive+") OR (MH "Diffuse Intrinsic Pontine Glioma") OR (MH "Nerve Sheath Tumors+") OR (MH "Infratentorial Neoplasms+") OR (MH "Neoplasms, Nerve Tissue+") OR (MH "Hypothalamic Neoplasms+"))

AND

((MH "Developing Countries") OR (MH "Low and Middle Income Countries") OR (MH "Madagascar") OR (MH "Asia, Central+") OR (MH "Asia, Southeastern+") OR (MH "Asia, Western+") OR (MH "Nepal") OR (MH "Pakistan") OR (MH "Sri Lanka") OR (MH "Afghanistan") OR (MH "Iran") OR (MH "Iraq") OR (MH "Lebanon") OR (MH "Syria") OR (MH "Jordan") OR (MH "Turkey") OR (MH

"China+") OR (MH "North Korea") OR (MH "Mongolia") OR (MH "Armenia") OR (MH "Azerbaijan") OR (MH "Albania") OR (MH "Bosnia-Herzegovina") OR (MH "Bulgaria") OR (MH "Belarus") OR (MH "Macedonia (Republic)") OR (MH "Moldova") OR (MH "Romania") OR (MH "Russia") OR (MH "Serbia") OR (MH "Ukraine") OR (MH "Georgia (Republic)") OR (MH "Kazakhstan") OR (MH "Kyrgyzstan") OR (MH "Turkmenistan") OR (MH "Uzbekistan") OR (MH "Commonwealth of Independent States+") OR (MH "Egypt") OR (MH "Libya") OR (MH "Yemen") OR (MH "New Guinea") OR (MH "Tajikistan") OR (MH "Papua New Guinea") OR (MH "Samoa+") OR (MH "Independent State of Samoa") OR (MH "American Samoa") OR (MH "Algeria") OR (MH "Morocco") OR (MH "Tunisia") OR (MH "Africa, Central+") OR (MH "Africa, Eastern+") OR (MH "Africa, Southern+") OR (MH "Africa, Western+") OR (MH "India") OR (MH "Bhutan") OR (MH "Bangladesh") OR (MH "Africa+") OR (MH "Africa, Northern+") OR (MH "Africa South of the Sahara+") OR (MH "Belize") OR (MH "Costa Rica") OR (MH "Guatemala") OR (MH "El Salvador") OR (MH "Nicaragua") OR (MH "Honduras") OR (MH "Central America+") OR (MH "Latin America") OR (MH "Mexico") OR (MH "Bolivia") OR (MH "Brazil") OR (MH "Colombia") OR (MH "Ecuador") OR (MH "French Guiana") OR (MH "Guyana") OR (MH "Peru") OR (MH "Suriname") OR (MH "Venezuela") OR (MH "Cuba") OR (MH "Dominica") OR (MH "Dominican Republic") OR (MH "Haiti") OR (MH "Jamaica") OR (MH "Martinique") OR (MH "Netherlands Antilles") OR (MH "Tibet"))

Google Scholar: (Using Publish or Perish, Restricted to 500 articles and Years = 2000–2022)

Neurosurgery|"**Neurosurgical** Procedures"|Radiosurgery "Brain Neoplasms"|"CentralNervous System Neoplasms"|"Brain tumor"|"Primary brain tumor"|"Pediatric brain tumor"|"Adult brain tumor" "Developing Countries"|"Low-and Middle-income countries"

Google Scholar: (Using Publish or Perish, Restricted to 500 articles and Years=2000–2022)

Perioperative|Preoperative|Intraoperative|Postoperative "Brain Neoplasms"|"CentralNervous System Neoplasms"|"Brain tumor"|"Primary brain tumor"|"Pediatric brain tumor"|"Adult brain tumor" "Developing Countries"|"Low-and Middle-income countries"

Google Scholar: (Using Publish or Perish, Restricted to 500 articles and Years = 2000–2022)

"Capacity Building"|"Health Resources"|"Services"|Workforce "Brain Neoplasms"|"CentralNervous System Neoplasms"|"Brain tumor"|"Primary brain tumor"|"Pediatric brain tumor"|"Adult brain tumor" "Developing Countries"|"Low-and Middle-income countries"

OR "Personnel, Hospital" OR "Health Personnel" OR "Personnel, Hospital" OR "Health Personnel" OR "Operating Room Technicians" OR "Operating Room Information Systems" OR "Operating Tables"