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Predictors of postoperative complication after craniotomy

Eman Badry Ali[1], Wael Mohamed Ali[2] & Ghada Shalabi Khalf[3]
[1.] Nursing Specialist of Neurosurgery Assiut University Hospital, Egypt.
[2.] Associate Professor of Neurosurgery, Faculty of Medicine, Assuit University, Egypt.
[3.] Associate Professor of Nursing Critical Care and Emergency, Faculty of Nursing, Assuit University, Egypt.

Abstract:
Background: Craniotomy is a common neurosurgical procedure for brain tumors and other intracranial disorders. Despite advances in surgery and perioperative care, complications remain a risk. Frailty and preoperative functional status are key predictors, with frail patients facing higher rates of complications and prolonged hospitalization. **Aim of study:** Assess predictors of postoperative complications after craniotomy. **Research design:** A descriptive research design was used in this study. Setting: The Neurosurgery Intensive Care and Intermediate Care Units at the Assiut University Hospital for Neuropsychiatric Sciences and Neurosurgery. **Patients:** (80) male and female patients undergoing craniotomy operation. **Tools:** Patient assessment questionnaire and assessment of the clinical and functional outcomes of patients undergoing craniotomy, with a particular focus on neurological and non-neurological complications. **Results:** Smoking was not significantly associated with neurological or non-neurological complications (P = 0.90). Comorbidities increased the likelihood of postoperative complications, but without statistical significance for neurological (P = 0.13, OR = 2.054) or non-neurological complications (P = 0.12, OR = 2.909). Pre-ventilator dependence also showed no significant association with complications (P = 0.30 and P = 0.56). **Conclusions:** Craniotomy carries risks, with frailty and preoperative status strongly impacting outcomes. While smoking and ventilator dependence have less effect, optimizing perioperative care and refining predictive models are key to improving recovery. **Recommendation:** Careful monitoring of patients undergoing elective craniotomy may help minimize postoperative complications.

Keywords: Craniotomy, Elective craniotomy, Neurological complication & Non neurological complication.

Introduction:
Neurosurgery remains the cornerstone of curative treatment for brain tumors but is associated with significant perioperative morbidity and mortality. The risk of perioperative mortality is more than double compared to the average mortality risk, even when adjusted for the patient's baseline severity. This elevated risk can be attributed to life-threatening complications that may occur during the perioperative period, such as intracranial bleeding, intracranial hypertension, and status epilepticus, among others. As a result, it has been suggested that overnight postoperative monitoring in an intensive care unit (ICU) should be mandatory for all patients undergoing elective craniotomy **(Alexandre et al., 2020).**

Neurosurgery has grown tremendously during the last century, since its inception as a new specialization. Its history is replete with pioneers who have broadened and diversified the profession in a variety of ways, leveraging advances in scientific understanding and technology to provide novel remedies and treatments for neurosurgical diseases. The vast number of subspecialties that have evolved within the field—from pediatric neurosurgery has grown significantly over a century since its inception as a new specialty. Its history is replete with pioneers who have broadened and diversified the profession in a variety of ways, leveraging advances in scientific understanding and technology to provide novel remedies and treatments for neurosurgical diseases **(Kim et al ., 2021).**

Neurosurgery remains vital for treating nervous system disorders, but other specialties, including neuroradiology, radiotherapy, and surgical fields, are increasingly entering traditionally neurosurgical domains such as pain management, peripheral nerve surgery, stereotactic radiosurgery, spinal surgery, and endovascular procedures **(McLean et al., 2024).**

The pandemic's first 12 weeks saw widespread surgical delays. Preoperative SARS-CoV-2 infection increased 30-day postoperative mortality. While long-term effects remain unclear, delayed cancer diagnoses and treatments may raise mortality rates. Limited studies on neuro-oncology services lack a global perspective. During the first wave **(Jan–Aug 2020)**, one in five neuro-oncology patients experienced treatment changes, mainly in surgery timing. Hospitals in LMICs faced lower SARS-CoV-2 risks, allowing analysis with minimal pandemic impact, but 30-day postoperative mortality was higher in LLMICs than in HICs. Targeted preoperative testing in high-risk areas may help reduce postoperative pulmonary complications **(Poon et al., 2023).**

A craniectomy is the surgical removal of a part of the skull without replacing the bone. Craniectomies are frequently used as a decompressive treatment in patients who have excessive intracranial pressure due to a variety of causes, including infarctions, intracranial bleeding, or intractable intracranial hypertension. Other indications for craniectomies include tumor excision and the removal of infected bone flaps from previous craniotomies. Depending on the patient's needs, the dura mater may be left open **(Chughtai et al., 2019).**

The complications were categorized into neurological and non-neurological groups. Preoperative neurological deficits were assessed through a clinical examination by a neurosurgery specialist and documented in the medical record the day before surgery **(Zetterling et al 2020).**

In neurosurgical oncology patients, neurological deficits may be more closely tied to preoperative functional status compared to other surgical populations. Postoperative neurological deficits (ND) are a significant concern, as new or worsening NDs after neurosurgery are known to impact patient outcomes. In a retrospective study, Rehman et al. found that the development of postoperative NDs following glioblastoma resection significantly affected survival. The study noted that patients who developed permanent NDs post-surgery had a poorer prognosis and shorter survival times. However, those with temporary deficits showed improved survival rates **(Venkatapura et al 2021).** Nurses should detect rising intracranial pressure (ICP) early and administer treatments like mannitol. Postoperative hematomas or hydrocephalus may require surgery. While brain tumor removal isn't always curative, it improves diagnosis, relieves symptoms by reducing ICP, and enhances response to treatments like chemotherapy and radiation **(Jasim & Jaddoue, 2023).**

Significance of the study:

Surgical complications increase the length and cost of hospitalization for patients **(Ramos2016).** Reduction of postoperative neurologic complications can improve surgical outcomes by decreasing the length of hospitalization, medical costs incurred over the hospitalization, and morbidity and mortality for patients. Through identification of accurate predictors, neurosurgeons can incorporate relevant information into their treatment plan, including postoperative monitoring and estimates of the risks involved to a patient for a certain operation.

Aim of the study:

To Assess predictors of postoperative complications after craniotomy

Research question:

What are predictors of postoperative complications after craniotomy.

Patients and Methods:

Study design:

A descriptive exploratory research design was utilized to conduct this study.

Setting:

The Neurosurgery Intensive Care and Intermediate Care Units at the Assiut University Hospital for Neuropsychiatric Sciences and Neurosurgery.

Sampling:

Purposive sample of patient at first 48 hour undergoing Craniotomy operation.

Exclusion criteria:

Patients undergoing craniotomy for simple biopsy aneurysm clipping arteriovenous malformation cerebral cavernoma or central nervous system infections and urgent craniotomy were not eligible for this study.

Tools for data collections:

To collect data pertinent to this study; four tools were developed by the researcher after reviewing different related literature.

Tool (1): Patient assessment tool: It consisted of two parts:

Part (1): (Sociodemographic and clinical data) Personal data of the studied patients which include age, sex, marital status, and occupation, in addition to clinical data which include anthropometric measurements(weight, length, BMI), patient diagnosis, date of admission, date of discharge, albumin, hematocrit, and lactic acid.

Part (2): (Past medical history) Past medical history or co-morbidity of the studied patients include hypertension, diabetes mellitus, sepsis, pneumonia, liver disease, acute renal failure, ascites, angina, heart failure, MI, chemotherapy, cardiac surgery, COPD, and previous vascular disease.

Tool (2): Preoperative assessment tool: This tool was developed to assess patients in the immediate perioperative period and is composed of the following parts:

Part1:(assessment of the preoperative current status of patient)

This part includes function status, current smoker, ventilator dependence, neurological deficit (paraplegia, quadriplegia, seizure, coma, ataxia, headache), and non-neurological deficit (nausea, vomiting, hyperglycemia, cough).

Part (2): (Tumor assessment tool)
This part includes2 items, Type of tumor, and location of tumor.

Tool (3): Intra-operative assessment tool: This tool was developed to assess patients during the intra-operative period, which includes a re-assessment of the duration of the operation, surgical position, duration of anesthesia, operative administration of mannitol, fluid administration, blood loss, and blood pressure.

Tool (4): Post-operative assessment tool: This tool was developed to assess patients during the post-operative period It consists of 3 parts as follows;

Part (1): use of ventilator, sedition time, duration of mechanical ventilation.

Part (2): Reaction level scale 85 (RLs85); this scale is used to assess consciousness level and neurological deficit.

Part (3) Appearance of complication:
Neurological complications (ataxia, coma, seizure, dysphasia, intracranial bleeding, headache, motor deficit (paraplegia, quadriplegia).

Non-neurological complication (nausea, vomiting, hyperglycemia, respiratory complication, hemodynamic complication).

Method:
This study was carried out in two phases:

Preparatory phase:

Tools development
Data collection tools were developed based on reviewing the current, past, local, and international related literature in various aspects using books, articles, periodicals, magazines, and references.

Pilot study
A sample of 10% of the study subjects (8 patients) over one month in the selected setting to test the tools' applicability and clarity. The data from the pilot study were analyzed; no changes were made to the tools used, so 10% of the subjects chosen for the pilot study were included in the study.

Ethical approval
Official permission to conduct the study was obtained from the Assiut University Hospital's responsible authorities in the intensive care unit and medium care unit in the Neurosurgery Department in Neuropsychiatric Sciences and Neurosurgery Hospital after explaining the nature and purpose of the study.

Ethical considerations

1. The research proposal was approved by the Ethical Committee in the Faculty of Nursing.
2. There was no risk for patients during the application of research.
3. The study followed common ethical principles in clinical research.
4. Oral consent was obtained from patients or relatives that participated in the study, after explaining the nature and purpose of the study.
5. The researcher assured the patients that their anonymity and confidentiality would be maintained.
6. The patients or relatives were informed that they had the option to participate in the study or not and that they could withdraw from the study at any point without providing any reasons.
7. The researcher assured the patients that their data would only be used for research purposes and that their privacy would be maintained.

Assessment phase:
This phase of data collection was started once official permission was granted to proceed with the proposed study; the researcher approached the head nurses of the ICU and MCU to obtain lists of patients and reviewed those patients while considering the inclusion and exclusion criteria to select eligible patients. Patients who agreed to participate in the proposed study were interviewed individually to explain the purpose, benefits, and nature of the study and to establish rapport and cooperation. Oral consent was obtained from each of the subjects. Each selected patient was monitored in days preoperative, during operation, and postoperative after being transferred to ICU or MCU until transferred to another unit or died. During which, all study tools were filled out.

Sociodemographic (age, sex, marital status, and occupation), clinical data which included (weight, length, BMI, diagnosis, date of admission and date of discharge) which were measured at the beginning of assessment of selected patient with study criteria and when patient monitoring was stopped for any cause, patient diagnosis and length of hospital stay were collected and documented by researcher **(tool 1 part 1).**

Each patient involved in the study was assessed for co-morbidity diseases as (hypertension, diabetes mellitus, sepsis, previous neurological disease, previous surgery, COPD, liver diseases, renal diseases, pneumothorax, and congestive heart failure) **(tool1 part2)**. The researcher assessed the patient laboratory investigation as (albumin, hematocrit, and lactic acid) **(tool 1 part 1)**.

Each patient involved in the study was assessed during the preoperative period for current status as (function status, current smoker, ventilator dependence, neurological deficit (paraplegia, seizure, quadriplegia, coma ataxia, and headache), and non-neurological deficit (nausea, vomit, hyperglycemia and cough) **(Tool2 part1)**.

Each patient involved in the study was assessed at the preoperative period for tumor criteria such as (type and location of tumor) **(tool 2 part 2)**.

Each patient involved in the study was assessed during the intra-operative period for duration of operation, surgical position, duration of anesthesia, operative administration of mannitol, fluid administration, blood loss, and blood pressure. **(Tool 3)**.

Each patient involved in the study; was assessed at postoperative period for(use of ventilator, sedition time, and duration of mechanical ventilation) **(tool4 part1).**

Each patient involved in the study; was assessed at postoperative period for(conscious level and neurological deficit) by Reaction level scale 85(RLs85) **(tool4 part2)**.

Each patient involved in the study was assessed during the postoperative period for neurological and non-neurological complications. **(Tool 4, part 3**). The researcher collected data for six months (from the beginning of October 2023 to the end of March 2024).

Statistical analysis

Data entry and data analysis were done using statistical package for the social science (SPSS) version 26. Data were presented as number, percentage means and standard deviation. The Chi-square test was used to show the relation between variables. P-value considered statistically significant when $p < 0.05$.

Limitation of the study:

The result of this study could not be generalized due to the small sample size, not representative of all population, and also not geographically distributed because of the purposive sample.

Result:

Table (1): Frequency distribution of socio-demographic data of study sample (n = 80)

Items			Frequency	Percent
Sex	Male		51	63.7
	Female		29	36.3
Smoking	Yes		23	(28.8%)
	No		57	(71.3%)
Comorbidity	Liver disease		1	1.3
	Renal disease		2	2.5
	Heart failure		1	1.3
	MI		1	1.3
	Chemotherapy		20	25.0
	COPD		7	8.8
	Previous vascular disease		7	8.8
	Non		41	51.2
Items		**Preoperative**	**Post-operative**	**P value**
Ventilator dependence	Yes	2(2.5%)	3(3.8%)	0.65

- *Frequencies and percentages.*
- *Chi-Square Test for (Number and percentage)* ** Statistically significant difference (P-Value < 0.05)*

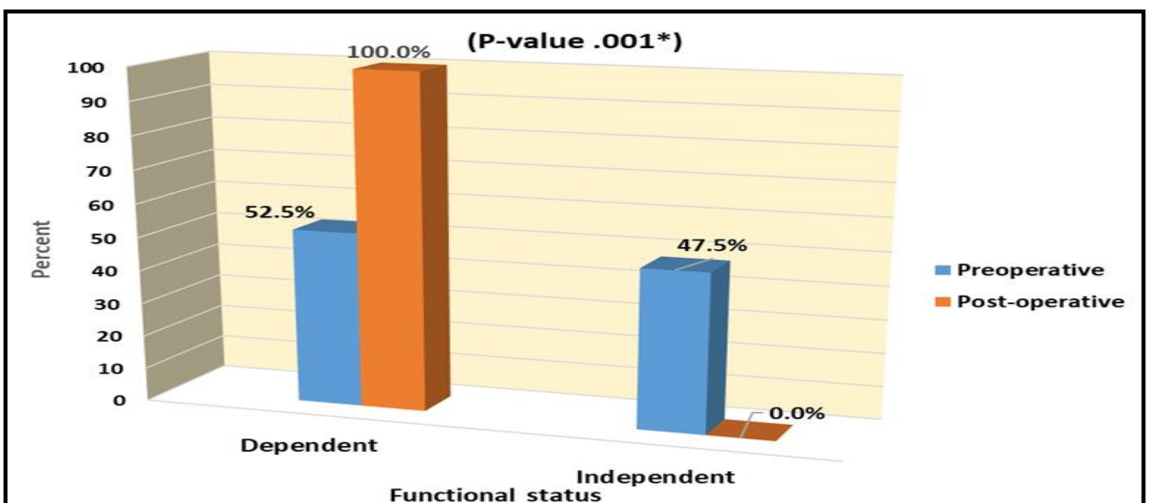

Figure (1): Pre and post-operative distribution of patients according to functional status (n = 80)

Table (2): Frequency distribution Mean & SD of clinical data of study sample (n = 80)

Items	Mean and Std. Deviation		
Age	54.06±15.58		
ICU stay	5.30±5.83		
Simplified 5_factors modified frailty index:(MFI_5)	1.67±1.30		
	Preoperative	**Post-operative**	**P value**
Albumen	39.77±5.44	37.09±4.92	0.001*
Hematocrit	39.54±3.91	36.42±4.90	0.001*
lactic acid	4.16±2.54	3.96±5.65	0.59

Paired Sample-T Test for (Mean and Std. Deviation) ** Statistically significant difference (P-Value < 0.05).*

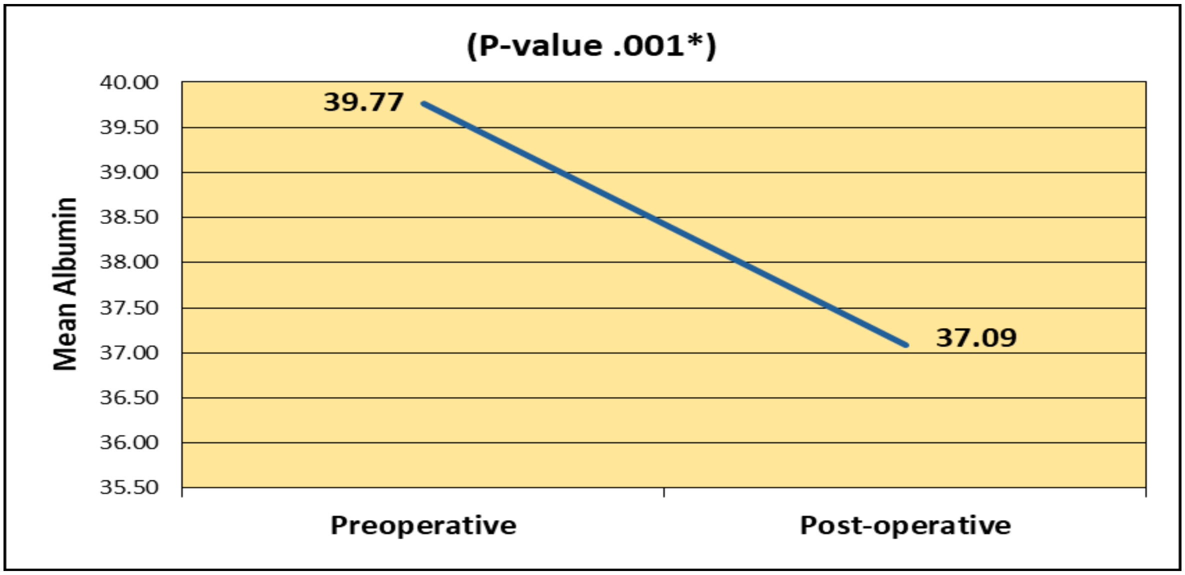

Figure (2): Relationship between pre and postoperative with mean albumin level (n = 80)

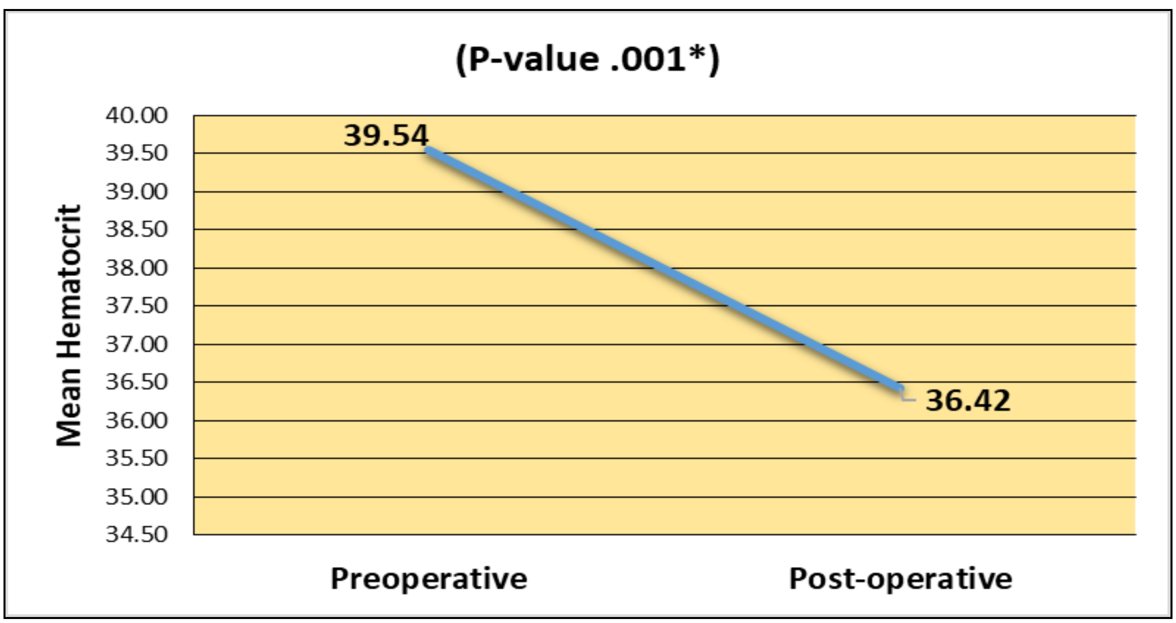

Figure (3): Relationship between pre and postoperative with mean hematocrit level (n = 80)

Table (3): Frequency distribution of neurological deficit complications (n = 80)

Deficit type	Preoperative deficit	Post-operative: Post - deficit	Post-operative: Operational deficit	P-Value
Other deficit type				
Seizures	22 (13.4%)	3 (5.0%)	6 (17.6%)	**.001***
Dysphagia	1 (0.6%)	0 (0.0%)	2 (5.9%)	
Coma	10 (6.1%)	3 (5.0%)	8 (23.5%)	
Ataxia	4 (2.4%)	2 (3.3%)	8 (23.5%)	
Headache	63 (38.4%)	48 (80.0%)	8 (23.5%)	
Visual impairment	29 (17.7%)	0 (0.0%)	0 (0.0%)	
Disturbed conscious level	35 (21.3%)	4 (6.7%)	2 (5.9%)	

Chi-Square Test for (Number and percentage) ** Statistically significant difference (P-Value < 0.05)*

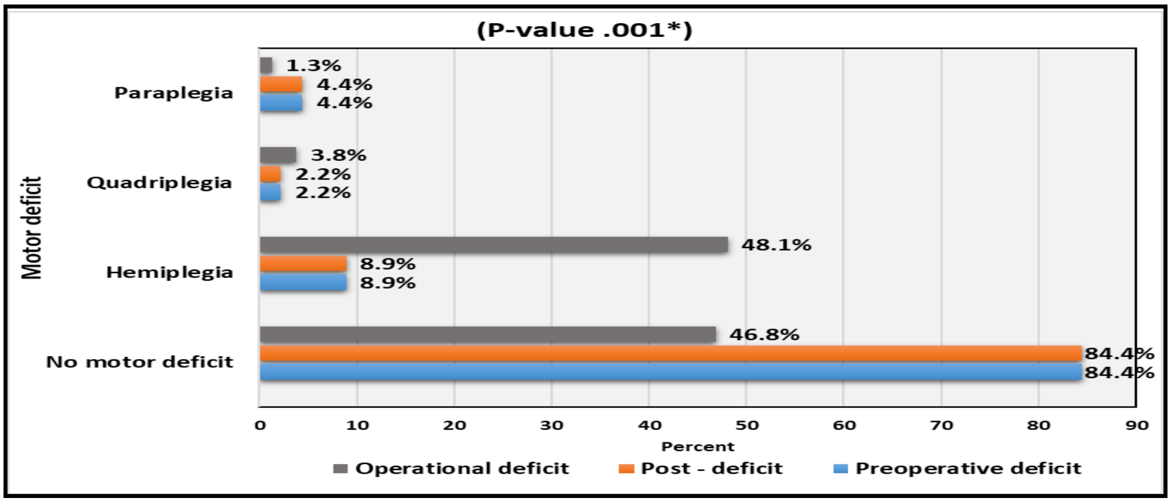

Figure (4): Frequency distribution of motor deficits among patients (n = 80)

Table (1): Shows frequency distribution of socio-demographic data of study sample. The sample consists of 80 individuals, with a majority being male (63.7%) compared to females (36.3%). Regarding smoking habits, 28.8% reported being smokers, while the majority (71.3%) were non-smokers. Various comorbidities were identified, including a small percentage with liver disease, renal disease, heart failure, myocardial infarction (MI), and chronic obstructive pulmonary disease (COPD). Chemotherapy, previous vascular disease, and a significant proportion with no comorbidities were also noted.

In terms of ventilator dependence, a low percentage were ventilator-dependent both preoperatively and postoperatively. Functional status showed a significant shift from dependency preoperatively to complete independence postoperatively. **Figure (1)** revealed a significant difference in functional status between the preoperative and postoperative stages (P = 0.001*), suggesting a notable improvement in functional independence following the operation.

Table (2): Presents frequency distribution Mean & SD of clinical data of study sample. The average age of participants was 54.06 years with a SD of 15.58, while the mean ICU stay was 5.30 days with a SD of 5.83. The Simplified 5-factor modified frailty index (MFI_5) had a mean of 1.67 with a SD of 1.30.

Figure (2): In terms of preoperative and post-operative values, albumin levels showed a significant decrease from 39.77±5.44 preoperatively to 37.09±4.92 postoperatively (P = 0.001*).

Figure (3): Similarly, hematocrit levels decreased significantly from 39.54±3.91 to 36.42±4.90 postoperatively (P = 0.001*), indicating changes in these parameters following the operation. However, no significant difference was observed in lactic acid levels between the preoperative and postoperative stages (P = 0.59).

Figure (4): Displays frequency distribution of motor deficits. Motor deficits such ssas paraplegia, quadriplegia, and hemiplegia showed varying patterns postoperatively, with hemiplegia notably increasing from 8.9% preoperatively to 46.8% postoperatively.

In contrast, the majority of patients had no motor deficits both before and after the operation.

Table (3): Among other deficit types, seizures decreased from 13.4% preoperatively to 5.0% postoperatively, whereas coma, ataxia, and headache exhibited increases postoperatively. Visual impairment and dysphagia were either reduced or absent after the operation. The statistical analysis showed significant differences in several deficits postoperatively compared to preoperatively, indicating the impact of the operation on neurological outcomes.

Discussion:

In light of the patient's demographic data, The findings of the current study indicate that more than half of the patients included were male, aligning with the results reported by **(Ran et al.,2024).** However, their study observed a higher male predominance of 80%, which deviates from the present study's findings. Conversely, **(Ravi et al., 2021)** reported a female-to-male ratio of 4:1, while **(Brani et al. (2022)** documented a near-equal gender distribution. These discrepancies highlight potential demographic variations in patient populations across different studies.

Regarding the patient prior co-morbiditis study, study indicate that a significant proportion of patients had no prior medical comorbidities. This aligns with the findings of **(Kang et al., 2021)**, who also reported a high prevalence of patients undergoing craniotomy without pre-existing conditions. Among patients with comorbidities, hypertension and diabetes were the most commonly reported conditions, as also noted by **(Ravi et al., 2021 & Shah et al., 2023).** Additionally, some studies compared the prevalence of these diseases between males and females but found no significant association between gender and the occurrence of these comorbid conditions, as demonstrated by **(Ryu et al., 2019 & Brani et al. 2022).**

In relation to the Laboratory parameters were assessed to evaluate the physiological impact of surgery. A significant decline in serum albumin levels was observed. Similarly, hematocrit levels showed a significant reduction before surgery and postoperatively. These findings suggest a notable postoperative change in nutritional and hematological status. However, lactic acid levels did not show a significant difference between the preoperative and postoperative ($p = 0.59$), indicating no major metabolic disruptions following surgery. Several recent studies have provided evidence supporting the observed changes in serum albumin and hematocrit levels postoperatively **(Xiao et al., 2023).**

Regarding neurological deficits, a study The study examined the presence of various neurological deficits before and after surgery. Seizures were reported in less than one quarter of patients preoperatively, which reduced to 5.0% postoperatively. Conversely, some neurological symptoms, including coma and ataxia, increased after surgery. Coma incidence rose from preoperatively to postoperatively, while ataxia increased. Additionally, headaches were highly prevalent, with more than one third of patients reporting headaches preoperatively, which escalated to more than three quarters (80.0%)postoperatively. The incidence of visual impairment completely resolved postoperatively, whereas disturbed consciousness levels dropped from preoperatively to after surgery.

Concerning non-neurological complication, several non-neurological complications were assessed. Intra-cranial bleeding showed a reduction postoperatively, reflecting a relatively low surgical complication rate in terms of bleeding. Nausea and vomiting were common but showed a decreasing trend postoperatively. Hyperglycemia, which was reported in less than one quarter of patients preoperatively, remained relatively stable postoperatively. However, postoperative pain levels increased significantly. Respiratory complications also increased. Hemodynamic complications, including bradycardia and tachycardia, were observed postoperatively in a small proportion of patients.

Regarding smoking status, The study findings indicate that the proportion of non-smokers was higher than that of smokers. This can be attributed to sociocultural norms discouraging smoking among women, resulting in all smokers in the study being male. Consequently, the higher proportion of non-smokers encompasses the entire female population. Smoking has been identified as a significant risk factor for postoperative complications following craniotomy, a conclusion also supported by **(Yadeta et al., 2024 & Brandi et al., 2022).** Their research further corroborates the association between smoking and increased postoperative morbidity, reinforcing the importance of smoking cessation before surgical interventions.

Regarding Tumor Characteristics and Treatment Several recent studies confirm the distribution of brain tumor types and treatment modalities observed in the current study for instance, A large-scale study on brain tumor classification and treatment trends conducted by **(Hutagalung & Dharmajaya., 2021)** found that the most common primary brain tumors include meningiomas, gliomas, pituitary adenomas, and metastases. This aligns closely with the current study. The study emphasized that meningiomas are typically managed with surgery alone, while gliomas often require a combination of surgery, radiotherapy, and chemotherapy, findings that reinforce the treatment patterns observed in the present study.

Regarding Intraoperative Data and Surgical Procedures The intraoperative findings highlighted several critical aspects of surgical intervention. The majority of craniotomies (86.3%) lasted between 3 to 5 hours, with only 13.8% classified as long craniotomies (5 to 7 hours). The supine position was the most commonly used surgical position, with majority of patients (95%) undergoing surgery in this position.

Regarding sedation protocols, a study comparing benzodiazepine-free sedation in awake craniotomy patients found that midazolam-based sedation led to a higher incidence of postoperative neurological deficits, including motor weakness and incoordination. This challenges the current study's use of standard sedation protocols, highlighting that sedation type could influence postoperative recovery outcomes **(Plitman et al., 2022).**

Dependance on mechanical ventilation. The findings of the current study revealed no statistically significant relationship between preoperative and postoperative ventilator dependence. However, a significant improvement in functional status was observed postoperatively, with a marked shift from dependency before surgery to complete independence afterward. Statistical analysis demonstrated a significant difference in functional status between the preoperative and postoperative stages (P = 0.001), highlighting the substantial impact of surgical intervention on patient independence. This is consistent with the study by (**Tufa et al., 2024)** which also reported a statistically significant relationship between functional health status before and after surgery (P < 0.001).

Conclusion:

Craniotomy remains a critical procedure with significant risks for both neurological and non-neurological complications. While factors such as frailty and functional status are important predictors of postoperative outcomes, other variables like smoking and preoperative ventilator dependence may have a lesser impact. Future research should focus on refining predictive models, improving perioperative management strategies, and exploring individualized approaches to minimize complications and enhance recovery, ultimately leading to better patient outcomes.

Recommendation:

- Replicate the study with a larger, more diverse sample for better generalizability.
- Maintain up-to-date care protocols to ensure safe, collaborative nursing for craniotomy patients.
- Show empathy to families facing difficult decisions.
- Encourage patient participation in daily activities to support mental well-being and prevent complications.
- Sustain social support through regular family check-ins.
- Conduct a thorough preoperative assessment, including medical history, medications, allergies, and psychological status.

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