POST-OPERATIVE INTENSIVE CARE UNIT ADMISSION FOR ELECTIVE BRAIN TUMOUR SURGERIES: A NIGERIAN NEUROSURGICAL UNIT EXPERIENCE

O.O. Agboola[1], O.O. Idowu[2], J.A. Balogun.[1,3]

1. Department of Neurological Surgery, University College Hospital, Ibadan.
2. Department of Anaesthesia, College of Medicine, University of Ibadan, Ibadan.
3. Department of Surgery, College of Medicine, University of Ibadan, Ibadan.

Correspondence:
Dr. J.A. Balogun
Division of Neurosurgery,
Department of Surgery,
Faculty of Clinical Sciences,
College of Medicine,
University of Ibadan,
Ibadan, Nigeria.
jamesabalogun@gmail.com.

Submission Date: 30th May, 2023
Date of Acceptance: 30th Oct., 2023
Publication Date: 1st Nov., 2023

ABSTRACT

Background: **Patients, post elective brain tumour surgeries, are usually admitted into the Intensive Care Unit (ICU) for quick identification of life-threatening complications or for elective ventilation. The Covid-19 pandemic exerted additional strain on the limited ICU spaces. This study was to probe the need for ICU admission following elective surgery for brain tumour in our environment on the background of enormous constraints.**

Methods: **Data was collected prospectively from patients who had elective brain tumour surgery over 12-months at the University College Hospital, Ibadan. Data included the indications for ICU admission and outcome. Chi-square test and Student t-test were used for analysis at ~ ≤ 0.05.**

Results: **There were 56 patients with a mean age of 44.6 years and M:F ratio of 1:1. 61.8% of the patients were admitted into the ICU for observation. Patients who had open surgeries were 2 times more likely to be admitted ($p<0.01$; OR = 2.2, CI: 2.0 – 36.8) than those who had endoscopic surgeries. Awake craniotomy patients did not require ICU care compared with the 63% of the patients who had General Anaesthesia + Endo Tracheal Tube (GA+ETT). Patients with skull base and posterior fossa tumours were more likely to be admitted into the ICU ($p=0.036$). Of the 34 patients admitted into the ICU, 11(19.6%) had prolonged ICU stay and were 2 times more likely to die compared with those with short admissions ($p<0.01$; OR = 2.5, CI: 2.29 – 70.02).**

Conclusion: **Observation is the main reason patients are admitted into the ICU. The endoscopic and awake surgery approaches appear to preclude the need for ICU admission, thus capable of cutting costs.**

Keywords: Brain tumour, Covid-19 craniotomy, Intensive care unit, Nigeria.

INTRODUCTION

The post-operative care of patients, following elective surgery for brain tumours, has traditionally been in the Intensive Care Unit (ICU).[1] This is usually to allow for close observation and swift identification of immediate post-op complications or planned elective ventilation.[2] A period of 24 – 48hours or more depending on the amount of peritumoral oedema pre-operative was recommended for the observation of these patients.[3] This philosophy is now being challenged as the need to cut the cost of care is becoming more inevitable.[4] The situation in Low- or Middle-Income Countries (LMICS), which includes our practice setting, is even more precarious because of limited ICU beds,[5] which when available, are expensive, with the cost of care in the ICU multiple folds of the general ward costs. Any need for ventilatory support further multiplies this cost of care.[6]

The cost of neurosurgical care generally has been described as the most expensive for a medical specialty[7] thus imposing varying significant burden on individuals, families and the nation's economy, especially in countries that practice some form of socialised health care system. In developing economies such as Nigeria with less than 5% of the population enrolled in the National Health Insurance Authority (NHIA),[8] 'out of pocket' payment by patients for healthcare is the predominant form of healthcare financing, which raises a significant challenge to both the access of neurosurgical care and the promptness of such access. The government funded health insurance scheme in Nigeria, the NHIA, does not cover most of the neurosurgical cost of care, with patients having to provide counterpart funding to offset some of the costs which includes Intensive Care Unit (ICU) fees, and only a small proportion of Nigerians have access to private health insurance schemes.[9, 10]

The evolution of Covid-19 virus pandemic had a major negative impact on the availability of ICU beds worldwide[11-14]. There was an increased demand for ventilators with up to 9 – 11% of Covid-19 patients requiring ventilatory support.[15-17] This without doubt, further stifled the availability of the ICU facilities for the care of patients with other pathologies. Consequently, those patients deemed to require the use of the ICU following elective procedures such as for brain tumour surgery could not get spaces; sometimes resulting in the cancellation of scheduled cases.[1] Thus, this is stimulating a re-think in the way these patients are managed in the light of these occurrences.[18, 19]

We therefore set out to study the indications for ICU admission post elective surgery for brain tumours, and identify the factors that determine prolonged ICU stay and the effect of ICU care on outcome.

MATERIALS AND METHODS

Ethical Considerations

Ethical approval was obtained from the University of Ibadan/University College Hospital ethics review committee with the reference number UI/EC/19/0374.

Study Setting

The study was carried out at the University College Hospital (UCH), Ibadan; a 900-bedded tertiary health care centre, in southwestern Nigeria. It is a major referral centre for brain tumour care in Nigeria, particularly in the southern part of the country. The hospital is equipped with a 12-bedded general intensive care unit, with ventilators. There is no dedicated neurosurgery ICU or neurosurgery bed.

The patients with brain tumours are usually first seen in the Neurosurgical out-patient clinic, where they are evaluated, subsequently optimised for surgery and then admitted to the ward, usually a few days to their proposed surgery. The study included all patients who had elective brain tumour surgery over a 12-month period starting from February 2020, which included periods of service disruption due to the Covid-19 lockdown, operative room slowing and industrial action by resident doctors.

Data Collection Procedure

Data was collected using a proforma pre-designed for the study. The details obtained included the patients' socio-demographic data, the clinical diagnosis, tumour location, the surgical approach, type of anaesthesia, surgery and anaesthesia duration, intra-operative blood loss and blood transfusion up till 24hours post-op, details of ICU admission, histologic diagnosis, and re-admission into the ICU. Peri-operative anaesthetic managements were documented, these include, analgesia which were essentially opioid-based. Induction and maintenance of anaesthesia were mostly done with propofol and dexmedetomidine while local anaesthetics and dexmedetomidine were used for local infiltration for awake craniotomy. All the vital signs and other intra-operative findings were documented and this trend continued with those admitted to the ICU until they were discharged.

Data Management and Analysis

Data was analyzed using Statistical Package for Social Sciences version 23. Data was cleaned and descriptive statistics was used to present the frequencies including the sociodemographic and surgery variables. Chi square test was used to test the association between the patients' sociodemographic, surgery and tumour characteristics and admission into ICU. Prolonged ICU admission was defined as ICU admission that is more than 48 hours.[20-22] Chi square test was also used to determine the association between sociodemographic, surgery and tumour characteristics, as well as type of ICU and prolonged ICU admission. All the statistically significant associations were then entered into logistic regression to further test the associations. Student t test was used to analyze the mean difference between those who were admitted into ICU and those who were not; it was also use to analyze the mean difference of patients who had prolonged and non-prolonged ICU admission with regard to their mean blood loss, total time on anesthesia and duration of surgery. The level of significance was $p<0.05$ for all analysis.

RESULTS

We recruited a total of 56 patients with 60.7% of the patients within the 25-64 years age bracket. The M:F ratio is approximately 1:1. The age range was between 1 year and 88 years, while the median age of the patients was 56years.

Table 1: Sociodemographic characteristics of studied patients

Sociodemographic characteristics	Frequency (n)	Percentage (%)
Age group (years)		
0 - 24	11	19.6
25 - 64	34	60.7
≥65	11	19.6
Gender		
Male	27	48.2
Female	29	51.8

Thirty-four (60.7%) of the patients were admitted into the ICU post-surgery, of which 61.8% were admitted mainly for observation. The indications for the ICU admissions are as shown in Table 2. The type of surgery and the location of the tumour were factors that were significantly associated with admission into

Table 2: Indication for ICU admission post elective brain surgery

Indication	Frequency (n)	Percentage (%)
Prolonged surgery	6	17.6
Elective ventilation	7	20.6
Observation	21	61.8

the ICU, however, the association between tumour location and ICU admission was no longer significant after logistic regression Table 3. The patients (21.3%) who had endoscopic procedures mainly for transphenoidal resection of pituitary adenomas were less likely to be admitted to the ICU compared with the 76.8% patients that had craniotomy. Patients who had open surgeries were 2 times more likely to be admitted into ICU (p<0.01; OR = 2.2, CI: 2.0 – 36.8) compared with those who had endoscopic surgeries. Almost all the patients with skull base and posterior fossa tumours were admitted into the ICU. The histology of the tumours did not determine admissions into the ICU, as an almost equal proportion of the patients with either benign or malignant tumours were admitted into the ICU following surgery: 58.8% of those with benign tumours and 60% of those with malignant tumours. Most of the patients recruited had pituitary adenoma (33.3%), followed by glioma (29.6%) and meningioma (22.2%). The predominant histologic diagnosis in children was pilocytic astrocytoma, making up 62.5 percent of the diagnosis within their age bracket. 87.5% of children were admitted to the ICU, compared with 55% of adults admitted into the ICU, however, this finding is not statistically significant P= 0.17).

The indications for ICU admission post elective brain surgery were prolonged surgery 6(17.6%), elective ventilation (20.6%) and observation (61.8%). Of the 34 patients admitted into the ICU, 11 (19.6%) had prolonged ICU stay (ICU admission more than 48 hours). Factors associated with admission into ICU and prolonged ICU admission are as shown in Tables 3 and 4.

Table 3: Factors associated with admission into ICU

	Admission into ICU		p value
	Yes n (%)	**No n (%)**	
Age group (years)			
0 - 24	9 (16.1)	2 (3.6)	0.10
25 - 64	17 (30.4)	17 (30.4)	
≥65	8 (14.3)	3 (5.4)	
Sex			
Male	16 (28.6)	11 (19.6)	0.83
Female	18 (32.1)	11 (19.6)	
Type of surgery			
Endoscopic	3 (5.4)	10 (17.9)	<0.01
Open	31 (55.4)	12 (21.4)	
Type of anesthesia			
GA + ETT	34 (60.7)	20 (35.7)	0.05
Awake craniotomy	0 (0)	2 (3.6)	
Type of resection			
Gross total resection	13 (23.2)	10 (17.9)	0.64
Near total	10 (17.9)	4 (7.1)	
Subtotal	11 (19.6)	8 (14.3)	
Tracheostomy			
Yes	3 (8.3)	0 (0)	0.46
No	30 (83.3)	3 (8.3)	
Tumour type			
Benign	20 (37.0)	14 (25.9)	0.93
Malignant	12 (22.2)	8 (14.8)	
Tumour location			
Supratentorial	11 (20.0)	7 (12.7)	<0.01
Sellar suprasellar	7 (12.7)	14 (25.5)	
Skull base	8 (14.5)	0 (0)	
Posterior fossa	7 (12.7)	1 (1.8)	

Table 4: Factors associated with prolonged ICU stay for patients post elective brain surgery

	Prolonged ICU stay		
	Yes (n)%	No (n)%	p value
Age group (years)			
0 – 24	4 (11.8)	5 (14.7)	0.31
25-64	6 (17.6)	11 (32.4)	
≥65	1 (2.9)	7 (20.6)	
Gender			
Male	2 (5.9)	14 (41.2)	0.02
Female	9 (26.5)	9 (26.5)	
Type of surgery			
Endoscopic surgery	1 (2.9)	2 (5.9)	0.97
Open surgery	10 (29.4)	21 (61.8)	
Tumour location			
Supratentorial	3(8.8)	8 (23.5)	0.50
Sellar suprasellar	2 (5.9)	6 (17.6)	
Skull base	2 (5.9)	6 (17.6)	
Posterior fossa	4 (11.8)	3 (8.8)	
Type of tumour resection			
Gross total resection	3 (8.8)	10 (29.4)	0.55
Near total resection	3 (8.8)	7 (20.6)	
Required tracheostomy			
Yes	3 (9.1)	0 (0)	<0.01
No	7 (21.2)	23 (69.7)	
Type of tumour			
Benign	6 (18.8)	14 (43.8)	0.76
Malignant	3 (9.4)	9 (28.1)	

Overall, 41 (73.2%) patients were discharged and 15 (26.8%) died. There was no significant association between admission into ICU and patients' outcome (p=0.07). However, prolonged ICU admission was associated with patients' outcome (p<0.01) as 8(66.7%) patients with prolonged ICU admission died compared with 4(33.3%) patients among those without prolonged ICU admission. Also, patients with prolonged ICU admission were 2 times likely to die compared with those with short admissions (p<0.01; OR = 2.5, CI: 2.29 – 70.02). The male sex was 2 times more likely to have prolonged ICU admission compared to the female sexes (p=0.02; OR = 2.0, CI: 1.32 – 42.77).

The mean estimated blood loss, total time on anesthesia and duration of surgery were higher for those admitted into the ICU compared with those who were not.

Table 5. Comparison of means of selected surgery characteristics among the patients admitted into ICU and others

Surgery characteristics	t	p value	Mean difference	95% CI
Estimated blood loss (ml)	1.86	0.07	619.7	-47.4 – 1286.8
Total anaesthesia time (min)	5.35	<0.01	168.7	105.5 – 231.9
Duration of surgery (min)	4.93	<0.01	144.97	85.96 – 203.98

Table 6. Comparison of means of selected surgery characteristics among patients with prolonged ICU admission and non-prolonged admission

Surgery characteristics	t	p value	Mean difference	95% CI
Estimated blood loss (ml)	0.10	0.92	59.78	1114.9 – 1234.4
Total anaesthesia time (min)	1.79	0.08	81.96	-11.3 – 175.2
Duration of surgery (min)	1.09	0.28	48.43	41.7 – 138.6

Also, those who had prolonged stay in ICU had higher mean blood loss, total time on anesthesia and duration of surgery. For the comparison of these selected surgery characteristics, the Levene's test for equality of variances was significant for all comparisons, so, the output for equal variances assumed was used. Table 5 showed that there was a statistically significant difference in the mean of the duration of anesthesia and surgery for those admitted into ICU and those that were not. Table 6 also showed that the difference in these selected surgery characteristics were not statistically significant among those with and without prolonged ICU admission.

DISCUSSION

Our study found a significant number of the patients (60%) admitted into the ICU following brain tumour surgery, with the reason mainly due to the decision by the surgeon or the anaesthetist to observe the patients in the ICU. This follows the traditional thought of neurosurgeons, which tend to err on the side of caution, in order to quickly recognize life-threatening complications. Evidence in the past few years however negated this position, as only a small percentage of brain tumour patients require ICU admission following surgery. This position in our environment, as may well be in other LMICs, may also be due to the non-availability of step down neurological units or the lack of facilities and trained personnel on the wards.

Whilst gender did not determine admission into the ICU, similar to the finding of 58.6% females by Bui et al[23], patients who had open procedures were twice more likely to be admitted into the ICU compared to those who had endoscopic procedures and this is in tandem with other reports. Though endoscopic procedures for pathologies such as pituitary adenoma have become gold standards of treatment in most hospitals in the High-Income Countries (HICs), the challenge of cost of acquisition, maintenance challenges and paucity of expertise has limited the adaptation of these procedures in climes such as ours. Though there were just two patients that had Awake craniotomy, none was admitted into the ICU. Previous reports have demonstrated the safety, practicability and effectiveness of awake craniotomy for a variety of intracranial tumours including in LMICs, in carefully selected patients with significant reduction in the probability of ICU admission, shorter hospital stay and ultimately reducing cost of care.[24-27] In fact, the San Francisco group, submitted from a 27year experience with awake craniotomy, that irrespective of the ASA classification and other seemingly unfavourable pre-operative parameters, awake craniotomy can be done safely with very low complications.[28] The concept of outpatient craniotomy popularized by Bernstein[29], has also had its feasibility tested in our environment despite the pre-supposed challenges, and this further reduces the total cost of care of these patients.[30] The acquisition of skills for these procedures and their adaptation may be reasonable ways to reduce the tendency for ICU admission for brain tumour patients in our practice and those of others in LMICs.

Though, our study showed that there is tendency to admit skull base and posterior fossa tumours into the ICU, the lack of statistical significance may be due to the small numbers in the study. Sioshansi *et al.* 2021 recognized large volume tumour (>4500mm^3) as an independent factor necessitating ICU admission in addition to their location in the lateral skullbase.[31] Previous studies suggested that 79.71% of patients who had posterior fossa tumour surgery required ICU admission. It has also been established that patients who had surgery for posterior fossa tumours were more likely to be readmitted to the ICU after initial discharge compared with other tumour locations. Therefore patients with posterior fossa tumour should be monitored for longer period in the ICU following surgery.[32, 33]

We also found that the mean estimated blood loss, total time on anesthesia and duration of surgery were higher for those admitted into ICU compared with those who were not. A number of these factors agree with previous findings (Zial and Mahajan), with the Mahajan *et al.* group identifying the following as indications for post-operative ventilatory support and ICU admission: preoperative lower cranial nerve palsy, haemodynamic instability, brainstem handling, massive blood loss; intraoperative acute brain bulge, residual tumour, prolonged surgery (more than 8 hours), not obeying commands (delayed recovery) and neurosurgeon's advice. However their most common indications for postoperative mechanical ventilation, were 'not responding to commands', and neurosurgeon advice.[34] A longer length of surgery corroborating with increasing tendency for ICU admission has also been further validated in other studies[35-37] with Rhondali *et al.* using a cut-off of 4-hours as in our study in their review of 306 patients. In all the cases recruited for this study, propofol (as an induction and maintenance agent), and isoflurane and fentanyl (as the analgesic agents) were used because of their recovery profiles. This is inspite of the fact that some studies showed slightly early extubation time[38,39] and achievement of Aldrete score ≥9 faster and no statistical or clinical significance between balance inhalational versus total intravenous anaesthesia.[40,41] The effect of opioid in the study (Fentanyl and morphine) on post-operative recovery have been studied extensively[42,43] and have been shown to be effective.

Prolonged ICU stay greater than 48-hours was associated with a poor outcome as they were two times more likely to die compared with those with a short stay in the ICU. This is in agreement with Pirrachio *et al.* who reported that ICU admission was associated with increased mortality.

We found that the male sex were more likely to have prolonged ICU stay as well as the patients that had higher mean blood loss, total time on anesthesia and duration of surgery. We do not know the reason for the gender disparity in the tendency for prolonged ICU admission, as there is no difference in the proportion of both genders admitted in the ICU or any peculiarity in the tumour pathologies. While Zial *et al.* found out that benign tumours were more likely to stay beyond 4hours in the ICU, the extent of resection was not significantly different between the different groups in their study.[37] We did not find such a difference in our study. Mahajan *et al.* found the mean ICU stay among their cohort of patient to be 92.2 ± 134.0 hours but interestingly noted that 47.6% of patients who had postoperative mechanical ventilation based on neurosurgeon's advice developed complications while only 33.2% for those ventilated for other reasons ($P < 0.05$) had complications.[34]

There has been remarkable progress in improving the safety and outcome of brain tumour surgery. These include advances in anatomical, physiological and functional imaging, micro-neurosurgery, intra-operative imaging such as neuronavigational, intra-operative MRI and now navigated ultrasound and even neuro-pathology[44, 45]; without prejudice to improved asepsis, anaesthesia and antibiotics.[46] While these are routine in most operating rooms (ORs) in HICs, a lot of countries such as ours, lack these equipment and/or support, thereby having to improvise or forge on without them. Indeed anatomy and surface markings may be very useful in localisation of brain tumours; it is unarguably true that a neuronavigational machine not only help to localise the tumour and the surrounding structures, it can be used to plan trajectories, identify surrounding structures including fibre tracts and determine the size of the craniotomy flap thus effectively limiting the anaesthesia/operative times which have been identified as one of the key factors determining admission into the ICU.

In the immediate post-operative period following brain tumour surgery, life-threatening complications like intracranial bleeding, intracranial hypertension, and status epilepticus, have been found to increase the risk of mortality to more than two folds.[47] This has traditionally been considered the reason for the post-operative care of the patients the ICU, a notion that is now being contested as unproven with a strain on available limited resources.[23] This has become even more burdensome in many developing countries where ICU space is scarce and the neurosurgical units often competes with other surgical specialties for the few ICU bed spaces. These countries also have infrastructural problem such as a lack or insufficient number of mechanical ventilators and even availability of oxygen[48-51]. There might also be deficiency in nursing care and other personnel needed for care[52] and sepsis control may be a major challenge in many of these centres.[53,54] It is therefore imperative to begin to optimize resources right from the pre-operative and intra-operative period to reduce the number of patients that are admitted into the ICU following brain tumour surgery. The resources in the ICU are limited and expensive, it is therefore necessary to identify and carefully select those who really require or benefit the most from such service.[55]

LIMITATIONS

This is a single institutional study and thus extrapolation of the findings must be interpreted within the peculiarities of other centers, though the result will be useful in other LMIC centers. We also acknowledge the small number of the cohort of the patients, which impacted on the limited comparisons of the different groups of patients and pathologies. This was due to the Covid-19 crisis as well as a prolonged industrial dispute between the resident doctors and the Nigerian government.

CONCLUSION

Our study finding suggests as previously established, that most patients are admitted to the ICU following brain tumour surgery for observation, therefore appropriate patient stratification can lead to more patients being managed in step down units or the wards. Investment in key equipment both pre-operatively and intra-operatively will ensure safety and timely completion of surgical procedures, thus further reducing the tendency to ICU admission. Training and developing expertise in techniques such as awake craniotomy and endoscopic interventions may also significantly reduce ICU admission and eventually the overall cost of caring for these patients. A larger, perhaps multi-centre study, will provide a more comprehensive review of this subject matter.

REFERENCES

1. **Laan Mt,** Roelofs S, Van Huet I, *et al.* Selective intensive care unit admission after adult supratentorial tumor craniotomy: complications, length of stay, and costs. Neurosurgery 2020;86(1): E54-E9.

2. **de Almeida CC,** Boone MD, Laviv Y, *et al.* The utility of routine intensive care admission for patients undergoing intracranial neurosurgical procedures: a systematic review. Neurocritical care. 2018;28(1):35-42. 10.1007/s12028-017-0433-4
3. **Kelly DF.** Neurosurgical postoperative care. Neurosurgery Clinics of North America. 1994;5(4):789-810.
4. **Osorio JA,** Safaee MM, Viner J, *et al.* Cost-effectiveness development for the postoperative care of craniotomy patients: a safe transitions pathway in neurological surgery. Neurosurgical Focus. 2018;44(5):E19. 10.3171/2018.2.FOCUS1812
5. **Balogun JA,** Akwada O, Awana E, *et al.* Access to the intensive care unit by severe head injury patients. Journal of Neurosciences in rural practice. 2019;10(04):666-71. 10.1055/s-0039-3399476
6. **Reardon PM,** Fernando SM, Van Katwyk S, *et al.* Characteristics, outcomes, and cost patterns of high-cost patients in the intensive care unit. Critical care research. 2018;2018:5452683. 10.1155/2018/5452683
7. **Benzil DL,** Zusman EE. Defining the value of neurosurgery in the new healthcare era. Neurosurgery. 2017;80(4S):S23-S7. 10.1093/neuros/nyx002
8. **Awosusi A,** Folaranmi T, Yates R. Nigeria's new government and public financing for universal health coverage. The Lancet Global Health. 2015;3(9):e514-e5. 10.1016/S2214-109X(15)00088-1
9. **Drislane FW,** Akpalu A, Wegdam HH. The medical system in Ghana. The Yale journal of biology medicine. 2014;87(3):321.
10. **Tagoe N,** Essuman V, Fordjuor G, *et al.* Neuro-ophthalmic and clinical characteristics of brain tumours in a tertiary hospital in Ghana. Ghana medical journal. 2015;49(3):181-6. 10.4314/gmj.v49i3.9
11. **Deschepper M,** Eeckloo K, Malfait S, *et al.* Prediction of hospital bed capacity during the COVID" 19 pandemic. BMC health services research. 2021;21(1):1-10. 10.1186/s12913-021-06492-3
12. **Goic M,** Bozanic-Leal MS, Badal M, *et al.* COVID-19: Short-term forecast of ICU beds in times of crisis. Plos one. 2021;16(1):e0245272. 10.1371/journal.pone.0245272
13. **Pecoraro F,** Luzi D, Clemente F. The efficiency in the ordinary hospital bed management: A comparative analysis in four European countries before the COVID-19 outbreak. PLoS One. 2021;16(3):e0248867.
14. **Sen-Crowe B,** Sutherland M, McKenney M, *et al.* A closer look into global hospital beds capacity and resource shortages during the COVID-19 pandemic. Journal of Surgical Research. 2021;260:56-63.
15. **Remuzzi A,** Remuzzi G. COVID-19 and Italy: what next? The lancet 2020;395(10231):1225-1228.
16. **Iyengar K,** Bahl S, Vaishya R, *et al.* Challenges and solutions in meeting up the urgent requirement of ventilators for COVID-19 patients. Diabetes Metabolic Syndrome: Clinical Research. 2020;14(4):499-501. 10.1016/j.dsx.2020.04.048
17. **Madekurozwa M,** Bonneuil WV, Frattolin J, *et al.* A Novel Ventilator Design for COVID-19 and Resource-Limited Settings. Frontiers in medical technology. 2021;3:53. 10.3389/fmedt.2021.707826
18. **Weller M,** Preusser M. How we treat patients with brain tumour during the COVID-19 pandemic. ESMO open. 2019;4:e000789.
19. **Mallari RJ,** Avery MB, Corlin A, *et al.* Streamlining brain tumor surgery care during the COVID-19 pandemic: A case-control study. Plos one 2021;16(7):e0254958. 10.1371/journal.pone.0254958
20. **Osuagwu UL,** Xu M, Piya MK, *et al.* Factors associated with long intensive care unit (ICU) admission among inpatients with and without diabetes in South Western Sydney public hospitals using the New South Wales admission patient data collection (2014–2017). BMC Endocrine Disorders. 2022;22(1):1-10.
21. **Liisanantti JH,** Ohtonen P, Kiviniemi O, *et al.* Risk factors for prolonged intensive care unit stay and hospital mortality in acute drug-poisoned patients: an evaluation of the physiologic and laboratory parameters on admission. Journal of critical care. 2011;26(2):160-165.
22. **Heimrath OP,** Buth KJ, Légaré JF. Long-term outcomes in patients requiring stay of more than 48 hours in the intensive care unit following coronary bypass surgery. Journal of critical care. 2007;22(2):153-158.
23. **Bui JQ,** Mendis RL, Van Gelder JM, *et al.* Is postoperative intensive care unit admission a prerequisite for elective craniotomy? Journal of neurosurgery. 2011;115(6):1236-1241.
24. **Idowu O,** Adeleye A, Amanor-Boadu S. Awake craniotomy for intracranial lesions: An audit of the anaesthetists' initial experience at the University College Hospital, Ibadan. Egyptian Journal of Anaesthesia. 2016;32(4):559-564.
25. **Serletis D,** Bernstein M. Prospective study of awake craniotomy used routinely and nonselectively for supratentorial tumors. J Journal of neurosurgery. 2007;107(1):1-6.

26. **Jones H,** Smith M, Pain. Awake craniotomy. Continuing Education in Anaesthesia Critical Care. 2004;4(6):189-192.
27. **Dziedzic T,** Bernstein M. Awake craniotomy for brain tumor: indications, technique and benefits. Expert review of neurotherapeutics. 2014;14(12) 1405-1415. 10.1586/14737175.2014.979793
28. **Hervey-Jumper SL,** Li J, Lau D, *et al.* Awake craniotomy to maximize glioma resection: methods and technical nuances over a 27-year period. Journal of neurosurgery. 2015;123(2):325-39. 10.3171/2014.10.JNS141520
29. **Bernstein M.** Outpatient craniotomy for brain tumor: a pilot feasibility study in 46 patients. Canadian journal of neurological sciences. 2001;28(2):120-4. 10.1017/s0317167100052781
30. **Balogun JA,** Idowu OK, Malomo AO. Challenging the myth of outpatient craniotomy for brain tumor in a Sub-Saharan African setting: A case series of two patients in Ibadan, Nigeria. Surgical Neurology International. 2019;10:71. 10.25259/SNI-47-2019
31. **Sioshansi PC,** Conway RM, Anderson B, *et al.* Risk Factors for Complications Following Lateral Skull Base Surgery and the Utility of ICU Monitoring. Otology. 2021;42(9):e1362-e8. 10.1097/MAO.0000000000003269
32. **Chand P.** Peri-operative anesthetic events in posterior fossa tumor surgery. Post-Graduate Medical Journal of NAMS. 2015;12(02).
33. **Lonjaret L,** Guyonnet M, Berard E, *et al.* Postoperative complications after craniotomy for brain tumor surgery. J Anaesthesia Critical Care. 2017;36(4):213-8. 10.1016/j.accpm.2016.06.012
34. **Mahajan C,** Rath GP, Sharma MS, *et al.* Rate and reasons for elective ventilation in patients undergoing intracranial tumour surgery. Journal of Neuroanaesthesiology Critical care research. 2014;1(02):125-130.
35. **Anthofer J,** Wester M, Zeman F, *et al.* Case-control study of patients at risk of medical complications after elective craniotomy. World Neurosurgery. 2016;91:58-65.
36. **Rhondali O,** Genty C, Halle C, *et al.* Do patients still require admission to an intensive care unit after elective craniotomy for brain surgery? Journal of neurosurgical anesthesiology. 2011;23(2):118-123.
37. **Ziai WC,** Varelas PN, Zeger SL, *et al.* Neurologic intensive care resource use after brain tumor surgery: an analysis of indications and alternative strategies. Critical care medicine. 2003;31(12):2782-2787.
38. **Todd MM,** Warner DS, Sokoll MD, *et al.* A prospective, comparative trial of three anesthetics for elective supratentorial craniotomy. Propofol/fentanyl, isoflurane/nitrous oxide, and fentanyl/nitrous oxide. Anesthesiology. 1993;78(6):1005-20. 10.1097/00000542-199306000-00002
39. **Lauta E,** Abbinante C, Del Gaudio A, *et al.* Emergence times are similar with sevoflurane and total intravenous anesthesia: results of a multicenter RCT of patients scheduled for elective supratentorial craniotomy. Journal of neurosurgical anesthesiology. 2010;22(2):110-118. 10.1097/ANA.0b013e3181c959da
40. **Magni G,** La Rosa I, Melillo G, *et al.* A comparison between sevoflurane and desflurane anesthesia in patients undergoing craniotomy for supratentorial intracranial surgery. Anesthesia Analgesia. 2009;109(2):567-571.
41. **Citerio G,** Pesenti A, Latini R, *et al.* A multicentre, randomised, open-label, controlled trial evaluating equivalence of inhalational and intravenous anaesthesia during elective craniotomy. European Journal of Anaesthesiology EJA. 2012;29(8):371-379. 10.1097/EJA.0b013e32835422db
42. **Dinsmore J.** Anaesthesia for elective neurosurgery. British journal of anaesthesia. 2007;99(1):68-74. 10.1093/bja/aem132
43. **From RP,** Warner DS, Todd MM, *et al.* Anesthesia for craniotomy: a double-blind comparison of alfentanil, fentanyl, and sufentanil. The Journal of the American Society of Anesthesiologists. 1990;73(5):896-904.
44. **Weiser TG,** Semel ME, Simon AE, *et al.* In-hospital death following inpatient surgical procedures in the United States, 1996–2006. World journal of surgery. 2011;35(9):1950-1956.
45. Organization WH. World Alliance for Patient Safety. WHO guidelines for safe surgery. http://www gawande com/documents/WHOGuide linesforSafeSurgery pdf. 2008.
46. **Mascha EJ,** Mazo V. Predicting In-hospital Postoperative Mortality for the Practitioner: Beyond the Numbers. Anesthesiology. 2016; 124 (3):523-525. 10.1097/ALN.0000000000000973
47. **Cinotti R,** Bruder N, Srairi M, *et al.* Prediction score for postoperative neurologic complications after brain tumor craniotomy: a multicenter observational study. Anesthesiology. 2018;129 (6):1111-20. 10.1097/ALN.0000000000002426
48. **Murthy S,** Leligdowicz A, Adhikari NK. Intensive care unit capacity in low-income countries: a systematic review. PloS one. 2015;10(1):e0116949. 10.1371/journal.pone.0116949

49. **Wunsch H,** Angus DC, Harrison DA, *et al.* Variation in critical care services across North America and Western Europe. Critical care medicine. 2008;36(10):2787-e8. 10.1097/CCM.0b013e318186aec8
50. **Bates I,** Maitland K. Are laboratory services coming of age in sub-Saharan Africa? Clinical Infectious Diseases. 2006;42(3):383-4. 10.1086/499368
51. **Baker T.** Critical care in low income countries. Tropical Medicine International Health. 2009;14(2):143-148.
52. **Argent A.** Critical care in Africa. Southern African Journal of Critical Care. 2009;25(1):4-8.
53. **Baelani I,** Jochberger S, Laimer T, *et al.* Availability of critical care resources to treat patients with severe sepsis or septic shock in Africa: a self-reported, continent-wide survey of anaesthesia providers. Critical care. 2011;15(1):1-12. 10.1186/cc9410
54. **Vincent JL,** Rello J, Marshall J, *et al.* International study of the prevalence and outcomes of infection in intensive care units. Jama. 2009;302(21):2323-9. 10.1001/jama.2009.1754
55. **Ghaffar S,** Pearse RM, Gillies MA. ICU admission after surgery: who benefits? Current Opinion in Critical Care. 2017;23(5):424-429. 10.1097/MCC.0000000000000448