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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

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Key words
- LMIC
- Low- and middle-income country
- Neuro-oncology
- Practice patterns
- Surgical neuro-oncology

Abbreviations and Acronyms
COVID-19: Coronavirus disease 2019
FTF: Face-to-face
HIC: High-income country
HRCT: High-resolution computed tomography
ICU: Intensive care unit
LMIC: Low- and middle-income country
OR: Operating room
PAPR: Powered air-purifying system
PPE: Personal protective equipment
RT: Radiotherapy
RT-PCR: Reverse transcriptase polymerase chain reaction

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BACKGROUND: **The coronavirus disease 2019 (COVID-19) pandemic has negatively affected the outcomes of surgical neuro-oncology patients worldwide. We aimed to review the practice patterns in surgical neuro-oncology in low- and middle-income countries (LMICs). We also present a situational report from our own country.**

METHODS: **A scoping review was performed following the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews) guidelines.**

RESULTS: **Twelve studies were included in the review. Most of the studies were from Asia (India, China, Iran, and Turkey), and 1 was from Brazil. Quantitative reports showed a decrease in the number of surgical neuro-oncology operations between pre-COVID-19 and post-COVID-19 time frames, but similar proportions of neuro-oncology procedures. Qualitative review showed similar practice patterns between LMICs and high-income countries, except for limitations in resources such as negative-pressure operating rooms and intensive care units, and maintenance of face-to-face consults despite the adoption of telemedicine. Limited data on adjuvant therapy were available in LMICs.**

CONCLUSIONS: **In our review, we found that the practice patterns in surgical neuro-oncology in LMICs during the COVID-19 pandemic are similar to those in high-income countries, except for a few modifications because of resource limitation and patient preferences.**

INTRODUCTION

The coronavirus disease 2019 (COVID-19) pandemic has resulted in a significant decrease in the number of neurosurgical procedures performed globally.[1] This decrease has negatively affected the outcomes of patients, and none more so than in neuro-oncology.[2] These patients have tumors that increase in size and cause mass effect if there are delays in neurosurgical management and adjuvant therapy.[3] Thus, there is a need to determine adequate precautions for operating on these patients and giving timely adjuvant therapy despite the pandemic.

As the global experience with COVID-19 increases, some centers have resumed their neuro-oncology services and proposed multiple guidelines.[4,5] These institutions and guidelines are usually from high-income countries (HICs) where COVID-19 has been controlled.[6-11] In low- and middle-income countries (LMICs), there has been difficulty controlling COVID-19 because of lack of resources and fragile health care infrastructure.[12] Reallocation of resources to COVID-19 efforts in these countries has also hindered the resumption of neurosurgery and neuro-oncology services.[13] For example, operating rooms (ORs) in LMICs have been converted to intensive care units (ICUs) to accommodate patients with severe COVID-19, decreasing operative capacity.[14] Conversion of tertiary hospitals capable of neurosurgical procedures into COVID-19 centers has also adversely affected neurosurgical care in LMICs.[13-15] All these factors have resulted in delays in patient care and poorer neuro-oncologic outcomes.[2]

Some neuro-oncology societies in LMICs have also published recommendations and guidelines in dealing with neuro-oncology patients, but these have been based on evidence and other guidelines from HICs.[16] Given the differences in COVID-19 situations and responses between HICs and LMICs, there may be differences in neuro-oncology practice patterns as well as guideline applicability. To investigate this theory, we reviewed the surgical neuro-oncology practice patterns among LMICs during the pandemic. We

also report on our institutional situation and surgical neuro-oncology practice in the Philippines.

METHODS

We performed a scoping review in accordance with the PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) guidelines.[17]

Criteria for Choosing Studies in the Review

We included studies that described the practice of surgical neuro-oncology in LMICs during the COVID-19 pandemic. The relevant study types were case series, cross-sectional, retrospective, and prospective cohort studies. We also included case reports, letters to the editor, and opinion articles, because there were more of these article types detailing specific strategies to guide practice, especially during the early part of the pandemic. The study populations were exclusively from LMICs or included LMICs in their sample.

Search Methods for Identification of Included Studies

We performed a systematic search of the major scientific databases including PubMed, Scopus, CENTRAL by Cochrane, EBSCOHOST, and Clinicaltrials.gov from December 2019 to September 2021. Gray literature was also searched. The search terms used were ["neuro-oncology" or "neurooncology" or "surgical neuro-oncology" or "brain tumor" or "brain cancer" or "central nervous system cancer"] AND ["COVID-19" or "coronavirus disease 2019" or "pandemic"] AND [low- and middle-income country" or "LMIC" or "lower middle income country"]. Individual articles were also hand searched by reviewing the references of identified relevant studies. The available Web sites of neurosurgical and neuro-oncologic societies from LMICs were also searched for relevant articles. Please see **Supplementary Tables 1–5** for the full search strategy.

Two investigators (J.S.G.P. and K.H.D.I.) independently searched the databases using the search strategy. After removal of duplicates, the titles and abstracts of the remaining articles were then assessed using predetermined eligibility criteria. After screening of the titles and abstracts, the full text of the remaining articles that met the criteria were evaluated. Disagreements were settled by a third author (M.R.L.C.), and all activity was supervised by the senior author (K.J.O.K.). Eligible studies that remained after this screening were included in the final review and analysis.

Data Collection and Analysis

Extracted data from the studies included author, country, and year published; study type; effect on surgical neuro-oncology cases; preoperative, intraoperative, and postoperative considerations; and outpatient and adjuvant treatment practices. These data were consolidated in a summary table (**Table 1**). An expanded summary of the included studies can be found in **Supplementary Table 6**.

RESULTS

Included Studies

We identified 125 studies from the electronic database search. We assessed the titles and abstracts of these studies and excluded 77 articles based on predetermined qualification criteria. After the full text of 48 articles was subjected to eligibility criteria, 12 articles were included in the qualitative analysis (**Figure 1**).

Included studies were from India ($n = 6$),[21-26] China ($n = 2$),[19,20] Brazil ($n = 1$),[18] Iran ($n = 1$),[27] Turkey ($n = 1$),[28] and multiple Asian countries (most from China).[29] Study types were case-control ($n = 6$),[20-22,25-27] expert opinion and review ($n = 3$),[18,23,28] cross-sectional survey ($n = 1$),[29] retrospective cohort ($n = 1$),[24] and letter to the editor with case report ($n = 1$).[19]

Impact of COVID-19 on Surgical Neuro-Oncology in LMICs

Most of the studies reported a decrease in the number of neuro-oncology cases that were seen during the pandemic (9/12 studies, 75%). Of these studies, 66.7% (6/9) reported decreases in caseloads ranging from 11.2% to 79.3%.[20-22,24,25,27] Of the 6 studies, 5 (83.3%) reported on the proportion of surgical neuro-oncologic compared with other types of cases. The proportions remained similar, ranging from 16.1% to 44% before the pandemic and 17.1% to 51.2% during the pandemic. Only 1 study from China reported on the tumor characteristics comparing prepandemic and postpandemic time frames, wherein larger tumors (mean, 8.7 vs. 4.6 cm^3) with greater midline shift (2 vs. 0 cm) were observed during the pandemic.[20]

Preoperative Considerations

All studies used a triaging system to classify patients requiring surgery according to urgency.[18-29] In general, emergent or urgent surgical treatment was recommended for patients with brain tumors with significant size and mass effect, malignant tumors, or those in herniation. Patients with benign asymptomatic tumors were deemed non- elective and had the least priority. Patients between these 2 categories were deemed semiurgent.[24,26,27]

All studies recommended COVID-19 screening with reverse transcriptase polymerase chain reaction (RT-PCR) for all patients undergoing surgical neuro-oncology procedures.[18-29] Two studies required a pulmonary high-resolution computed tomography (HRCT) scan in addition to the RT-PCR test.[18,27] One study recommended the use of a COVID-19 rapid antigen test in patients who needed acute and emergent treatment while waiting for the RT-PCR.[24]

The personal protective equipment (PPE) classification uniformly used was in accordance with World Health Organization recommendations.[30] Level I PPE consisted of disposable surgical cap, surgical mask, latex gloves, and isolation clothing. Level II PPE was level I PPE that used an N95 mask instead of a surgical mask and the addition of goggles. Level III PPE was level II PPE with the addition of a full facial covering (face shield) instead of goggles, with or without the use of a powered air-purifying respirator (PAPR). All studies were consistent in using level I PPE for COVID-19–negative patients and level III PPE for COVID-19–positive patients.[18-29]

Intraoperative Considerations

Most (11/12, 91.7%) of the studies reported a decrease in OR availability during the pandemic,[19-29] for the following reasons: ORs being used as ICUs, ORs being used as donning/doffing areas,[25] or decreasing OR capacity to increase personnel availability for patients with COVID-19.[29] Eight studies[21-28] (66.7%) reported

Table 1. Summary Table of Surgical Neuro-Oncology Practice Patterns Among Low- and Middle-Income Countries

	Brazil	China	India	Iran	Turkey	Multiple
Number of studies	1	2	6	1	1	1
Studies included (reference)	Batistella et al., 2021[18]	Hu et al., 2020[19], Zou et al., 2021[20]	Goyal et al., 2020[21], Sahoo et al., 2020[22], Gupta et al., 2020[23], Deora et al., 2021[24], Sharma et al., 2021[25], Sudhan et al., 2021[26]	Tavanaei et al., 2021[27]	Ozoner et al., 2020[28]	Hameed et al., 2021[29]
Study types	Expert review and opinion	Letter to the editor with case report; case-control	Expert review and opinion; case-control (n = 4); retrospective cohort	Case-control	Expert review and opinion	Cross-sectional survey
Reduction in surgical neuro-oncology cases (%)	NR	Yes (NR)	Yes (11.2—79.3)	Yes (46.9)	Yes (NR)	Yes (25—50)
Proportion of surgical neuro-oncology cases (before vs. after pandemic) (%)	NR	NR	22.2—44 versus 22.6—51.2	16.1 versus 17.1	NR	NR
Preoperative considerations						
Patient triage system	Yes	Yes	Yes	Yes	Yes	Yes
Patient screening (type)	Yes (RT-PCR and chest HRCT)	Yes (RT-PCR)	Yes (RT-PCR; 1 study used rapid antigen test)	Yes (RT-PCR and chest HRCT)	Yes (RT-PCR)	Yes (at least RT-PCR)
Intraoperative considerations						
Decrease in OR availability	NR	Yes	Yes	Yes	Yes	Yes
Negative-pressure OR availability	NR	Yes	Yes in only 1 study	Yes	NR	NR
Minimize OR personnel	NR	NR	Yes	Yes	Yes	NR
PPE considerations (level)						
COVID-19—negative	I	I	I	I	I	I
COVID-19—positive	III	III	III; some advocate for PAPR	III; PAPR mandatory	III	III
Anesthetic considerations						
Only anesthesia team inside room during intubation/extubation	NR	NR	Yes	Yes	Yes	NR
Use of video laryngoscope	NR	NR	Yes	NR	Yes	NR
Use of plexiglass box	NR	NR	Yes	NR	No	NR
Surgical procedural considerations						

NR, not reported; RT-PCR, reverse transcriptase polymerase chain reaction; HRCT, high-resolution computed tomography; PAPR, powered air-purifying respirator; OR, operating room; PPE, personal protective equipment; ICU, intensive care unit; RT, radiotherapy.

Continues

Table 1. Continued

	Brazil	China	India	Iran	Turkey	Multiple
Use of endonasal approaches	NR	NR	Avoid	Avoid	Avoid	NR
Use of special patient draping	None	None	Yes in 1 study; no in remainder	None	None	NR
Avoidance of sinuses in craniotomy	NR	NR	Yes	Yes	NR	NR
Avoidance of excessive drilling	NR	NR	Yes	Yes	Yes	NR
Use of special suction for cautery smoke	NR	NR	NR	Yes	Yes	NR
Use of awake craniotomy	Avoided	Avoided	Yes in 1 study; avoid in remainder	NR	NR	NR
Use of intraoperative adjuncts	NR	Limited use (lack of supplies)	Avoid intraoperative magnetic resonance imaging	NR	NR	NR
Postoperative considerations						
Decrease in ICU availability	NR	NR	Yes	Yes	NR	Yes
Negative-pressure ICU availability	NR	NR	No	Yes	NR	NR
Postoperative patient testing	NR	NR	NR	No	NR	NR
Need for patient quarantine postoperatively	Yes (2 weeks)	NR	No	No	NR	NR
Routine postoperative personnel testing	No	NR	Yes in 1 study; no in remainder	No	NR	NR
Outpatient considerations and adjuvant therapy						
Telemedicine use	Yes	Yes	Yes	NR	NR	Yes
Face-to-face consults	No	Yes (in PPE)	Yes (in PPE) in 1	NR	Yes	Yes
Minimize outpatient department personnel	NR	Yes	Yes	NR	Yes	Yes
Radiotherapy considerations						
COVID-19 screening for RT	Yes	NR	Yes	NR	NR	Yes
Continue usual RT protocols	No	No (discontinued)	Yes if malignant and young	NR	NR	NR
Hypofractionated RT use	Yes	NR	Yes	NR	NR	NR

Chemotherapy considerations						
Continue in-hospital chemotherapy	Yes	NR	Yes	NR	Yes	NR
Consider outpatient chemotherapy only	No	NR	Yes	NR	Yes	NR
Continue usual chemotherapy protocols	Yes	No (discontinued)	Yes if malignant and young	NR	Yes	NR
Consider less toxic protocols	Yes	NR	Yes	NR	Yes	NR

NR, not reported; RT-PCR, reverse transcriptase polymerase chain reaction; HRCT, high-resolution computed tomography; PAPR, powered air-purifying respirator; OR, operating room; PPE, personal protective equipment; ICU, intensive care unit; RT, radiotherapy.

decreasing OR personnel both to reduce their exposure and to reallocate them to other areas. Only 3 studies reported the availability of a negative-pressure OR for COVID-19–positive patients.[19,24,27]

Anesthetic considerations included having only the anesthesia team inside the OR during intubation and extubation,[22,24,27,28] using a video laryngoscope,[22,24,28] and the use of a plexiglass box during these procedures.[24,26]

For surgical considerations, it was generally recommended to avoid endonasal approaches.[22-25,27,28] One study reported using a special tenting drape for patients during surgery,[26] and advocated the use of awake craniotomy to avoid aerosolization from intubation.[26] In contrast, other studies recommended limiting the use of awake craniotomy because having the patient awake and talking increases aerosolization risk; furthermore, the technique necessitates having the assessor close to the patient.[18-23] Precautions regarding cranium drilling were also suggested, such as avoiding the paranasal sinuses when plotting craniotomies[22,24,27] and limiting excessive drilling procedures.[22,24,27,28] Two articles[27,28] reported the use of special suction devices for cautery smoke during surgery. Only 2 studies[26] reported on the use of intraoperative adjuncts: one recommended avoiding intraoperative magnetic resonance imaging use, whereas another reported that a lack of supplies during the pandemic limited the use of adjuncts that required consumables (e.g., Yellow 560 for fluorescence-guided surgery).[19]

Postoperative Considerations

A decrease in ICU availability was reported in 6 studies,[22,24-27,29] and only 1 study[27] reported the availability of a negative-pressure ICU (for both COVID-19–positive and COVID-19–negative patients). Routine screening of postoperative elective patients for COVID-19 was not reported, although postoperative elective COVID-19–negative patients had to undergo a 2-week home quarantine in Brazil.[18] Routine postoperative COVID-19 testing was performed for OR personnel in 1 study from India.[25]

Outpatient and Adjuvant Therapy Considerations

Most studies (10/12, 83.3%) reported a shift to telemedicine outpatient consults during the pandemic.[18-26,29] This strategy meant an online video consult,[18-24,26] a purely telephone consult,[25,29] or a combination of both. Face-to-face (FTF) consults were maintained in 4 studies,[20,24,28,29] with 2 studies[20,24] reporting that it was conducted in full PPE. The number of outpatient personnel was minimized in all studies reporting FTF consults. RT-PCR screening was not required for FTF consults, but all patients were screened using a symptom checklist questionnaire.[20,24,28,29] The reasons why FTF consultation was preferred included patient preference and local culture, as well as the lack of patient resources for teleconsults.[24]

Four studies reported continuing radiotherapy (RT) for neuro-oncology cases during the pandemic, but in a decreased capacity.[18,24,25,29] All also required COVID-19 screening before RT. Two studies[18,23] recommended the use of hypofractionated RT to reduce hospital visits, and 1 study[23] suggested continuing all standard RT protocols for young patients with malignancies. RT and chemotherapy services were reported to be discontinued in 1 study.[20]

Three studies[18,23,29] recommended the continuation of in-hospital chemotherapy during the pandemic. The use of less toxic protocols (e.g., temozolomide over procarbazine-lomustin-vincristine for high-grade glioma) was advocated in 2 studies,[18,23] and 1 study[29] described the use of home-based chemotherapy regimens. The continuation of standard chemotherapy protocols was recommended by 2 studies,[18,23] particularly for young patients with malignant tumors.

DISCUSSION

Multiple neuro-oncology guidelines from high-volume centers in HICs have recommended the following: symptom-based and disease-based patient triaging; patient segregation based on COVID-19 status; PPE based on World Health Organization recommendations with emphasis on PAPR for level III; limiting aerosolizing procedures in the OR; use of negative-pressure ORs for COVID-19–

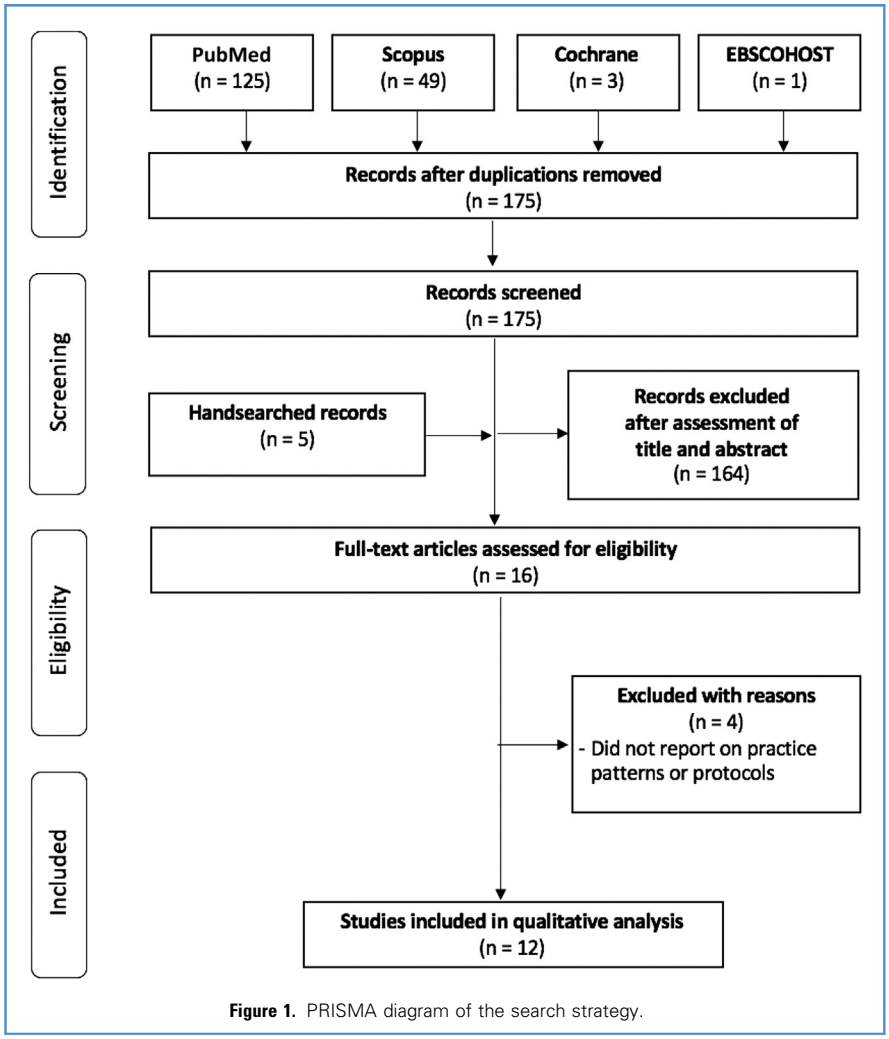

Figure 1. PRISMA diagram of the search strategy.

positive patients; use of negative-pressure ICUs for postoperative patients (in case these patients develop COVID-19 infection); immediate postoperative step-down areas; the use of telemedicine for outpatient consults; the use of hypofractionated RT; and the use of less toxic chemotherapy protocols in managing neuro-oncology patients.[1,2,6-11,31-34] Our review has shown that the experience and practice patterns reported in LMICs were generally similar to these recommendations but had some differences attributed to resource availability and patient preferences.

Triage for Surgical Neuro-Oncology Patients in LMICs

During the COVID-19 pandemic, patient triaging has emerged as a key strategy in managing limited resources. There has generally been a consensus regarding which neuro-oncology patients were emergent and which were nonurgent, but there is a gray area of urgent/semiurgent classification that may have different interpretations. This point was shown in some of the articles we reviewed. For example, the case of a patient with an 8-cm frontal meningioma causing a 0.5-cm midline shift with a mild motor deficit may be classified as semiurgent in 1 study[24] and emergent in another.[26]

Another aspect of triaging is determining the allowable delay in surgery for each patient and establishing the definitions of the common terms used to denote the urgency of the situation. It was generally agreed that emergent patients were those who were immediately admitted and required surgical intervention within 24–48 hours, whereas the timing and allowable delays for urgent, semiurgent, and nonurgent patients were less clear.[24,26,28] Triaging systems from HICs were also not unified on the matter, with reports of allowable delays in nonemergency cases ranging from 1 week to 1 month, to postponement of the surgery.[35-37] During prepandemic times, the acceptable delay to surgery for patients with brain tumor in LMICs was considered to range from 0 to 14 days.[38]

Preoperative Patient Screening and OR Considerations from LMICs

In our review, all the studies recommended RT-PCR screening for surgical neuro-oncology patients before surgery. RT-PCR has a reported sensitivity of 90.3%–99.7%, a short turnaround time, and a relatively low cost.[39] Chest HRCT, which has a high sensitivity of 89.8%–93.7%, was also used as an additional screening tool for COVID-19 in 2 studies.[18,27,40] Because chest HRCT is more expensive than an RT-PCR test, it was not surprising that the studies that recommended HRCT screening came from Brazil and Iran, which are upper-middle-income and lower-middle-income countries, respectively.[41]

Regarding ORs, the economic disparity was apparent in that only 3 centers reported having a negative-pressure OR.[19,24,27] In lieu of this facility, some investigators have reported the use of multiple directed air-conditioning systems to channel the airflow away from the OR that was in use.[26] Unlike HICs, the emphasis was placed on PPE and PAPR use rather than on the OR setup when operating on COVID-19–positive patients in LMICs.[21,22,24,27] The same strategy was used in the ICU because only 1 center had a negative-pressure ICU.[27]

The anesthetic considerations reported were similar to international recommendations,[42] except for the use of a plexiglass box reported in 2 studies.[24,26] This strategy was also used in other centers during the early phase of the pandemic but has seen decreased use later.[43]

Operative considerations such as avoidance of sinuses and excessive drilling were also similar to international recommendations.[44,45] The latter was based on laboratory studies on aerosolized

particles, and their real-life efficacy in preventing COVID-19 infections has yet to be elucidated.[46] The avoidance of awake craniotomy was also seen in our review, except for 1 study[26] that recommended it to avoid aerosolization during intubation. This situation was different from international recommendations to perform awake craniotomy when indicated in COVID-19–negative patients and avoid its use for COVID-19–positive patients. Although our review showed that some LMIC centers suggested avoidance of endonasal procedures, many international studies recommended its continued use, detailing proper patient screening and using PPE with PAPR as key elements to COVID-19 prevention.[47,48]

Telemedicine for Outpatient Clinics in LMICs

The advent of the COVID-19 pandemic has seen the increase of telemedicine and its applications.[31] This was also the case in LMICs, although some centers continued FTF consults because of patient preference.[24] In the care of neuro-oncology patients, a few situations necessitate FTF consultation, such as the removal of staplers or sutures post-operatively.[49] Direct meetings can also facilitate more accurate clinical assessment of preoperative patients so that they can be triaged properly[1] and can improve counseling and rapport, particularly for patients facing end-of-life care or those with debilitating signs and symptoms.[31,49]

Given economic disparities, there may be difficulties conducting telemedicine in LMICs because of the lack of technological resources, digital infrastructure, and Internet speed.[50,51] This limitation was reported in 1 study,[24] whereas the others were able to adopt the use of telemedicine for outpatient consults during the pandemic. This situation may be a result of the decreasing prices of electronic equipment (computers and smartphones) and improved Internet services in their locality.[50]

Need for Adjuvant Therapy Protocols in LMICs

In our review, practices for adjuvant care mirrored those of international recommendations, except for the practice of home care chemotherapy in 1 study[29] to limit hospital consults during the pandemic. Several studies barely reported on adjuvant therapy at all, stating that these were already mostly unavailable even before the pandemic because of lack of health financing.[18]

Situational Report from a Tertiary Referral Center in the Philippines

Our institution, the Philippine General Hospital, is the largest tertiary referral hospital in the country. Before the pandemic, it catered to 600,000 patients annually, and the neurosurgery service performed 1500–2000 operations yearly.[13] When the pandemic started, the Philippine General Hospital became a COVID-19 referral center and continues to function as such, with reallocation of resources and personnel to the COVID-19 efforts of the hospital.

From a census review (unpublished data, 2019 and 2020 annual censuses of the Division of Neurosurgery), the neurosurgery service saw a 49.5% (1804 vs. 911 in 2019 vs. 2020) decrease in the total number of operations performed after the onset of the pandemic. There was also a proportionate reduction in surgical neuro-oncology operations by 52.2% (270 vs. 129) in the same time frame. The proportion of these operations was similar across the 2 time frames (14.9% vs. 14.2%).

We have adopted the recommendations for general neurosurgery proposed by our local neurosurgical society, with some minor institutional modifications.[52-54] Surgical neuro-oncology patients were triaged, and only COVID-19–negative patients were scheduled for elective surgery, requiring only 1 negative RT-PCR result within 3 days of surgery. One OR wing was used for COVID-19–negative patients, whereas the other wing was used for COVID-19–positive ones. Level I PPE was recommended for non-COVID ORs, whereas level III PPE with PAPR was recommended for COVID ORs. Anesthetic considerations included the anesthesia team being the only personnel inside the OR during intubation and extubation, and the use of a video laryngoscope. A water-impermeable occlusive dressing over the nose and mouth were also used after intubation.[13] Awake craniotomy and endonasal procedures were performed in COVID-19–negative patients only. At the start of the pandemic, a sterile transparent plastic sheet was set up like a tent over the surgical field to serve as a barrier when drilling bone to minimize surgeon exposure to aerosolized particles.[13] The neurosurgery ICU was turned into a COVID ICU, and patients were decked to a common 8-bed ICU for the entire hospital; thus, most post-operative neurosurgical patients stayed in the postanesthesia care unit for a few hours before being transferred back to the wards.

For outpatient services, telemedicine comprised 75% of our outpatient consults, and FTF consults were reserved for those requiring suture removal or a more detailed clinical assessment. In our setting, many cranial imaging studies were still printed on photographic paper instead of being available in digital form. Thus, patients should also have high-resolution smartphone cameras, because they are frequently asked to take pictures of imaging plates and send them electronically to the surgical neuro-oncology team for proper assessment.

In our hospital, service patients receive full coverage from the national health insurance system for surgery and partial compensation for RT, but no coverage for chemotherapy.[55] This strategy means that surgery is free, RT is subsidized, and chemotherapy is an out-of-pocket expense for neuro-oncology patients.[55] Consequently, our rates of adjuvant treatment, especially chemotherapy, were low, similar to other LMICs.[18,19,29,55] During the pandemic, our radiation oncology service has seen a further decline of 56.9% in the number of neuro-oncology patients undergoing treatment (93 vs. 40, 2019 vs. 2020). Chemotherapy enrollment also declined from 14 patients in 2019 to 4 in 2020.

Limitations

Our study has several limitations. First, it is a scoping review and is subject to reviewer biases. Second, despite a thorough search, the topic being reviewed is still evolving and likely to produce more information, including gray literature, so our review may be applicable for only a specific period. Third, the studies included were heterogeneous because of the nature of the review. No direct quantitative comparisons were made among the studies.

CONCLUSIONS

In our review, we found that the practice patterns in surgical neuro-oncology in LMICs during the COVID-19 pandemic are similar to those in HICs, except for a few modifications attributed to resource limitation and patient preferences.

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SUPPLEMENTARY DATA

Supplementary Table 1. Search Terms and Items Found in MEDLINE by PubMed

Search Terms	Items Found
1. Neuro-oncology or "surgical neuro-oncology" or "neurosurgical oncology" or "CNS tumor" or "central nervous system tumor" or "brain tumor" or "brain cancer"	42,366
2. "COVID-19" or "coronavirus disease 2019" or "SARS-COV-2"	182,701
3. 1 and 2	125

Supplementary Table 2. Search Terms and Items Found in Scopus

Search Terms	Items Found
1. Neuro-oncology or "surgical neuro-oncology" or "neurosurgical oncology" or "CNS tumor" or "central nervous system tumor" or "brain tumor" or "brain cancer"	420,162
2. "COVID-19" or "coronavirus disease 2019" or "SARS-COV-2"	298,299
3. "lower income" or "middle income"	158,268
4. 1 and 2 and 3	49

Supplementary Table 3. Search Terms and Items Found in Cochrane

Search Terms	Items Found
1. Neuro-oncology or "surgical neuro-oncology" or "neurosurgical oncology" or "CNS tumor" or "central nervous system tumor" or "brain tumor" or "brain cancer"	2313
2. "COVID-19" or "coronavirus disease 2019" or "SARS-COV-2"	2428
3. 1 and 2	3

Supplementary Table 4. Search Terms and Items Found in EBSCOHOST

Search Terms	Items Found
1. Neuro-oncology or "surgical neuro-oncology" or "neurosurgical oncology" or "CNS tumor" or "central nervous system tumor" or "brain tumor" or "brain cancer"	198,672
2. "COVID-19" or "coronavirus disease 2019" or "SARS-COV-2"	539,966
3. "lower income" or "middle income"	111,543
4. 1 and 2 and 3	1

Supplementary Table 5. Search Terms and Items Found in ClinicalTrials.gov

Search Terms	Items Found
1. (Neuro-oncology or "surgical neuro-oncology" or "neurosurgical oncology" or "CNS tumor" or "central nervous system tumor" or "brain tumor" or "brain cancer") AND ("COVID-19" or "coronavirus disease 2019" or "SARS-COV-2")	0

Supplementary Table 6. Summary of Included Studies in the Review

Reference	Country	Type of Study	Preoperative Consideration	Intraoperative Consideration	Postoperative Consideration	Outpatient Consideration	Outcomes and Other Findings
Batistella et al., 2021[18]	Brazil	Expert opinion and review	All patients screened for COVID-19 (RT-PCR); all patients need Pulmonary CT scan before admission All staff wear PPE, N95, and face shield If COVID-19—positive and stable, wait until COVID-19—negative before performing surgery If life-threatening status, bypass all protocols and treat accordingly	Awake craniotomy not recommended for COVID-19—positive patients If for reoperation, maximize all medical management first	All postoperative patients to stay in home quarantine for 2 weeks Standard adjuvant therapy given; hypofractionated RT offered to reduce hospital visits	Telemedicine used for outpatient If blood tests needed, do so in nonhospital setting	Health care inequity tackled: most centers for adjuvant care are in tertiary centers, cross-contamination is a concern Chemotherapy is not widely available
Hu et al., 2020[19]	China	Letter to the editor with case report	All patients undergo COVID-19 screening (RT-PCR) COVID-19—negative: surgical cap, surgical face mask, protective gown and gloves COVID-19 suspect: surgical cap, N95 face mask, goggles, face shield, full face piece respirator, protective gown, gloves COVID-19—positive: transfer to a COVID-19 center OR is negative pressure	OR is negative pressure for all	ICU is negative pressure for all	Triaging in the clinic If benign, operate at a later (safer) time Prioritized malignant tumors in a "timely" manner If in with symptoms of increased intracranial pressure or herniation, admit	Patient with COVID-19—negative swab and unremarkable chest CT, but with symptoms was operated on with COVID-19—positive precautions
Goyal et al., 2020[21]	India	Case-control	All patients screened with COVID-19 RT-PCR If COVID-19—positive, delay surgery if elective If urgent/emergent and COVID-19 status unknown, assume COVID-19—positive Level 1 PPE for COVID-19—negative; level III for COVID-19—positive/unknown	OR staff decreased COVID-19 OR (negative pressure) separate from non-COVID-19 OR Avoidance of endonasal procedures and excessive bone drilling If need to perform endonasal, performed in full level III PPE, negative-pressure OR, and with powered air-purifying system	ICU and floor staff decreased	Elective surgeries canceled to provide beds for COVID-19—positive patients All outpatient consults via telemedicine	Proportion of brain tumor operations similar between pre-COVID-19 and post-COVID-19, but overall numbers decreased Leaves of physicians canceled to prevent COVID-19 spread All conferences online (neuro-oncology MDC)

Continues

Supplementary Table 6. Continued

Reference	Country	Type of Study	Preoperative Consideration	Intraoperative Consideration	Postoperative Consideration	Outpatient Consideration	Outcomes and Other Findings
Sahoo et al., 2020[22]	India	Case-control	All patients screened with RT-PCR Single test for urgent/emergent cases, double tests for elective cases FFP1 face mask for COVID-19—negative OR, N95 mask for COVID-19—positive If COVID-19—positive and semiurgent/elective: Patient transferred to designated COVID-19 center and surgery rescheduled if can wait	FFP1 face mask for COVID-19—negative N95 mask for COVID-19 positive	Separate OR for COVID-19—positive and COVID-19—negative	NR	Decreased proportion of supratentorial brain tumor cases during COVID-19 pandemic (more vascular cases); significantly increased proportion of posterior fossa tumor cases treated
Ozoner et al., 2020[28]	Turkey	Expert opinion and review	All patients screened with RT-PCR PPE level 1 if COVID-19—negative PPE Level 3 if COVID-19—positive Continue all surgery for urgent and emergent, postpone if truly elective (low acuity)	Negative-pressure OR for COVID-19—positive Video laryngoscope for intubation Minimal OR staff	NR	Triaging of patients: low acuity—benign asymptomatic Intermediate acuity—symptomatic benign High acuity—malignant, posterior fossa Telemedicine in outpatient Minimal staff in clinic Level 1 PPE	In Turkey, because of lack of resources, some ORs converted to ICUs
Gupta et al., 2020[23]	India	Expert opinion and review	All patients need to be screened with RT-PCR Consider use of less invasive procedures (minicraniotomy, burr hole) if possible Consider cerebrospinal fluid diversion first if with hydrocephalus	NR	NR	Triage patients according to priority Hypofractionated RT for benign tumors; usual RT for malignant tumors Continue chemotherapy; if possible use oral (no admission) and less toxic protocols Experimental therapies not recommended	Still offer standard-of-care as much as possible

Hameed et al., 2021[29]	Asian countries (mostly China, 93%; also included India, Japan, and South Korea)	Cross-sectional survey of hospitals	All patients to undergo COVID-19 screening Elective surgery for COVID-19—negative patients only in 77% Elective surgery for COVID-19—positive patients in 23% If COVID-19—negative, routine gowning in 51% If COVID-19—positive, completely enclosed gowns with self- contained breathing apparatus in 70%	NR	Postponement or cancellation of adjuvant therapy clinics in 36% Transferred patients to other hospitals for adjuvant treatment in 24%; home-based adjuvant treatment in 3%	If asymptomatic and benign, postpone to a safer time For malignant tumors, prioritize surgery Emergent procedures and patients in extremis, perform immediate surgery Telemedicine (online) clinics in 18%, telephone consults in 74%	Response of the hospital determined by COVID-19 status in the area as well as available PPEs Median reduction in surgical neuro-oncologic workload of 25%—50% Surgical neuro-oncologic workforce allocated to COVID-19 areas in 63%
Zou et al., 2021[20]	China	Case-control	All patients in review were elective and COVID-19—negative Standard preoperative imaging and workup for all tumor patients	Intraoperative wake-up technology and Yellow fluorescence not available during COVID-19 pandemic because of limited resources	NR	Use video or telephone consultation as much as possible PPE warranted in FTF consults Social distancing practice in clinic	Patients presented with larger tumors and more midline shift during pandemic Longer waiting times during pandemic More gliomas had functional deficit when operated on during pandemic, otherwise outcomes (complications and neurologic status) were similar
Tavanaei et al., 2021[27]	Iran	Case-control	COVID-19 RT-PCR and high-resolution CT of the chest required for elective surgery	Use disposable airway equipment Intubation in the OR by anesthesia team only, at least 5 minutes before others enter Smoke evacuator used for cautery Avoidance of aerosolization (drilling) and endonasal procedures For COVID-19—positive OR: powered air-purifying respirators used Full PPE by all OR personnel screened after surgery	ICU is negative pressure	Patients triaged by symptom into emergency and semiurgent/elective	No patient treated as elective tested positive for COVID-19 at 30 days postoperatively, but 16% became COVID-19—positive at 60 days Proportion of oncology-type surgeries performed increased compared with other types in the COVID-19 period (but total number decreased)

Continues

Supplementary Table 6. Continued

Reference	Country	Type of Study	Preoperative Consideration	Intraoperative Consideration	Postoperative Consideration	Outpatient Consideration	Outcomes and Other Findings
Deora et al., 2021[24]	India	Retrospective cohort	Rapid antigen test for emergent procedures RT-PCR for elective procedures	Box intubation used 2 neurosurgeons worked simultaneously for complicated cases to reduce OR time Intraoperative MRI not used	If health care personnel exposed, quarantine for 5 days then perform RT-PCR	Cases triaged according to acuity Telemedicine advocated but FTF pursued; patient can choose how to consult For FTF: limit number of patients; personnel in N95, face shield, gloves Gamma Knife continued during pandemic despite 70% reduction in cases	If delay in surgery was expected to be 3—6 months, routine MRI was performed at 3 months
Sharma et al., 2021[25]	India	Case-control	All patients screened with COVID-19 RT-PCR COVID-19—negative: level I COVID-19—positive: level III	Some ORs repurposed to be donning/doffing areas Surgeons worked in 3-hour to 4-hour shifts then changed teams	Level II PPE in COVID-19—negative ICU; level III in COVID-19—positive Workers in 6-hour shifts	Telemedicine adopted for all consults Gamma Knife continued during pandemic (77% reduction)	Neurosurgeons allocated to COVID-19 areas
Sudhan et al., 2021[26]	India	Case-control	All patients screened with RT-PCR Level III PPE for all types of operations	Intubation with video laryngoscope and plexiglass box No negative-pressure OR available Awake craniotomy used as much as possible Patient placed in a barrier tent Craniotomy plotted to avoid paranasal sinuses	NR	Triaged into: emergency, essential, routine with corresponding timelines	All staff underwent surveillance with enzyme-linked immunosorbent assay IgG and IgM

RT-PCR, reverse transcriptase polymerase chain reaction; CT, computed tomography; PPE, personal protective equipment; RT, radiotherapy; OR, operating room; MRI, magnetic resonance imaging; ICU, intensive care unit; NR, not reported; FTF, face-to-face; MDC, multi-disciplinary conference.