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The Effect of Anesthesia Practices in Intracranial Mass Surgery on Mortality: A Retrospective Study

İntrakraniyal Kitle Cerrahisinde Anestezi Uygulamalarının Mortalite Üzerindeki Etkisi: Retrospektif Bir Çalışma

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Abstract

Objective: Brain tumors constitute a critical disease group within the field of neuroanesthesia. This study aimed to analyze our clinical experience with patients undergoing intracranial mass surgery and compare our perioperative outcomes with the existing literature.

Method: Patients who received anesthesia for intracranial mass surgery between April 2021 and April 2023 were retrospectively evaluated in this single-center study. Demographic data, anesthesia and monitoring methods, intraoperative fluid and blood product replacement, procedure durations, analgesia management, and lengths of intensive care unit and hospital stays were recorded. Postoperative in-hospital mortality and potential anesthesia-related risk factors were analyzed. Patients with incomplete records or canceled operations were excluded.

Results: In the study analyzing 370 patients, the overall in-hospital mortality rate was 9.2%. In the multivariate logistic regression analysis, restricted to the adult subgroup (n=351), high American Society of Anesthesiologists (ASA) score [particularly ASA IV; odds ratio (OR)=11.24, 95% confidence interval (CI): 2.68-47.12, p=0.001], colloid use (OR=4.65, 95% CI: 1.33-16.24, p=0.016), and blood product replacement (OR=2.94, 95% CI: 1.13-7.62, p=0.027) were identified as independent predictors of mortality. Male gender was marginally significant in the model (p=0.091), whereas age had no statistically significant effect.

Öz

Amaç: Beyin tümörleri, nöroanestezi alanında önemli bir hastalık grubunu oluşturmaktadır. Bu çalışmada, intrakraniyal kitle cerrahisi uygulanan hastalardaki klinik deneyimlerimizin analiz edilmesi ve perioperatif sonuçlarımızın literatür ışığında karşılaştırılması amaçlanmıştır.

Yöntem: Nisan 2021 ile Nisan 2023 tarihleri arasında intrakraniyal kitle cerrahisi nedeniyle anestezi uygulanan hastalar bu tek merkezli çalışmada retrospektif olarak değerlendirilmiştir. Hastaların demografik verileri, anestezi ve monitorizasyon yöntemleri, intraoperatif sıvı ve kan ürünü replasmanları, girişim süreleri, analjezi yönetimi ile yoğun bakım ve hastanede kalış süreleri kaydedilmiştir. Postoperatif hastane içi mortalite ve anestezi ile ilişkili olası risk faktörleri analiz edilmiştir. Kayıtları eksik olan veya ameliyatı iptal edilen hastalar çalışma dışı bırakılmıştır.

Bulgular: Üç yüz yetmiş hasta üzerinde yapılan çalışmada genel mortalite oranı %9,2 olarak belirlenmiş olup, 351 yetişkin hasta (n=351) ile yapılan çok değişkenli lojistik regresyon analizinde; yüksek Amerikan Anesteziyologlar Derneği (ASA) skoru [özellikle ASA IV; olasılık oranı (OO)=11,24, %95 güven aralığı (GA): 2,68-47,12, p=0,001], kolloid kullanımı (OO=4,65, %95 GA: 1,33-16,24, p=0,016) ve kan ürünü replasmanı (OO=2,94, %95 GA: 1,33-16,24, p=0,027) mortalitenin bağımsız öngördürücüleri olarak saptanmıştır. Bulgulara göre erkek cinsiyet mortalite üzerinde sınırda anlamlılık (p=0,091) gösterirken, yaşın anlamlı bir etkisi tespit edilmemiştir.

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Abstract

Conclusion: Surgery for intracranial masses requires close perioperative monitoring because of the risk of mortality. High ASA scores, colloid infusion, and blood product administration stand out as independent predictors of mortality. Maintaining systematic clinical registries allows for institutional self-evaluation and cross-center comparisons, thereby guiding prospective trials and contributing to the advancement of neuroanesthesiology.

Keywords: Intracranial mass, mortality, neuroanesthesia, perioperative management

Öz

Sonuç: İntrakraniyal kitle cerrahisi, mortalite riski nedeniyle yakın bir perioperatif takip gerektirir. Yüksek ASA skorları, kolloid infüzyonu ve kan ürünü uygulaması mortalitenin bağımsız öngördürücüleri olarak öne çıkmaktadır. Düzenli klinik kayıtların tutulması, kurumların kendi özdeğerlendirmelerini yapmalarına ve merkezler arası karşılaştırmalara olanak tanıyarak gelecekteki prospektif çalışmalara yön verecek ve nöroanesteziyolojinin gelişimine katkı sunacaktır.

Anahtar kelimeler: İntrakranyial kitle, mortalite, nöroanestezi, perioperatif yönetim

Introduction

The US Central Brain Tumor Registry reported an age-adjusted average annual incidence rate of 25.34 per 100,000 population for all primary malignant and benign brain and other central nervous system tumors between 2017 and 2021 (1). According to 2022 data from the Turkish Ministry of Health Department of Cancer, brain tumors rank 11th among all cancer types, with a 5-year prevalence rate of 29 per 100,000 population (2). Although brain tumors are less common than other major cancer types, they represent a significant disease burden in neurosurgery, with substantial morbidity and mortality. In general, brain tumors are classified as malignant (glial and metastatic tumors) or benign (meningiomas, pituitary adenomas, craniopharyngiomas, dermoid and epidermoid tumors, hemangioblastoma, colloid cyst, subependymal giant cell astrocytoma, and neuromas), and are further divided into primary and secondary types (3). In patients undergoing intracranial mass (ICM) surgery, the mass effect may cause impaired intracranial compliance or increased intracranial pressure (ICP). Furthermore, various painful stimuli during anesthesia procedures, such as laryngoscopy, skull pin placement, and skin incisions, can elevate heart rate and blood pressure, leading to sudden and dangerous increases in ICP (4).

Neuroanesthesia plays a critical role during intracranial surgery by preserving cerebrovascular autoregulation and maintaining optimal physiological conditions of the brain. Adequate cerebral perfusion pressure depends on a stable mean arterial pressure and normal ICP (5). Preventing increases in ICP, optimizing intracranial compliance to facilitate tumor resection, maintaining a level of consciousness that allows for early neurological assessment, ensuring intraoperative hemodynamic stability, and managing blood loss are among the key priorities of optimal neuroanesthesia (6,7).

In this retrospective study, the primary objective was to evaluate the in-hospital mortality rate among patients who underwent ICM surgery at our tertiary center. The secondary outcomes included demographic characteristics and intraoperative and postoperative data. We aimed to analyze the predictors affecting mortality and discuss these findings in light of the existing literature

Materials and Methods

This retrospective, observational, single-center study was conducted to evaluate patients who received anesthesia for ICM surgery between April 2021 and April 2023. The study was approved by the Local Ethics Committee of University of Health Sciences Turkey, Bursa Yüksek İhtisas Training and Research Hospital (date: 19.04.2023; decision no: 2011-KAEK-25 2023/4-19) and was conducted in accordance with the principles of the Declaration of Helsinki. Patient consent was waived due to the retrospective nature of the study and the anonymity of the data. Study data were retrieved from the hospital's electronic medical record system and pre- and intraoperative patient charts. Patients whose surgeries were canceled, those with incomplete records, and those undergoing emergency or repeat operations were excluded. Patients of all ages who underwent elective ICM surgery were included.

Demographic characteristics [age, gender, comorbidities (hypertension, diabetes mellitus, cardiovascular diseases, pulmonary diseases, renal diseases, and endocrine diseases), and American Society of Anesthesiologists (ASA) physical status], intraoperative monitoring methods, anesthesia technique [total intravenous anesthesia (TIVA) or inhalation anesthesia], anesthetic and anti-edema drugs, procedure duration, types and amounts of administered fluids, erythrocyte suspension (ES) and fresh frozen plasma (FFP) transfusions, and intraoperative complications were recorded. Complications were defined as hypertension (mean blood pressure >105 mmHg or a >20% increase in

mean arterial pressure from baseline), hypotension (blood pressure <90/60 mmHg or a >20% decrease in mean arterial pressure from baseline), tachycardia (>100 beats/min), and bradycardia (<50 beats/min). Additionally, administered treatments, analgesic management, and durations of intensive care unit (ICU) stays and hospital stays were documented. Postoperative in-hospital mortality and factors potentially related to anesthesia practices were analyzed.

According to institutional routine, patients received intravenous midazolam for premedication. Anesthesia was induced with propofol (2-3 mg kg^{-1}), fentanyl (2 µg kg^{-1}), and rocuronium bromide (0.6 mg kg^{-1}). For the maintenance of anesthesia, either TIVA (propofol-fentanyl infusion; 5-6 mg kg^{-1} h^{-1}, 1-2 µg kg^{-1} h^{-1}) in a 50% air-50% oxygen mixture or inhalation anesthesia with 2% sevoflurane or 6% desflurane was administered. At the end of the procedure, neuromuscular blockade was reversed using 0.015 mg kg^{-1} atropine with 0.05 mg kg^{-1} neostigmine, or 2-4 mg kg^{-1} sugammadex intravenously, for patients scheduled for extubation. All patients underwent invasive arterial, central venous (via the right subclavian vein), and urinary catheterization for intraoperative hemodynamic and fluid monitoring.

Statistical Analysis

Data analysis was performed using SPSS version 21.0 (IBM Corp., Armonk, NY, USA). Continuous variables were presented as mean ± standard deviation or median (minimum-maximum), and categorical variables as number (percentage). Due to the sample size imbalance, no comparative statistical tests were performed between the adult (n=351) and pediatric (n=19) subgroups; pediatric data were evaluated descriptively.

To identify mortality predictors, univariate logistic regression was performed. Due to the small sample size (n=19) and a low number of events (n=2) in the pediatric cohort, multivariate regression modeling was restricted to adult patients (n=351). Variables with $p<0.20$ in univariate screening, or those considered clinically significant (including continuous age to control for intra-cohort variations), were included in the multivariate model. To prevent multicollinearity, the highly correlated ES and FFP transfusions ($r=0.859$, $p<0.001$) were merged into "blood product transfusion". The final adult model was built using the backward-stepwise likelihood-ratio method. Model fit was verified via the Hosmer-Lemeshow test ($p=0.342$) and Nagelkerke R^2 ($R^2=0.181$). A p-value of <0.05 was considered statistically significant.

The primary outcome of the study was in-hospital mortality among patients undergoing ICM surgery. The sample size calculation was based on a mortality rate of 17.5% (299/1709) reported in the literature (8-10). A G*Power (v3.1.9.7) calculation indicated that a total of 370 patients would be required to achieve the targeted statistical power, assuming a two-sided $\alpha=0.05$ and 80% power and that the observed mortality rate could deviate by at least 4% from the reference value (effect size $g=0.04$).

Results

Five of the 375 ICM surgical patients were excluded from the study due to insufficient data, leaving 370 patients (19 of whom were pediatric) for final analysis. The demographic characteristics, intraoperative data, and postoperative data of the patients are summarized in Tables 1 and 2. Of the included patients, 57.6% were male. The median age was 59 years for males and 53 years for females, with an age range from 2 to 98 years. The most common comorbidity was hypertension (28.9%). The overall rate of systemic comorbidities was 75.5% across all age groups, with the highest prevalence observed in patients over 65 years of age.

The mean anesthesia and surgery durations were 272.2±66.2 min and 214.7±63.3 min, respectively. Midazolam was

Table 1. Demographic characteristics

Variable	Whole cohort (n=370)	Adult (n=351)	Pediatric (n=19)
Age (years), median (min-max)	53 (2-98)	55 (18-98)	8 (2-17)
- Female	53 (2-95)	54 (18-95)	7 (2-17)
- Male,	59 (6-98)	60 (18-98)	10 (6-17)
Gender, n (%)			
- Male	213 (57.6)	202 (57.5)	11 (57.9)
ASA score, n (%)			
- I	78 (21.1)	70 (19.9)	8 (42.1)
- II	223 (60.3)	216 (61.5)	7 (36.8)
- III	55 (14.9)	52 (14.8)	3 (15.8)
- IV	14 (3.8)	13 (3.7)	1 (5.3)
Comorbidities, n (%)			
- Hypertension	107 (28.9)	107 (30.5)	0 (0.0)
- Diabetes mellitus	55 (14.9)	55 (15.7)	0 (0.0)
- Cerebrovascular disease	56 (15.1)	56 (16.0)	0 (0.0)
- Pulmonary diseases	50 (13.5)	49 (14.0)	1 (5.3)
- Kidney diseases	8 (2.2)	8 (2.3)	0 (0.0)
- Endocrine diseases	21 (5.7)	20 (5.7)	1 (5.3)

ASA: American Society of Anesthesiologists

Table 2. Intraoperative and postoperative data of patients

Variable	Total (n=370)	Adult (n=351)	Pediatric (n=19)	p
Duration of surgery (min), mean ± SD	214.7±63.3	217.3±62.1	166.7±48.3	
Duration of anesthesia (min), mean ± SD	272.2±66.2	274.6±64.9	227.1±55.4	
Anesthetic agents used, n (%)				
- Propofol/rocuronium/fentanyl	370 (100.0)	351 (100.0)	19 (100.0)	
- Sevoflurane	332 (89.7)	318 (90.6)	14 (73.7)	
- Desflurane	15 (4.1)	15 (4.3)	0 (0.0)	
- TIVA	23 (6.2)	18 (5.1)	5 (26.3)	
Premedication, midazolam (yes), n (%)	281 (75.9)	272 (77.5)	9 (47.4)	0.049*
Intraoperative antiedema therapy, n (%)				
- Mannitol	145 (39.2)	141 (40.2)	4 (21.1)	
- Steroid	52 (14.1)	50 (14.2)	2 (10.5)	
Blood product replacement, n (%)				
- Erythrocyte suspension	51 (13.8)	48 (13.7)	3 (15.8)	
- Fresh frozen plasma	45 (12.2)	43 (12.3)	2 (10.5)	
- Colloid use	16 (4.3)	15 (4.3)	1 (5.3)	
Crystalloid fluid (mL), median (min-max)	4030 (400-7000)	4100 (600-7000)	2100 (400-3500)	
Intraoperative hemodynamic complications, n (%)				0.341*
- Hypertension**	49 (13.2)	47 (13.4)	2 (10.5)	
- Hypotension	102 (27.6)	95 (27.1)	7 (36.8)	
- Tachycardia**	54 (14.6)	45 (12.8)	9 (47.4)	
- Bradycardia	28 (7.6)	28 (8.0)	0 (0.0)	
Intraoperative cardiac complication incidence, n (%) 1-17 18-6 >65 years Early postoperative analgesics, n (%) Paracetamol Paracetamol+tramadol Paracetamol+tramadol+tenoxicam Paracetamol+tenoxicam None Condition at the end of anesthesia, n (%)	 13 (68.4) 139 (54.9) 60 (61.2) 226 (61.1) 83 (22.4) 23 (6.2) 33 (8.9) 5 (1.4)	 215 (61.3) 78 (22.2) 22 (6.3) 31 (8.8) 5 (1.4)		<0.001* <0.001*
- Extubated	284 (76.8)	271 (77.2)	13 (68.4)	
- Intubated	86 (23.2)	80 (22.8)	6 (31.6)	
Length of stay in the ICU (days), mean ± SD	6±3.9	6±3.8	5±3.1	
Length of stay in hospital (days), mean ± SD	12±3.9	12±3.8	9±3.4	
Discharge status, n (%)				
- Living	336 (90.8)	319 (90.9)	17 (89.5)	
- Dead (exitus)	34 (9.2)	32 (9.1)	2 (10.5)	

Continuous variables were presented as mean ± standard deviation (SD) or median (minimum-maximum) based on their distribution characteristics, while categorical variables were reported as number (percentage). For intergroup comparisons of continuous variables, the independent-samples t-test or the Mann-Whitney U test was used; for categorical data, the Pearson chi-square or Fisher's exact test was employed. TIVA: Total intravenous anesthesia, ICU: Intensive care unite, **: The hypertension limit was defined as MBP >105 mmHg or a >20% increase in mean arterial pressure from baseline, and the hypotension limit was defined as 90/60 mmHg or a >20% decrease in mean arterial pressure from baseline. **The tachycardia and bradycardia limits were set at 100 and 50 beats/min, respectively

administered for premedication in 75.9% of the patients. Anesthesia was induced with propofol (100%), rocuronium (100%), and fentanyl (100%). For the maintenance of anesthesia, sevoflurane was used in 89.7% of patients, desflurane in 4.1%, and TIVA in 6.2%. Anti-edema treatment included intraoperative administration of mannitol in 39.2% of patients and of steroids in 14.1%. The average volume of crystalloid solution administered per patient during surgery was 4.030 mL. Regarding transfusions and fluids, 11.4% of patients received 1 unit of ES, 10% received 1 unit of FFP, and 3.2% received 500 mL of colloid.

Intraoperative cardiac complications were observed in 57.3% of the cases. The most common complication was hypertension (31.9%), followed by tachycardia (17%), hypotension (16.8%), and bradycardia (4.3%). While the intraoperative cardiac complication rate did not differ significantly across age groups, it was significantly lower in patients who received premedication than in those who did not (p=0.341 and p=0.049, respectively).

According to the medical records, 76.8% of patients were successfully extubated at the end of surgery. Sugammadex was used to reverse neuromuscular blockade in 89.1% of patients. For postoperative analgesia, a combination of 1 g paracetamol and 100 mg tramadol was administered to 84.3% of patients. Postoperatively, 9.46% of patients were transferred directly to the ICU, and 90.54% to the post-anesthesia care unit (PACU). The mean hospital and ICU lengths of stay were 12±39 days and 6 ±39 days, respectively. The overall in-hospital mortality rate was 9.2%.

In the univariate logistic regression analysis conducted strictly within the adult subgroup (n=351), gender demonstrated a borderline-significant association [odds ratio (OR) =2.14, 95% confidence interval (CI): 0.97-4.72, p=0.060], indicating an increased trend toward mortality among male patients. No statistically significant relationship was found between age and mortality within the adult cohort (OR =1.01, 95% CI: 0.99-1.03, p=0.384). Evaluation of the ASA physical status revealed a significant overall association with mortality (p=0.002), which was primarily driven by the ASA IV group; the risk of mortality was significantly higher in ASA IV patients compared to the ASA I reference group (OR =9.45, 95% CI: 2.41-36.80, p=0.001). Conversely, no significant differences were found for the ASA II and ASA III groups compared to ASA I. Regarding clinical interventions, colloid use (OR =6.82, 95% CI: 2.28-20.41, p<0.001) and blood product replacement (OR =3.42, 95% CI: 1.49-7.85, p=0.004) were significantly associated with increased mortality. In contrast, no statistically significant associations were found for the maintenance anesthesia method (OR =1.48, 95% CI: 0.41-5.32, p=0.548), premedication (OR =0.89, p=0.776), anesthesia duration (OR =1.002, p=0.491), or surgical duration (OR =1.001, p=0.588) (Table 3). Gender, age, ASA score, colloid use, and blood product transfusion (variables found significant at p<0.20 in the univariate screening or considered clinically important) were included in the multivariate logistic regression model. To eliminate the risk of multicollinearity, highly correlated ESs and FFP transfusions (r=0.859, p<0.001) were evaluated as a single composite variable named “blood product transfusion”. The model was constructed using the backward likelihood ratio method. The multivariate analysis showed that the model was statistically significant and had an acceptable goodness-of-fit (Hosmer-Lemeshow test, p=0.342). The explanatory power of the model remained at a clinically interpretable level Nagelkerke (R^2=0.181). In the final multivariate analysis, the ASA score was identified as the

Table 3. Restricted logistic regression analysis of predictors for mortality (adult subgroup only, n=351)

Variable	Univariate analysis		Multivariate analysis	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Gender (Ref: Female)	2.14 (0.97-4.72)	0.060	2.08 (0.89-4.87)	0.091
Age (per year continuous)	1.01 (0.99-1.03)	0.384	—	—
ASA classification	—	0.002	—	0.002
- ASA II (ref: ASA I)	0.84 (0.30-2.35)	0.741	0.81 (0.28-2.31)	0.694
- ASA III (ref: ASA I)	1.71 (0.52-5.48)	0.375	1.63 (0.46-5.72)	0.444
- ASA IV (ref: ASA I)	9.45 (2.41-36.80)	0.001	11.24 (2.68-47.12)	0.001
Use of colloids (Ref: No)	6.82 (2.28-20.41)	<0.001	4.65 (1.33-16.24)	0.016
Blood product replacement (Ref: No)	3.42 (1.49-7.85)	0.004	2.94 (1.13-7.62)	0.027
Model fit statistics: Nagelkerke R^2=0.181, Hosmer-Lemeshow p=0.342.				

OR: Odds ratio, ASA: American Society of Anesthesiologists, CI: Confidence interval. Analysis was restricted to the adult subgroup (n=351) to evaluate age and clinical predictors within a homogeneous cohort. Variables with p<0.10 in the univariate screening were included in the multivariate model

strongest independent predictor of mortality, with a marked increase in risk in the ASA IV group compared to ASA I (OR =11.24, 95% CI: 2.68-47.12, p=0.001). Colloid use (OR =4.65, 95% CI: 1.33-16.24, p=0.016) and blood product transfusion (OR =2.94, 95% CI: 1.13-7.62, p=0.027) were the other independent predictors of mortality. The gender variable remained at the margin of significance (OR =2.08, 95% CI: 0.89-4.87, p=0.091), and age demonstrated no significant independent risk within the adult model (Table 3).

Discussion

This retrospective study analyzed data from patients who underwent anesthesia for ICM surgery. The youngest patient was 2 years old, the oldest was 98 years old, and 57.6% of the patients were male. Hypertension was the most common comorbidity; systemic comorbidities were significantly more prevalent in the group aged 65 years or older. Premedication with midazolam was administered to approximately three-quarters of the patients, and intraoperative cardiac complications occurred less frequently among these patients. Age, maintenance anesthesia method, premedication, and the durations of anesthesia and surgery had no significant independent effect on mortality. On the other hand, a high ASA score (ASA IV), blood product transfusion, and colloid use were significantly associated with increased mortality, while male gender was of marginal significance.

Our findings showed that 57.6% of patients undergoing surgery for ICM were male, which is consistent with the general neurosurgical literature showing a slight male predominance (8-10). For instance, Gökduman et al. (8) reported this rate as 52%, Çetinkaya et al. (9) as 52.9%, and Yegin et al. (10) as 56.1%.

ICMs can affect individuals across all age groups. In our study, the median age was 59 years for men and 53 years for women. In comparison, Özmete and Arıboğan (11) reported a mean patient age of 48.6 years, while Yegin et al. (10) reported a mean age of 42.7 years, with 72.9% of patients falling between 18 and 74 years of age. Furthermore, Aslantürk et al. (12) found that 44% of their population were pediatric patients (<18 years) and 56% were adults. In our cohort, the most common age range was 18-64 years, accounting for 68.4% of the cases. Because our institution had active pediatric neurosurgery programs during the study period, 5.1% of our patients were between 2 and 17 years old.

In a study by Özmete and Arıboğan (11) involving 112 patients undergoing ICM surgery, 11 patients were classified as ASA I, 55 as ASA II, and 46 as ASA III. Similarly, the vast majority of our patients were classified as ASA II, particularly in the 18-64-year age group. The high prevalence of ASA II patients is attributable to the fact that patients undergoing ICM surgery are typically middle-aged or older. Consequently, the prevalence of at least one systemic comorbidity increases with age, while factors such as smoking or alcohol use in otherwise healthy patients can also elevate the baseline ASA score.

The prevalence of concomitant systemic diseases increases with advancing age. Yegin et al. (10) noted that the prevalence of systemic diseases was higher in adult and geriatric populations than in pediatric age groups, with cardiovascular diseases being the most common comorbidity at 26.9%. Hypertension was the most frequent comorbidity in our study (28.9%), and the geriatric population (>65 years) had the highest rate of systemic comorbidities (75.5%).

Premedication is typically avoided in patients with severe intracranial hypertension, as hypercapnia resulting from respiratory depression can further elevate ICP. However, benzodiazepines can be safely administered to patients with normal ICP for their amnestic, anxiolytic, and sedative benefits (12). A previous study reported that IV midazolam (1-3 mg) was administered for premedication in 77.7% of suitable patients without inducing respiratory depression (11). Similarly, 75.9% of the patients in our study received premedication with 2 mg of IV midazolam. We observed no instances of respiratory depression, and premedicated patients experienced fewer intraoperative cardiac complications. This favorable clinical outcome highlights the key role of midazolam's anxiolytic properties in stabilizing perioperative hemodynamics.

Ensuring rapid and smooth emergence for early neurological assessment is paramount in neurosurgery. Consequently, agents such as thiopental, propofol, rocuronium, and fentanyl are widely reported in the literature as preferred for induction, whereas maintenance is typically provided by inhalation anesthetics (sevoflurane, desflurane) or by TIVA with propofol and remifentanil. These agents are well-documented for preserving cerebral metabolism, reducing ICP, and allowing rapid reversibility (9,10,13-17). Yegin et al. (10) reported that thiopental or propofol was used for induction in 85.6% of cases, with rocuronium (15.9%) or cisatracurium (11.8%) as muscle relaxants; for maintenance, TIVA was utilized in 69.3% of cases and inhalation anesthesia in 17.7%. Another study reported that induction was performed with propofol (90.2%), rocuronium (100%),

and fentanyl (100%), while maintenance was achieved with sevoflurane (49.1%), isoflurane (18.8%), or TIVA (32.1%) (11). In our study, propofol, rocuronium, and fentanyl were uniformly administered to all patients during induction. For anesthesia maintenance, various techniques were used in accordance with the literature, with sevoflurane being the most commonly used agent.

Intraoperative cardiac complications are common during neurosurgery, with a reported incidence ranging from 16% to 62% (10). Minami et al. (18) reported an intraoperative complication rate of 28.7%, with 15% related to the cardiovascular system. Furthermore, Gerçek et al. (19) reported cardiac complications in 25.6% of cases, and Çetinkaya et al. (9) reported them in 24.1%. In our study, the cardiac complication rate was 57.3%, higher than that reported in several studies, and hypertension developed in one-third of the patients. This high rate of intraoperative cardiac responses is likely driven by the high baseline prevalence of systemic comorbidities (75.5%) in our geriatric group and by hypertension being our most common baseline comorbidity (28.9%).

Surgery for ICMs carries an inherent risk of significant blood loss. Çetinkaya et al. (9) reported that blood products were required in 6.6% of 5,172 patients undergoing neuroanesthesia. In our cohort, 13.8% of patients required ES transfusions, and 12.2% required FFP replacement. While univariate and multivariate analyses showed that colloid use and blood product transfusions (FFP and ES) were associated with increased mortality, this finding does not imply a direct causal relationship between administration of fluids or blood and mortality. Instead, the need for colloids and blood products reflects greater blood loss, higher surgical complexity, and a more critical patient condition. Therefore, rather than being direct causes of mortality, these variables should be interpreted as indicators of high perioperative risk and increased severity of illness.

Numerous factors, including the patient's physical status, surgical technique, and the expertise of the anesthesia and surgical teams, can influence the duration of procedures. Çetinkaya et al. (9) reported an average anesthesia duration of 146 minutes, whereas Yegin et al. (10) reported an average of 217 minutes. In our study, the mean durations of anesthesia and surgery were 272 and 214 minutes, respectively. Statistical analysis revealed no significant relationship between the duration of anesthesia or of surgery and patient mortality.

Moderate or severe pain after craniotomy is reported to be quite common (20). In a retrospective study by Quiney et al. (21), the postoperative pain of 52 patients was evaluated over 24 hours; within the first 2 hours, the rates of intolerable, severe, moderate, and mild pain were reported as 18%, 37%, 29%, and 4%, respectively, among patients experiencing pain. Similarly, Mordhorst et al. (22) noted that 55% of patients experienced moderate-to-severe pain within the first 24 hours after a craniotomy. Non-steroidal anti-inflammatory drugs (NSAIDs), paracetamol, and opioids are widely used for postoperative pain management. Although opioids provide effective analgesia, they can obscure early neurological assessments, cause respiratory depression, and increase the risk of dependence. Conversely, concerns regarding an increased risk of postoperative bleeding often limit the routine use of NSAIDs after a craniotomy. In our cohort, postoperative analgesia relied heavily on multimodal regimens to minimize bleeding risks; a high proportion of patients (84.3%) received a combination of intravenous paracetamol and tramadol.

To facilitate early neurological assessment following ICM surgery, patients are routinely extubated in the operating room unless specific anesthetic or surgical contraindications arise. A study focusing on posterior fossa surgery reported that 25 out of 30 patients were successfully extubated in the operating room, while 5 were transferred to the ICU intubated; another study noted that all 112 analyzed patients were transferred to the ICU extubated (11,15). In our study, 76.8% of the patients were extubated at the end of the procedure and transferred to the PACU. Additionally, intravenous sugammadex (4 mg kg^{-1}) was administered to 89.1% of these extubated patients, ensuring rapid and safe neuromuscular blockade reversal.

In our study, the lengths of hospital and ICU stay ranged from 1 to 547 days, with overall median durations of 7 days for hospital stay and 1 day for ICU stay. Regarding the postoperative ICU length of stay, Yegin et al. (10) reported an average of 6 days, Özmete and Arıboğan (11) reported 3 days, and İlçe et al. (23) reported 11 days. Our results demonstrate that the duration of ICU stay in our clinic was considerably shorter than that reported in the referenced literature.

Mortality rates for ICM surgery range from 17.49% to 20% (10,12). In our study, 90.9% of adult patients were successfully discharged, and the mortality rate was lower at 9.1%. While age and gender had no significant impact within the adult subgroup, a high ASA score significantly increased mortality, aligning with previous findings (24).

However, these findings should be interpreted in light of our statistical limitations. First, because of the small sample size (n=19) and the low number of mortality events (n=2) in the pediatric cohort, multivariate regression modeling could not be performed reliably, restricting our risk factor analysis to the adult subgroup (n=351). Furthermore, our adult model's Nagelkerke R^2 of 0.181 indicates limited explanatory power, suggesting that mortality is largely driven by other clinical factors, such as tumor characteristics, which were not included. Additionally, because of the small number of mortality events, a low events-per-variable ratio and risk of overfitting cannot be ruled out. Therefore, our results should be interpreted with caution.

Study Limitations

Our study has several limitations. First, although intracranial tumors inherently differ in etiology, localization, and prognosis between pediatric and adult populations, a separate risk analysis for mortality could not be performed due to the small sample size of the pediatric subgroup and the extremely low number of mortality events in that subgroup. Additionally, due to the retrospective design of our study, critical tumor-specific variables that directly impact mortality rates—such as exact anatomical localization (supratentorial vs. infratentorial), histopathological features, benign/malignant status, and metastatic status—could not be evaluated. Data constraints also prevented the assessment of intraoperative positioning and post-surgical complications that influence mortality, such as venous thromboembolism.Second, the exact causes of in-hospital mortality (e.g., surgical complications, sepsis, cardiovascular events, or anesthesia-specific complications) could not be classified. This lack of specific cause-of-death data limits our ability to establish a direct causal link between the selected anesthesia methods and patient mortality. Furthermore, the proportion of patients in the TIVA group was relatively small (6.2%), resulting in limited statistical power when comparing outcomes between total intravenous and inhalation anesthesia. Finally, the absence of detailed records of postoperative pain assessment restricted our ability to define and recommend specific and more effective pain management strategies.

Conclusion

ASA IV physical status, colloid use, and blood product transfusion were identified as independent predictors of mortality in patients undergoing elective ICM surgery. Notably, an ASA IV classification was associated with the most significant increase in mortality risk. These findings should be carefully considered during perioperative management and treatment planning for high-risk neurosurgical patients. Furthermore, maintaining structured and systematic anesthesia records is essential to facilitate clinical self-evaluation, quality improvement, and objective institutional comparisons. Periodic retrospective audits will continue to contribute significantly to the advancement of clinical neuroanesthesiology.

Ethics

Ethics Committee Approval: The study was approved by the Local Ethics Committee of University of Health Sciences Turkey, Bursa Yüksek İhtisas Training and Research Hospital (date: 19.04.2023; decision no: 2011-KAEK-25 2023/4-19) and was conducted in accordance with the principles of the Declaration of Helsinki.

Informed Consent: Patient consent was waived due to the retrospective nature of the study and the anonymity of the data.

Footnotes

Authorship Contributions

Concept: Ş.E., K.Ç., M.A., Design: Ş.E., K.Ç., M.A., S.E., Ş.E.Ö., N.K., A.D., O.S.A., A.O., D.K., Data Collection or Processing: Ş.E., K.Ç., M.A., S.E., Ş.E.Ö., N.K., A.D., O.S.A., A.O., D.K., Analysis or Interpretation: Ş.E., K.Ç., M.A., S.E., Ş.E.Ö., Literature Search: Ş.E., K.Ç., M.A., S.E., Ş.E.Ö., N.K., A.D., O.S.A., A.O., D.K., Writing: Ş.E., K.Ç., M.A., S.E., Ş.E.Ö., N.K., A.D., O.S.A., A.O., D.K.

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