



Perioperative Outcomes Following Surgery for Pediatric Brain Tumors: Assessment of Eight-year Single-center Short-term Results

Pediyatrik Beyin Tümörlerinde Cerrahi Sonrası Perioperatif Sonuçlar: Sekiz Yıllık Kısa Vadeli Sonuçların Değerlendirilmesi

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Abstract

Introduction: Various perioperative problems occur in patients operated on brain tumors. While many studies focused on the long-term effects of surgery, few focused on the perioperative period. The aim of this study to evaluate clinical and laboratory features and determining the factors which are effecting the outcome in operated patients for brain tumors our pediatric intensive care unit (PICU).

Methods: Patients who underwent intracranial tumor surgery in the PICU during the eight-year period were retrospectively screened.

Results: Seventy-four patients were included in the study, mean age was 60 (1.5-192) months, and supratentorial tumors were detected in 41 (55.4%) patients. The median length of stay (LOS) in PICU of the patients was 5 (1-150) days. When supratentorial tumor localization, ventriculoperitoneal shunt presence, central venous catheter related bloodstream infection, ventilator-associated pneumonia and other infections were evaluated, a statistically significant difference was found between the two groups when patients' LOS in the PICU is evaluated in 2 groups of more than 15 days (77%) and less than 15 days (23%). In the postoperative period, diabetes insipidus (DI) in 12 (16%), septicemia in 9 (12%), shunt infection in 8 (10%), hydrocephalus in 7 (9%), seizures in 5 (6%), cranial nerve palsy in 5 (6%) in patients.

Conclusion: Neurological sequelae increased with younger age and were more common in patients with infratentorial tumors. While a relationship was found between delta sodium and DI in the postoperative first 4 days, without relationship was found with neurological sequelae.

Keywords: Brain tumor, child, perioperative period problems, pediatric intensive care, delta sodium

Öz

Giriş: Beyin tümörü nedeniyle ameliyat edilen hastalarda ameliyat sırasında çeşitli sorunlar ortaya çıkmaktadır. Pek çok çalışma ameliyatın uzun vadeli etkilerine odaklanırken, çok azı perioperatif döneme odaklandı. Bu çalışmanın amacı çocuk yoğun bakım ünitemizde (ÇYBÜ) beyin tümörü nedeniyle opere edilen hastaların klinik ve laboratuvar özelliklerinin değerlendirilmesi ve sonuca etki eden faktörlerin belirlenmesidir.

Yöntemler: Sekiz yıllık süreçte ÇYBÜ'de intrakraniyal tümör ameliyatı geçiren hastalar geriye dönük olarak tarandı.

Bulgular: Çalışmaya 74 hasta dahil edildi, ortalama yaş 60 (1,5-192) ay olup, 41 (%55,4) hastada supratentoryal tümör tespit edildi. Hastaların ÇYBÜ'de ortalama kalış süresi 5 (1-150) gündü. Supratentoryal tümör lokalizasyonu, ventrikülperitoneal şant varlığı, santral venöz kateter ilişkili kan dolaşımı enfeksiyonu, ventilatör ilişkili pnömoni ve diğer enfeksiyonlar değerlendirildiğinde, hastaların ÇYBÜ'de kalış süreleri 15 günden fazla (%77) ve 15 günden az (%23) olarak değerlendirildiğinde iki grup arasında istatistiksel olarak anlamlı fark bulundu. Ameliyat sonrası dönemde 12'sinde (%16) diyabet insipidus (Dİ), 9'unda (%12) septisemi, 8'inde (%10) şant enfeksiyonu, 7'sinde (%9) hidrosefali, 5'inde (%6) nöbet, hastaların 5'inde (%6) kraniyal sinir felci görüldü.

Sonuç: Nörolojik sekeller yaş ilerledikçe arttı ve infratentoryal tümörlü hastalarda daha sık görüldü. Ameliyat sonrası ilk 4 günde delta sodyum ile Dİ arasında ilişki bulunurken, nörolojik sekellerle ilişki saptanmadı.

Anahtar Kelimeler: Beyin tümörü, çocuk, perioperatif dönem sorunları, çocuk yoğun bakım, delta sodyum

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Introduction

Central nervous system (CNS) tumors are the most common solid neoplasms in childhood.¹ One of four childhood cancers appear in CNS and CNS tumors account for the highest rate of death in children. Brain tumors are approximately 8-15% of pediatric cancers and third most common cancer type after leukemia (30%) and lymphoma (15%).² Although there are differences in tumor type and age at diagnosis, the 5-year survival rate of primary malignant and non-malignant brain tumors is 73%. Mass effect and treatment modalities (brain surgery procedure, radiotherapy, and chemotherapy) in the treatment of brain tumors create various difficulties for patients. Most of the first symptoms of CNS tumors are also seen in more common and less severe childhood diseases like gastroenteritis, migraine, and behavioral problems.^{3,4}

Surgically removal of the tumor is the main treatment for brain tumors. Patients especially must be followed in pediatric intensive care unit (PICU) for managing surgical, neurological, infectious, and endocrinological problems and maintaining electrolytes in the postoperative period. Most of the studies focus on long-term outcomes of brain tumor patients but only a few study short-term outcomes. In our study, we evaluated demographic, clinical, and laboratory features of patients who operated on brain tumors and affecting factors of morbidity and mortality in our PICU.

Materials and Methods

Study Design and Study Population

In our study, there are 86 patients who followed up in PICU after intracranial tumor surgery between 2014-2022 in 8 years period. This retrospective was approved by the Local Ethics Committee of Ankara University Hospital (ethics committee number: İ11-696-22). Two of 86 patients were excluded due to lack of data while 10 of 86 patients were excluded due to length of stay (LOS) in PICU less than 24 hours. This study's main focus is on evaluating patients operated on brain tumor perioperative period.

Data Collection

Patients' symptoms at admission, the time between diagnosis and symptoms, patients' pediatric risk of mortality (PRISM III) scores, pediatric logistic organ dysfunction (PELOD 2) scores, Glasgow Coma score (GCS), complete blood count, blood gas, biochemical indicators, radiological findings at admission, tumor localization, tumor origin, tumor grade, surgery technique, the existence of residue mass, postoperative imaging findings, tumor histology, existence of ventriculoperitoneal (VP) shunt and implantation time,

existence of external drainage and implantation time, complications after surgery were recorded. The patients were examined in terms of their characteristic features in subgroups with and without DI, with and without neurological sequelae.

Definitions

Hyponatremia level was accepted as 135 mEq/L in the study. Patients' daily delta sodium values in the first 7 days were recorded. Delta sodium value is defined as the difference between the highest and lowest sodium values. In the study, delta sodium 5 is stated as the difference value between two measures is five and more as delta sodium 10 is stated as the difference value between the highest and lowest sodium measure is more than 10. DI was typically diagnosed with polyuria, polydipsia, high sodium level, and urine density below 1005. Whether tracheostomy is implemented, mechanical ventilation (MV) duration, usage of an inotrope, whether CRRT and PEX are done, and patients' outcomes were recorded. The reference range of different values is stated below.

Adrenocorticotrophic hormone (ACTH): 7.2-63.3 pf/mL, cortisol: 6.02-18.4 mcg/dL, thyroid-stimulating hormone (TSH): 0.38-5.33 microIU/mL.

Statistical Analysis

The data were analyzed using the SPSS version 25.0 software (IBM Corp, Armonk, NY). Mean, standard deviation, median, frequency distribution, and percentage values were determined as descriptive statistics of the variables. Mean values were used in parametric tests and median values were used in non-parametric tests. Pearson's chi-square test and Fisher's Exact test were used to analyzing categorical variables. The data were tested for normal distribution using visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk test). The independent samples t-test was used to analyze differences in normally distributed variables between two independent groups. The Mann-Whitney U test was used to analyze differences between the median values of non-normally distributed variables. P-values <0.05 were considered statistically significant.

Results

Patient Demographic Data

We enrolled 74 patients to this study and their mean age was 60 (1.5-192) months. 39% of the patients were male. There were 55.4% of the patients' tumor where in the supratentorial area (Figure 1). Patients' GCS, PRISM III scores, PELOD 2 scores median after surgery were 12.3 (3-15), 2.6 (0-8), 2.5 (0-40), respectively (Table 1).

Postoperative Laboratory Data [Delta Sodium (Δ Na)]

When patients are compared of having DI (16%) or not (84%), there was no statistical difference between 2 groups in age, hydrocephalus or convulsion existence, LOS in PICU, and hospital ($p=0.21$, $p=0.61$, $p=0.59$, $p=0.65$, $p=0.53$, respectively). Patients' delta sodium 5 (Δ Na5 in Day 1, $p=0.002$) and delta sodium 10 values (Δ Na10 in Day 1, $p=0.01$) on the first day are statistically significant between

the 2 groups. There was a statistical difference on the second day between delta sodium and delta sodium 5 values, while no difference between delta 10 sodium values ($p<0.001$, $p=0.001$, $p=0.067$). There was a statistical difference on the third day between delta sodium and delta sodium 5 values, while no difference between delta 10 sodium values ($p=0.002$, $p=0.01$, $p=0.79$). There were statistical differences in delta sodium values on the fourth and seventh days, while no difference in delta sodium 5 values ($p=0.01$, $p=0.32$, $p=0.04$). Eleven patients (14.9%) in the DI patient group and 7 patients (9.5%) in other group had hypothalamic-pituitary-adrenal (HPA) axis defect ($p<0.001$) (Table 2).

Table 1. Demographic characteristics of patients

Parameters	Total patients
Age (months)	60 (1.5-192)
Age at being symptomatic (months)	59 (0.5-192)
Female, yes	35 (47.3%)
PRISM III score	2 (0-8)
PELOD 2 score	0 (0-40)
Hydrocephalus, n (%)	36 (59%)
Tumor location, supratentorial, n (%)	41 (55%)
High grade, n (%)	37 (50%)
Tumor resection, total, yes	46 (62.2%)
Time to diagnosis (months)	1 (0-74.5)
Number of symptoms	1 (1-4)
Initial symptom	
Headache	33 (44%)
Vomiting	28 (37%)
Cerebellar symptoms	19 (25%)
Nausea	17 (22%)
Tumor location	
Posterior fossa	29 (39%)
Midline	22 (29%)
Left hemisphere	12 (16%)
Right hemisphere	6 (8%)
Brainstem	4 (5%)
Bilateral hemispheres	1 (1%)
Tumor histology	
Astrocytoma, (%)	16 (21%)
Glioma, (%)	13 (17%)
Ependymoma, (%)	10 (13%)
Craniopharyngioma, (%)	9 (12%)
Medulloblastoma, (%)	6 (8%)
Germ, (%)	2 (2%)
Others, (%)	14 (18%)
MV usage, yes, (%)	25 (33.8%)
NIV usage, yes, (%)	4 (5.4%)
Inotrope usage, yes, (%)	6 (18%)
PICU lenght of stay (day)	5 (1-150)
Lenght of hospital stay (day)	21.5 (2-228)
28-day mortality rate, (%)	4%
Mortality, yes, (%)	11 (14%)

PRISM III: Pediatric Risk of Mortality III, PELOD2: Pediatric Logistic Organ Dysfunction 2, NIV: Non-invasive ventilation, MV: Mechanical ventilation, PICU: Pediatric intensive care unit

Neurological Disabilities

When patients are analyzed into two groups; with neurological disabilities in 20 (27%) patients and without neurological disabilities in 54 (73%) patients. There was no statistical significance between the two groups in hydrocephalus existence, sodium value on the first day after surgery ($p=0.54$, $p=0.9$, respectively). There was no statistical significance between the two groups in delta sodium levels for every days within the first 5 days ($p=0.26$, $p=0.57$, $p=0.66$, $p=0.66$, $p=0.12$, respectively). The mean age was 50 ± 46 months in the patient group with neurological disabilities whereas 82 ± 54 months in the patient group without having neurological disabilities ($p=0.02$). Tumor localizations were the supratentorial area in 6 patients (30%) in the patients with neurological disabilities, and 35 patients (64%) in the patients without neurological disabilities ($p=0.007$). According to the state of neurological disability, there was no statistical significance in terms of HPA axis defect and convulsion patients ($p=0.06$, $p=0.41$), respectively. When patients were compared with non-invasive ventilation (NIV) requirement, MV requirement, LOS in PICU and hospital, values were high in the patients with neurological disabilities and there was statistical significance between the two groups ($p=0.01$, $p<0.001$, $p<0.001$, $p<0.001$) (Table 3).

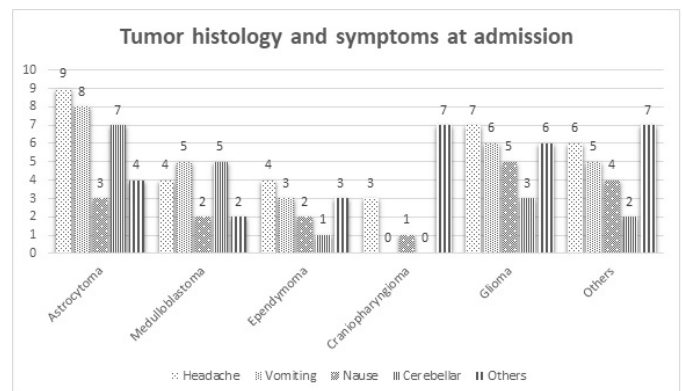


Figure 1. Tumor histology and symptoms at admission

Patient Characteristics, Preoperative and Postoperative Endocrine Laboratory Data

Hormonal studies were performed on 15 patients before surgery and 19 patients after surgery. Patients' preoperative ACTH median value was 11.8 (1.1-38), cortisol median value was 6.7 (0.5-22), TSH median value was 1.2 (0.1-4.4). Patients' postoperative ACTH median value was 4.8 (1-38),

cortisol median value was 15.3 (0.5-45.3), TSH median value was 0.4 (0-11.5). In the preoperative period, ACTH was low in 5 patients (33%), TSH was low in 3 patients (20%), and cortisol was low in 8 patients (53%). In the postoperative period, ACTH was low in 11 patients, TSH was low in 8 patients (42%), cortisol was low in 8 patients, and high in 8 patients.

Table 2. Comparison of the characteristics of patients with and without diabetes insipidus

Parameters	Total (n=74)	DI, no (n= 62)	DI, yes (n=12)	p-value
Age (months)	60 (1.5-192)	60 (1.5-192)	79 (13-170)	0.21*
Supratentorial, n (%)	41 (54%)	30 (40.5%)	11 (14.9%)	0.006***
Hydrocephalus, yes	36 (59%)	32 (52.5%)	4 (6.6%)	0.61***
Na value, first day	138 (124-166)	137 (122-148)	138 (129-148)	0.06*
ΔNa, first day (n=69)	2 (0-28)	2 (0-18)	8.5 (0-14)	0.01*
ΔNa 5, first day	23 (33.3%)	14 (20.3%)	9 (13%)	0.002***
ΔNa 10, first day	10 (14.5%)	5 (7.2%)	5 (7.2%)	0.01***
ΔNa, second day (n=54)	3.5±4.8	2.26±2.7	8±7.6	<0.001**
ΔNa 5, second day	14 (25.9%)	6 (11.1%)	8 (14.8%)	0.001***
ΔNa 10, second day	5 (9.3%)	2 (3.7%)	3 (5.6%)	0.067***
ΔNa, third day (n=53)	2 (0-11)	1 (0-11)	3 (1-8)	0.002*
ΔNa 5, third day	9 (17%)	4 (7.5%)	5 (9.4%)	0.01***
ΔNa 10, third day	1 (1.9%)	1 (1.9%)	0	0.79***
ΔNa, fourth day (n=50)	2±2.7	1.54±1.6	3.9±4.6	0.01**
ΔNa, fifth day (n=51)	2.6±4.4	1±3	3±7.4	0.32*
ΔNa, seventh day	3.2±5.3	1±5.3	3±5	0.04*
HPA axis damage, yes	18 (24.3%)	7 (9.5%)	11 (14.9%)	<0.001***
Seizure, yes	5 (6.8%)	4 (5.4%)	1 (1.4%)	0.59***
PICU length of stay	5 (1-150)	4.5 (1-150)	6.5 (1-30)	0.65*
Length of hospital stay	21.5 (2-228)	21 (2-238)	24.5 (8-46)	0.53*

ΔNa: Delta sodium, ΔNa 5: Delta sodium 5, ΔNa 10: Delta sodium 10, HPA: Hypothalamic-pituitary-adrenal, PICU: Pediatric intensive care unit, *: Independent samples t-test, **: Mann-Whitney U test, *** Fischer's Exact test

Table 3. Comparison of patient characteristics according to neurological sequelae

Parameters	Total (n=74)	NS, no. (n=54)	NS, yes (n=20)	p-value
Age (months)	73.7±53.8	82±54	50±46	0.02*
Supratentorial, n (%)	41 (54%)	35 (47%)	6 (8.1%)	0.007***
Hydrocephalus, yes	36 (59%)	27 (44%)	9 (14%)	0.54***
Na value, first day	138 (124-166)	137 (128-148)	137 (122-148)	0.9**
ΔNa first day (n=69)	2 (0-18)	2 (0-17)	3 (0-18)	0.26**
ΔNa second day (n=54)	2 (0-28)	1 (0-28)	2 (0-13)	0.57**
ΔNa fifth day (n=51)	1 (0-25)	1 (0-25)	1 (0-17)	0.12**
HPA axis damage, yes	18 (24.3%)	16 (21.6%)	2 (2.7%)	0.06***
Seizure, yes	5 (6.8%)	3 (4.1%)	2 (2.7%)	0.41***
NIV usage, yes	0.3±1.7	0.04±0.2	1.1±3.2	0.01*
MV usage, yes	5.4±17.7	0.7±2	18.3±30	<0.001*
PICU length of stay	14.3±27.4	6.9±7.7	34±46	<0.001*
Length of hospital stay	32±38	20±16	62±16	<0.001*

NS: Neurological sequelae, ΔNa: Delta sodium, ΔNa 5: Delta sodium 5, ΔNa 10: Delta sodium 10, HPA: Hypothalamic-pituitary-adrenal, NIV: Non-invasive ventilation MV: Mechanical ventilation, PICU: Pediatric intensive care unit, *: Independent samples t-test, **Mann-Whitney U test, *** Fischer's Exact test

The Patient Characteristics According to the Median LOS in PICU

When the patients were divided into 2 as less than 15 days (77%) and over (23%) according to the number of intensive care hospitalization days, respectively; patients with hydrocephalus on admission imaging were 26 (42.6%) and 10 (16.4%) ($p=0.48$). The tumor was located supratentorially in 36 (48.6%) patients in the group hospitalized for less than 15 days and in 5 (6.8%) patients in the group hospitalized for 15 days or more ($p=0.01$). The frequency of VP shunt, central venous catheter (CVC) associated, VAP, and accompanying infections was higher in the group with intensive care hospitalization for 15 days or more ($p<0.001$, $p=0.009$, $p=0.009$, $p<0.0001$, respectively). The characteristics of the patients according to the number of intensive care hospitalization days are given in the supplemental file.

Patients' Outcome and Mortality

Patients' median LOS in PICU was 5 (1-150) days, whereas the mean LOS in hospital was 21.5 (2-228) days. The median day of MV requirement was 0 days (0-132), whereas the mean day of NIV requirement was 0 days (0-12). One (1%) patient needed CRRT. Patients' mortality rate was 4% on the 28th day and 14% at discharge ($n=11$).

Discussion

There could be delays and difficulties in the diagnosis process since brain tumors are childhood's third most common tumor and having non-specific symptoms. Target treatments like genetic defining and immunotherapy will increase survival on this type of tumor in the future. Patients must be evaluated with multidisciplinary approach and patients' clinics, vitals and laboratory values must be carefully monitored to decrease morbidity and mortality. In the perioperative period, problems like convulsion, cranial nerve paralysis, muscle strength loss, cerebellar syndrome, central salt loss, syndrome of inappropriate secretion of antidiuretic hormone (SIADH), DI, CNS infection, shunt infection, HPA axis damage, endocrine disorders, and biochemical imbalances can be seen according to tumor's type, localization, surgery technique, the trend of patients' endocrinal and biochemical values.

Ten percent of children with CNS tumor has convulsions. The timing of convulsions divides into two groups early period inside the first week and the late period. Uncontrolled convulsions have bad effects on neurological outcome. A study made in adults suggests that using antiepileptics decreases convulsions in adults although no such benefit couldn't be shown in child patients. A study of Saadeh et al.⁵ researched risk factors of convulsions after supratentorial tumor resection and relations between convulsions, age, tumor localization, extent of resection, pathology, occurrence

of hydrocephalus and sodium levels, found factors that were evaluated with multiple variant regression, which are temporal lobe localization, age less than 2 years, the existence of hydrocephalus before surgery, convulsions before surgery and parietal lobe localization statistically significant. Three of our patients had convulsion as presenting symptom and 5 of our patients had convulsions after surgery. Three of 5 patients had convulsions after surgery was less than 2 years and 3 patients' tumors were localized in supratentorial area. All of three patients' had convulsions as presenting symptoms, delta sodium levels were high, and developed DI. Hydrocephalus and sodium levels were found related whereas no relations were found between DI occurrence and neurological disability.

A study by Houdemont et al.⁶ that researched postoperative neurological complications and outcomes with 117 pediatric patients who were operated on brain tumors, found a relation between LOS in PICU and severity of neurological complications ($p=0.006$). In a study of Houdemont et al.⁶ researched short-term complications in the postoperative period with 117 children in 2011, complications caused by tumor localization were cranial nerve paralysis (60 patients, 51.7%), motor deficit (21 patients, 18.1%), cerebellar syndrome (40 patients, 34.5%), convulsion (7 patients, 6%) and endocrine disorder (14 patients, 12.1%) they found statistically significant. In the postoperative period, postoperative hydrocephalus in 3 patients (2.6%), cerebrospinal fluid leak in 8 patients (6%), meningitis in 10 patients (8%), ventriculitis in 1 patient (1%) and brain abscess in 1 patient (1%) detected. Twenty-seven patients (23%) had a better neurological state, while 9 patients (7.6%) had a worse neurological state.⁶ In our study DI in 12 patients (16%), sepsis in 9 patients (12%), hydrocephalus in 7 patients (9%), convulsion in 5 patients (6%), cranial nerve paralysis in 5 patients (6%), shunt infection in 4 patients (5%), intracranial hemorrhage in 4 patients (5%) and central salt loss in 3 patients (4%), were seen in the postoperative period. In the postoperative period, 39% of the complications were seen in the first 2 days, 31% between 3 and 7 days, and 29% of them were seen in 8 days or more. Accompanying infections in 21 patients (28%), shunt infection in 8 patients (10%), CVC infection in 5 patients (6%), ventilator-associated pneumonia in 5 (6%) patients, and sepsis in 4 patients (5%) were seen during patients' PICU follow-up.⁶ Neurological disabilities were seen more in younger age and patients with infratentorial tumors. No relation was found between neurological disability and first-day delta sodium level and delta sodium. Fluctuations in sodium levels could cause temporary mental status change and convulsions unless intervened but change in sodium levels were not related to neurological disabilities in our center particularly.

Hypothalamo-hypophyseal hormone deficiencies are seen in 40-87% of children with craniopharyngioma and 73%

of adults. GH, FSH/LH, ACTH, TSH, and ADH values can be deficient at diagnosis and a spectrum from one hormone deficiency to panhypopituitarism can be seen.⁷ Hypophyseal tumors could cause many hormones and water metabolism deficiencies other than mass effects to critical areas. Brain surgeons are trying to protect and restore pituitary functions while they resect tumors and remove the mass effect on critical areas. Checking hypophyseal hormones before surgery is important for understanding deficiency situations and excluding possible hormone-secreting tumors. In hypophyseal TSH, LH, FSH, IGF1, prolactin, morning ACTH and cortisol values must be looked at before surgery. A prospective study by Chen et al.⁸ with 385 patients found hypothyroidism of 36%, hypogonadism of 41%, hypoprolactinemia of 18%, and GH deficiency of 61%. One of three hypothyroidism patients has also hypocortisolism.⁹ In our study 5 patients' ACTH levels, 3 patients' TSH levels, and 8 patients' cortisol levels were low in the preoperative period.

A study by Sorba et al.¹⁰ which evaluated the postoperative period of 174 hypophyseal surgery patients, defined 13 (7.5%) DI and 11 (6.3%) SIADH patients. Patients who developed DI has more LOS in the hospital than SIADH patients. Four patients were discharged with persistent DI and 2 patients were discharged with SIADH.¹⁰ Kruis et al.'s¹¹ retrospective study with 120 child patients who was performed surgery on their sellar and suprasellar areas, found a relation between high plasma sodium levels, sodium level fluctuation during the day, and postoperative neurological status. Thus the importance of monitorization of patients' sodium level with sellar lesions was emphasized. DI was detected in 67% of patients. The difference between the highest and lowest sodium values in the first 10 days of DI patients was ≥ 10 mmol/L/24 hours in 75.3% of the patients. Mental status changes were more detected in DI patients than in non-DI patients and related to low sodium levels. At the end of the study, it was suggested that patients with sellar and suprasellar lesions must be monitored and followed up in experienced medical centers since mental status changes related to sodium level fluctuations in the first 10 days.¹¹ In our study, DI-developed patients' mean age was found more than DI undeveloped patients, and the development of DI was not found to affect PICU and hospital LOS. Patients' delta sodium level differences who had convulsions were ≥ 10 mmol/L/24 hours. A relation was detected between DI and the first 5 days' delta sodium levels but no relation was detected between DI and convulsion. A relation was found between DI, tumor localization, and HPA axis defect.

Infectious, endocrinological, and surgical complications and shunt infections can be seen in short and long-term periods of patients who were operated on brain tumors.

One of the most important ones is hyponatremia seen after supratentorial tumor surgery. A hyponatremia level of 130 mEq/L and below was related to 21% of patients with convulsions and 41% of patients with mental status changes. A hyponatremia level of 130 mEq/L and below was also found related to poor neurological outcomes.¹² Schipman et al.'s¹³ study which researched complications in the first 30 days with 2511 adult patients, showed nosocomial infections in 305 patients (12.1%), cerebrospinal fluid (CSF) leak in 156 patients (6.2%), surgical site infections in 104 patients (4.1%), surgical site bleeding in the postoperative period in 95 patients (3.8%), hydrocephalus in 30 patients (1.2%). Our study found no relation between hyponatremia, supratentorial localization, and neurological disabilities. Hyponatremia and hydrocephalus at admission were found related while PICU LOS was not found related. Obstructive hydrocephalus and young age were found related to hyponatremia in our study.

The purpose of Helmbold et al.'s¹⁴ study with 70 pediatric patients was to assess settled risk factors and to define factors related to new inflammations and postoperative VP shunt implantation. Postoperative shunt implantation was done in patients who had surgery before age of 3, external ventricular drainage (EVD) implantation before surgery, hydrocephalus signs after postoperative imaging, FOHR index more than 0.46 in the postoperative period, intraventricular hemorrhage, CRP levels more than 40 in the first 48 hours after surgery, CSF leak. Datas in hand suggest that reducing intraventricular hemorrhage could decrease the frequency of shunt implantation but aseptic inflammation pathways behind shunt need and CRP levels increase must be researched more.¹⁴ Four (72%) patients were implanted shunt before or after surgery in our study. 58.1% of patient's tumor resected who didn't have shunts while 12% of patient's tumor resected who had shunts. It was statistically significant between those two groups. No relation was found between CRP, intraventricular hemorrhage, and VP shunt. In our study, 31 patients were put external drainage 8 of them before surgery and 23 of them during surgery.

MV was applied to 25 (33%) of the patients in our study. The median of MV administration was 7 (0.5-130) days. In the follow-up of 4 patients who were intubated, NIV was needed. In the follow-up, tracheostomy was performed on 5 patients. Inotrope was started in 6 patients who were followed up for sepsis. The 28th-day mortality of the patients was 4% (3 patients). Two of the 3 patients who died were clinically and radiologically diagnosed with brain death. One patient died due to sepsis. Fifteen (75%) of the patients with neurological sequelae needed MV. We think that our results are good considering the disease severity of the patient population we follow.

Study Limitations

The limitation of the study is that it is a single center and retrospective study.

Conclusion

In our study, neurological sequels were related to NIV need MV to need, longer PICU, and hospital LOS. Neurological disabilities were seen more in younger age and patients with infratentorial tumors. No relation was found between neurological disability and first-day delta sodium level and fifth-day delta sodium. Fluctuations in sodium levels could cause temporary mental status change and convulsions unless intervened but change in sodium levels were not related to neurological disabilities in our center particularly. Hyponatremia and hydrocephalus at admission were found related with neurological sequelae while PICU LOS was not found related. Obstructive hydrocephalus and young age were found related to hyponatremia in our study. Patients' delta sodium level differences who had convulsions were ≥ 10 mmol/L/24 hours. A relation was detected between DI and the first 5 days' delta sodium levels but no relation was detected between DI and convulsion. A relation was found between hydrocephalus and sodium levels whereas no relation was found between hydrocephalus, DI development, and neurological disabilities. Patients operated of intracranial surgery must be evaluated with a multidisciplinary approach and for reducing morbidity, complications, and mortality during perioperative period patients must be followed up in experienced medical centers.

Ethics

Ethics Committee Approval: This work has not been published or is being considered for publication elsewhere. Written permission was obtained from the Local Ethics Committee of Ankara University Faculty of Medicine (ethics committee number: İ11-696-22).

Informed Consent: Written informed consent was obtained from all patients' relatives or legal authorities when necessary. Our study was conducted in accordance with the ethical principles of the World Medical Association Declaration of Helsinki.

Authorship Contributions

Concept: F.K., M.A.Ü., E.Ü., T.K., Design: F.K., A.G., H.U., İ.D., G.K., H.U.D., E.Ü., T.K., Data Collection or Processing: F.K., A.D.A., M.Z., M.H., Analysis or Interpretation: M.Z., M.H., İ.D., G.K., H.U.D., M.A.Ü., Literature Search: F.K., M.H., Writing: F.K., E.Ü.

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