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Brain Tumors in Infancy: An Institutional Experience of the Surgical Outcome, Predictive Factors, and Overall Survival

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Abstract

Objective

To describe the clinicoradiological profile, surgical outcomes, prognostic factors, and overall survival of infants undergoing resection for intracranial brain tumors at a tertiary neurosurgical center.

Methods

A retrospective review of patients aged ≤ 12 months who had primary intracranial brain tumor surgery was conducted, with data on demographics, radiology, surgery, pathology, and follow-up from records, survival rates, and surgical predictive factors.

Results

The cohort included 141 infants (mean age 8 months), mostly with supratentorial tumors and a slight male predominance. Factors like advanced paternal age, consanguinity, cesarean delivery, and preterm birth were linked to tumor occurrence. Most children showed progressive head enlargement and developmental delay; symptoms lasted shorter in malignant than benign tumors. AT/RT was the most common type. Patients received risk-adapted chemotherapy; some benign lesions were only monitored after excision, while early death and poor health prevented chemo in some malignant cases. Overall survival was 90.9% for benign tumors and 41.6% for malignant tumors, with median survivals of 109.4 and 18 months, respectively. Most survivors had good long-term outcomes. Malignant tumors were associated with shorter symptom duration, larger size (> 60 cm^3), solid consistency, infratentorial location, hydrocephalus, craniospinal spread, preterm birth, and intraoperative complications. Poorer outcomes are linked to younger age, male gender, lower birth order, preoperative hydrocephalus, craniospinal spread, and surgical complications.

Conclusions

Early diagnosis—preferably at or before birth—allows prompt intervention and better outcomes. New findings, like advanced paternal age and consanguineous marriage, drive further research. Careful staging to reduce risks, followed by personalized therapy, is key to long-term survival and quality of life.

INTRODUCTION

Management of brain tumors in infants is challenging. It demands a specialized approach due to the delicate, developing brain, its smaller size, and its fragility. Infants can develop both benign and malignant brain tumors. Although benign tumors usually have favorable outcomes with appropriate treatment, malignant tumors pose significant treatment difficulties.[9] Gaining a thorough understanding

of their epidemiology, tumor characteristics, and outcomes is crucial for refining treatment strategies and improving prognosis. In this study, we evaluate obstetric and perinatal histories, survival outcomes, and predictive factors in a cohort of 141 infants.

MATERIALS AND METHODS

Study Design and Data Collection:

This retrospective study reviewed 141 infants who had surgery at our institute from 2014 to 2024. Electronic records were examined for patient history, perinatal details, preoperative hydrocephalus, examinations, radiology, surgical and postoperative complications, shunt failure, recurrence, and adjuvant therapy. Children's families were not contacted for this study, and the data was collected from medical records. Therefore, according to the institutional scientific ethics committee (NIMHANS), ethical approval is not required. All human subjects had given consent to participate in the research during their hospital stay.

Neurological status was assessed using the Lansky scale at 6, 12, 24 months, and up to 5 years.

Tumors were classified as benign or malignant based on histopathology. The extent of resection was noted as residual tumor on postoperative MRI: gross total resection (no visible lesion), subtotal resection (99%-20%), or biopsy (< 20%).

The WHO classification of CNS tumors has evolved; some diagnoses have been renamed or removed. Cases were classified per the 2021 WHO guidelines. Surgical mortality was death within 30 days post-surgery.

Statistical Analysis

Categorical variables were presented as numbers and percentages, and continuous variables as means ± standard deviation. Two-group comparisons used χ^2, Fisher’s exact tests for categorical variables, and Student’s t-test for continuous ones. Kaplan-Meier analysis calculated overall survival (OS), while Cox regression identified factors linked to survival. A P value < 0.05 was significant. Analysis using SPSS 24.0 (IBM).

RESULTS

DEMOGRAPHY (Table 1):

Table 1
PATIENT CHARACTERISTICS, RADIOLOGY, AND TREATMENT

Variables	Category	Benign (33)	Malignant (108)	Total (141) (%)
Age (days)	< 240	14	43	57(40.4)
	> 240	19	65	84((59.6)
Gender	Female	17	43	60(42.5)
	Male	16	65	81(57.5)
Location	Supratentorial	25	50	75(53.2)
	Infratentorial	8	58	66(46.8)
Symptoms	Increasing head size and developmental delay	25	85	110(78.2)
	Seizures	3	10	13(9.2)
	Limb weakness	1	5	6(4.2)
	Cranial nerve involvement	3	3	6(4.2)
	Abnormal head shape	1	5	6(4.2)
Duration of symptoms	< 36 days	16	93	109(77.3)
	> 36 days	17	15	32(22.7)
Size	< 60 cm^3	22	49	71(50.3)
	> 60 cm^3	11	59	70(49.7)
Morphology	Mainly solid	14	71	85(60.3)
	Mainly cystic	4	6	10(7)
	Solid-cystic	15	31	46(32.7)
Location (detailed)	Lobar	6	19	25(17.7)
	4th ventricle	4	41	45(32)
	CP angle	2	4	6(4.2)
	Posterior 3rd ventricle	1	7	8(5.6)
	Lateral ventricle	8	21	29(20.6)
	Sellar/suprasellar	9	5	14(10)
	Cerebellar	2	5	7(5)

Variables	Category	Benign (33)	Malignant (108)	Total (141) (%)
	Clival	0	1	1(0.7)
	Thalamus	0	3	3(2.1)
	Hypothalamus	1	0	1(0.7)
	Vertex	0	2	2(1.4)
MANAGEMENT				
Pre-op CSF diversion	Shunt	11	63	74(52.5)
	Endoscopic third ventriculostomy	3	6	9(6.4)
	None	19	39	58(41.1)
Extent of resection	Gross total	21	70	91(64.6)
	Subtotal	7	27	34(24.1)
	Biopsy	5	11	16(11.3)
Adjuvant therapy	Yes (86)	4	82	86(61)
	No (55)	29	26	55(39)

A cohort of 141 patients was divided into various categories and analyzed using both univariate and multivariate analysis.

The mean age of patients was 247 days (8 months) (Median: 280 days, Range: 30–330, SD: 88.97). The male-to-female patient was 1.35. Most lesions were in the supratentorial region.

Obstetric and Perinatal History

The father's median age was 32 years (mean: 31.83, range: 20–43, SD: 3.64). According to NFHS-5[43], the average paternal age in India is around 30, so patients over 30 were considered to have advanced paternal age. The mother's median age was 25 years (mean: 25.14, range: 15–35, SD: 3.10). The prevalence of Consanguineous marriages was 51.8%, which is more than 10% higher than in the general population. NFHS-5 population data suggest a possible link to brain tumors. Further research is needed on prenatal factors. The most common cause of cesarean was preterm birth (21), followed by prolonged labor (11), malposition (3), previous cesarean (9), and antenatal CNS tumor diagnosis (4). There were 48 preterm births and 38 cases of perinatal distress. A z-test compared maternal and paternal ages, consanguinity, cesarean, and preterm birth rates with general population data. Advanced paternal age, consanguinity, cesarean, and preterm birth are significantly associated with brain tumors (Table 2).

Table 2
COMPARISON OF OBSTETRIC HISTORY IN THE COHORT VERSUS POPULATION DATA

Outcome	Cohort estimate	95% CI	Baseline (p0 or mu0)	Test	Statistic (df)	p (two-sided)
Father age > 30 years	93/141 (66.0%)	57.8% – 73.3%	0.40 [2]	One-sample z	z = 6.29	< 0.001
Maternal age (Mean-25 years)	25.14 ± 3.10	24.6–25.7	25 [2]	One-sample z	z = 0.54	0.768
Consanguineous union	73/141 (51.8%)	43.6% – 59.9%	0.10 [2]	One-sample z	z = 16.53	< 0.001
Caesarean section	48/14/1 (34%)	26.4%-41.6%	0.22 [2]	One-sample z	z = 3.44	< 0.0003
Preterm birth	48/141 (34.0%)	26.7% – 42.2%	0.10–0.15 [3]	One-sample z	z = 6.33 vs 15%	< 0.001

SYMPTOMATOLOGY

The overall mean duration of symptoms is 36 days. In benign lesions, the mean duration was 62.70 days (median: 45, SD: 58.64, range: 10–270 days). For malignant lesions, it was 28.41 days (median: 25, SD: 29.11, range: 7-280 days). Most patients had an increasing head circumference and developmental delay. Features of raised ICP, such as vomiting, inconsolable crying, downcast eyes, and scalp veins due to non-fusion of sutures and open fontanelles, are rare. (Table 1)

RADIOLOGY

The tumor volume, calculated from preoperative MRI, had a median of 60 cm^3 (mean: 73.6 cm^3, SD: 69, range: 4-400 cm^3). Tumors were classified as solid, cystic, or purely cystic. Craniospinal spread was seen in 13 patients before surgery. (Table 1)

SURGICAL MANAGEMENT (Table 1)

Patients with raised ICP had ventriculoperitoneal shunt via Frazier's point opposite the tumor side by dictum (74). When conditions were allowed, they underwent definitive surgery. Some had endoscopic third ventriculostomy (9), but some needed a shunt later (3). Surgery aimed for maximal safe resection, with blood loss limited to allowable levels. Gross total excision, with no tumor on the postoperative scan, was achieved in 91 patients. Subtotal resection (34) involved 99% to 20% tumor removal. Biopsy (< 20% removal, 16) was grouped as non-GTR.

COMPLICATIONS

The most common complication was uncontrolled bleeding. It required a massive transfusion during surgery, with 19 patients needing it due to intraoperative bleeding. Two patients developed a brain bulge at the surgical site, leading to rapid cranial wound closure without replacing the bone flap. Three patients experienced asystole. Forty-three patients were transferred to the ICU for post-surgery care.

Postoperative complications included CSF leak and infection (14), hydrocephalus (7), shock (7), seizures (5), and subdural hygroma (1).

Shock and seizures were managed with medication and support. Wound infection and meningitis were treated with antibiotics. Six patients with pus discharge and wound dehiscence underwent exploration and debridement. Two patients had post-op hematomas requiring re-exploration.

Postoperative shunts were common for hydrocephalus, CSF leaks, and infection. Within 30 days, three benign and 15 malignant tumors underwent shunt surgery. From 30 to 90 days, 11 patients (three benign, eight malignant) had shunted; after 90 days, four (one benign, three malignant) had shunt surgery for delayed hydrocephalus. Of 33 patients, 16 (two benign, 14 malignant) had been shunted before tumor surgery and failed CSF diversion. Three patients did not respond to ETV and needed VP shunt placement.

HISTOPATHOLOGY

All tissue samples were sent to our dedicated neuropathology department, and classification was performed in accordance with WHO guidelines. The most common pathology was atypical teratoid rhabdoid tumor, followed by medulloblastoma and choroid plexus tumors. (Table 3)

Table 3
HISTOPATHOLOGICAL DISTRIBUTION OF VARIOUS PATHOLOGIES

Group	Subtype	No. of patients
Embryonal tumor	Atypical teratoid rhabdoid tumour	28(19.8)
	Medulloblastoma (total)	22(15.6)
	Medulloblastoma - Extensive nodular type	14
	Medulloblastoma - Classical type	7
	Medulloblastoma - Large cell anaplastic	1
	Other embryonal tumours	9(6.6)
Choroid plexus tumor	Choroid plexus papilloma	10(7.4)
	Atypical choroid plexus papilloma	7(5.2)
	Choroid plexus carcinoma	8(5.6)
Ependymal Tumor	Ependymoma grade 2	3(2)
	Ependymoma grade 3	14(10)
Glioma	Low grade glioma	3(2.5)
	High grade glioma	4(2.8)
	Circumscribed glioma (Pilocytic astrocytoma)	8(5.6)
Pineal region tumor	Pinealoblastoma	5(3.3)
	Retinoblastoma (Triradiate)	1(0.7)
Glioneural tumor	Desmoplastic infantile ganglioglioma	5(3.5)
Mesenchymal tumor	Rhabdomyosarcoma	1(0.8)
	Ewings sarcoma	3(2)
Germ cell tumor	Mature teratoma	2(1.4)
	Immature teratoma	2(1.4)
Vascular tumor	Cavernoma	2(1.4)
	Cavernous haemangioma	1(0.7)
Tumor of sellar region	Craniopharyngioma	2(1.4)
Hamartoma	Hypothalamic hamartoma	1(0.7)

ADJUVANT THERAPY

Patients were primarily referred to as pediatric oncologists for adjuvant chemotherapy. The mean time to receive adjuvant therapy post-surgery is 16.48 days (SD: 5.4, Range: 5–45). Thirteen patients received delayed adjuvant therapy due to perioperative morbidity. Of the patients who did not receive chemotherapy, twenty-four benign lesions did not require further treatment because of gross total resection. Five patients with subtotal resection were monitored with serial scans because of the benign nature of the tumors. Out of the malignant lesions, seven patients died within one month of surgery from perioperative complications. Twelve patients had grade 2 lesions with gross total resection and were kept on close follow-up with serial scans. Three patients died of non-surgical causes during the postoperative period, three could not tolerate adjuvant therapy because of poor general conditions, and one defaulted on adjuvant treatment. (Table 1) Fig. 3 showed extent of resection in supratentorial and infratentorial tumors.

FOLLOWUP AND OUTCOME

The mean follow-up duration is 33.89 months (Median: 24 months, Range: 1-120 months). Patients were graded using the Lansky play performance scale for pediatric functional status. The median overall survival for benign lesions was 109.44 months, with survival rates of 96.96%, 93.33%, and 89.28% at 6, 12, and 24 months of follow-up, respectively. In malignant tumors (108), the overall survival rates were 66.6%, 51.4%, and 40.38% at 6, 12, and 24 months, respectively, with a median overall survival of 18 months. If perioperative deaths were excluded from the analysis, overall survival among patients with malignant lesions improved from 18 months to 36 months. Overall, regardless of follow-up duration, survival rates were 90.9% for patients with benign tumors and 41.6% for those with malignant lesions.

Sixty-six patients succumbed to the disease. Three patients died from systemic causes, including bowel perforation, dengue shock syndrome, and systemic sepsis, while eleven patients died due to neurosurgical reasons during the perioperative period. Forty-seven patients with malignant tumors and two patients with benign tumors died because of disease progression. Both patients with benign disease had residual lesions post-first surgery. One patient died because of pneumonia and one because of dengue shock syndrome after discharge from the hospital.

The disease progression was classified as either tumor recurrence (when gross total resection was achieved) or regrowth (when residual disease persisted after the first surgery). Among patients with benign tumors, four experienced regrowth from residual tumors. The median progression-free survival (PFS) was 12 months for benign tumors and 6 months for malignant lesions. The histology group showed a borderline association with PFS ($p = 0.055$), not reaching significance but suggesting a potential trend. Further multivariable analysis did not identify any significant factors (Fig. 2).

Among patients with benign tumors, four experienced regrowth, and two opted for re-surgery. A total of six patients underwent re-surgery due to disease progression, including two patients with pilocytic astrocytoma who were operated on after one year, with good outcomes. Among malignant cases, one

with choroid plexus carcinoma recurred at 24 months, one with atypical papilloma at six months, and two with grade 3 ependymomas had surgery at 12 and 24 months.

LONG-TERM NEUROLOGICAL OUTCOME

The neurological status was evaluated at regular intervals using the Lansky Performance Scale to assess pediatric functional status. Our analysis showed that in 6 months, 92 patients scored 100, two scored 90, one scored 80, two scored 70, six scored 60, and one scored 50. At 12 months, 77 patients scored 100, and at 24 months, 65 patients scored 100. Long-term follow-up of over five years was available for 38 patients, of whom 37 scored 100. (Fig. 1) A child's ability to adapt to cerebral injuries over time is impressive. At 6 months, five patients still experienced developmental delays, while three showed considerable catch-up in growth. Nearly all other deficits improved, except for one patient with severely poor vision that persisted in lifelong and limited independent work. Four patients experienced new weakness at discharge; three continued to have it at the 6-month follow-up but eventually recovered. Three patients developed postoperative seizures, which were effectively controlled with antiepileptic medication.

PREDICTIVE FACTORS AND OVERALL SURVIVAL

Variables were analyzed concerning tumor grade and resection extent. Factors linked to malignancy include shorter symptom duration, preterm birth, lesion size greater than 60 cm^3, solid lesions, infratentorial location, preoperative hydrocephalus, craniospinal spread, intraoperative complications, and postoperative ICU stays. Intraoperative complications restrict gross total resection. (Table 4) Separate analyses of benign and malignant tumors identified prognostic factors for surgery outcomes. identified prognostic factors for surgery outcomes. (Table 4)

Table 4
UNIVARIATE ANALYSIS FOR COMPARISON VARIABLES IN RELATION TO GRADE (BENIGN VS MALIGNANT) TUMOURS, EXTENT OF RESECTION (NON GTR) AND SURVIVAL OF PATIENTS

Sr. No.	Variable	Association with grade (p)	Association with extent of resection (p)	Survival (p)		
				Benign	Malignant	Overall
1	Age	0.789	0.521	**0.034**	0.370	0.137
2	Gender	0.234	0.922	0.078	**0.032**	0.083
3	Duration of symptoms	**0.001**	0.571	0.582	0.121	**0.005**
4	Order of birth (lower)	0.301	0.436	**0.009**	**0.024**	**0.039**
5	Preterm birth	**0.028**	0.960	0.456	0.890	0.367
6	Perinatal distress	0.369	0.835	0.346	0.131	0.765
7	Size	**0.032**	0.302	0.800	0.252	0.069
8	Morphology	0.500	0.207	0.400	0.400	0.348
9	Location	**0.024**		0.877	0.500	0.700
10	Preop craniospinal spread	**0.017**	**0.008**	NA	**0.009**	**< 0.001**
11	Preop hydrocephalus	**0.036**	0.093	**0.034**	0.590	**0.050**
12	Intraop complication	**0.050**	**0.042**	**0.029**	0.071	**0.003**
13	Extent of resection	0.901	NA	0.901	0.252	0.068
14	Histopathology		0.901	0.500	**0.003**	**< 0.001**
15	Post-op ICU stay	**0.034**	0.530	**0.003**	**0.004**	**< 0.001**
16	Immediate post-op complications	0.539	0.172	**0.001**	0.280	**0.004**
17	Morbidity at 30 days	0.350	0.400	**0.001**	0.150	**0.050**
18	Morbidity at 90 days	0.400	**0.050**	-	0.460	**0.008**

Table 5
MULTIVARIATE COX REGRESSION ANALYSIS FOR FACTORS AFFECTING OVERALL SURVIVAL (MALIGNANT TUMOURS)

VARIABLE	HR	CI_LOW	CI_HIGH	HR (95% CI)	P VALUE
Preterm Birth	1.603	0.54	4.68	1.603 (0.54–4.68)	0.388
Gender	3.567	1.002	12.701	3.567 (1.002–12.701)	**0.050**
Size	0.5966	0.207	1.714	0.5966 (0.207–1.714)	0.596
Location	1.028	0.402	3.629	1.028 (0.402–3.629)	0.955
Spread	3.574	1.13	11.307	3.574 (1.130-11.307)	**0.030**
Intraop Complication	20.323	0.689	154.606	20.323 (0.689-154.606)	**0.001**
GTR/nonGTR	0.787	2.777	2.34	0.787 (2.777–2.34)	0.664
ICU stay	10.323	2.777	38.37	10.323 (2.777–38.370)	**< 0.001**
Pre-hydrocephalus	0.96	0.121	0.763	0.960 (0.121–0.7630)	0.969
Post-op shunt	0.234	0.59	0.922	0.234 (0.590–0.922)	**0.038**
Adjuvant therapy	4.026	0.486	33.394	4.026 (0.486–33.394)	**0.004**

DISCUSSION

Infant brain tumors are rare, less than 1% of pediatric cases, posing challenges due to their fragility, diversity, and limited data. They are biologically intriguing but difficult to manage. CNS neoplasms are among the most common childhood tumors.[18] The present series is one of the larger contemporary cohorts and provides a detailed assessment of prognostic factors that influence outcome.

PATIENT CHARACTERISTICS AND RADIOLOGICAL FEATURES

In this cohort of 141 infants, the male-to-female ratio was 1.35:1. A slight male predominance in pediatric brain tumors has been documented in several epidemiological studies and has been attributed to genetic, hormonal, immunological, and metabolic influences. Sex-dependent differences in brain development in utero have been proposed as a possible mechanism by which sexual dimorphism may predispose to tumor formation before birth.[37] In the current study, survival was significantly higher in girls, consistent with a 2015 report by Tao Sun et al., which showed superior outcomes for female patients with ependymoma and high-grade glioma. The biological basis is likely multifactorial, involving hormonal and epigenetic pathways, and further work is needed to clarify these mechanisms, especially in infants.[38]

Published series suggest that 30–40% of fetuses with congenital tumors may experience stillbirths.[39] In addition, most infants in low- and middle-income settings are present late. [19, 30] Therefore, more cases occur in children over six months during the first year, as shown by the skew toward older children at diagnosis.

Obstetric and Perinatal History:

Advanced paternal age (≥ 30), consanguinity, and preterm labor are linked to infant brain tumors, adding limited research on parental and perinatal risks. Common complications like polyhydramnios, dystocia, large-for-gestational-age, and fetal distress increased preterm birth and cesarean rates of population.[20, 24]

A case-control study done in 2021 established a strong association between preterm labor, the occurrence of a cesarean section, and the incidence of congenital brain tumors.[1] Considering that most of the tumors presenting earlier than six months are of malignant nature[35], an association has been noted in our study of malignant tumors with preterm labor. ($p = 0.028$)

Studies of childhood cancers have exhaustively investigated the order of birth. Similar to our research, birth order, specifically the second-born and beyond, has been significantly associated with better outcomes ($p = 0.039$). A pooled analysis conducted by Behren et al. in 2010 reported similar findings in most childhood solid tumors. [7] The link between birth order and childhood brain tumors involves various biological mechanisms. One key theory is immune development: laterborn children are exposed to infections earlier and more often through siblings, boosting immune maturation and potentially protecting against tumors. Hormonal factors, like higher estrogen in first pregnancies, may also influence tumor risk. Other factors linked to birth order—such as in utero nutrition, birth weight, and maternal age—might also impact risk through epigenetic changes and growth factor regulation.[32]

Early prenatal detection of brain tumors, macrocephaly, and hydrocephalus using advanced prenatal imaging such as detailed ultrasonography and fetal MRI—can be crucial for quick diagnosis and timely treatment.[32] Due to better and more comprehensive prenatal care in developed countries, the incidence of maternal detection is 2–3 times higher than in developing countries.[41] Progressive head enlargement was the main symptom, followed by seizures and neurological deficits, common in infants with intracranial tumors. Supratentorial lesions were more common than infratentorial tumors, which were often cancerous, showed up earlier, and had a higher risk of affecting the brainstem early on because they didn't take up as much space in the posterior fossa.[6, 15, 22, 25, 31, 34]

Most tumors were solid or solid–cystic, with purely cystic lesions being rare, likely because many infant tumors are highly cellular masses with secondary cystic change.[8] This is because our most common pathology was embryonal tumors, followed by choroid plexus tumors, ependymal tumors, and gliomas. This contrasts with a 31-patient study conducted at our institute in 2013 by Mohanty et al., in which choroid plexus tumors were most common.[4, 30] Although a survey by Attina et al. in 2020 reported findings similar to ours.[4] This may be explained by the disproportionate concentration of AT/RT in the

younger age group, especially less than one year, compared to more common tumors, which are benign, like pilocytic astrocytoma.

In a recent study of 70 patients, Isikay et al. describe that the larger tumors are associated with worse surgical outcomes.[19] Larger tumor size increased perioperative risks but didn't independently affect long-term survival, indicating skilled surgery can mitigate bulk disease impacts. Craniospinal dissemination occurs in 10%-30%, higher in medulloblastoma, embryonal tumors, pineal region, and posterior fossa tumors.[13] Apart from providing an abysmally poor prognosis, as seen in our study, prior knowledge of the spread is also necessary for charting a treatment plan for patients. Systematic preoperative screening of the entire neuroaxis is therefore crucial for accurate staging, operative planning, and risk-adapted adjuvant therapy in this age group.[12]

MANGEMENT

Managing infants with brain tumors necessitates a comprehensive approach. In emergencies, CSF diversion helps lower elevated ICP, which, in turn, minimizes damage to the periventricular white matter tracts. However, the time from symptom onset to hospital reporting is relatively high.[21] Despite saving a patient's life, shunt malfunction and failure frequently lead to significant morbidity. In patients with saved lives, shunt malfunction and failure are common complications that cause significant morbidity. Shunt malfunction and failure are common complications causing significant morbidity in patients.[3] Whenever feasible, patients should undergo definitive surgery if hydrocephalus persists; CSF diversion should be performed. Hydrocephalus acts as a poor prognostic factor for overall survival ($p = 0.05$). Persistent elevation of intracranial pressure can stretch white matter pathways and cause leakage of cerebrospinal fluid into periventricular regions. Over time, these changes contribute to significant brain injury, resulting in long-term neurological and neurocognitive morbidity in affected patients.

Maximal safe resection remained the principal surgical objective[17], but in infants, the therapeutic window is narrow because of limited blood volume, vulnerability to hemodynamic instability, and tumors that frequently cross the midline or encase eloquent structures.[25] In this series, gross total resection did not uniformly translate into superior overall survival, emphasizing the value of case selection and functional preservation over purely volumetric goals. Biopsy was reserved for deeply seated[28] or eloquent tumors and for lesions in which neoadjuvant chemotherapy was anticipated to facilitate later cytoreduction.[36] A surgeon's expertise goes beyond diagnosing and planning; operative skill and decision-making are vital for success. Preparedness and a good surgical team improve intraoperative performance. Worse outcomes are likely due to excessive blood loss and major transfusions, which can lead to cerebral hypoperfusion, edema, and brain swelling that limit safe resection.

Survival in infant brain tumors has improved substantially with the introduction of intensive chemotherapy and carefully timed radiotherapy, with contemporary series reporting overall survival of roughly 60–85% in selected subtypes compared with less than 50% with surgery alone.[16] Delaying or modifying cranial radiotherapy until after three years of age remains a key strategy to reduce late neurocognitive and endocrine toxicity while preserving disease control.[44] For example, a 2025 study

reported improvements in survival rates for patients with AT/RT who received high-dose chemotherapy, stem cell therapy, targeted radiotherapy, and immunotherapy.[11] Similar studies have been conducted for high-grade ependymomas, choroid plexus carcinoma, and high-grade astrocytoma.[2, 29, 42] In this cohort, the mean interval between surgery and initiation of adjuvant therapy was 16 days, and the decision to administer or omit indicated adjuvant treatment had a greater impact on outcome than modest variation in timing.

COMPLICATIONS

Post-surgical care for these patients is as crucial as the surgery itself. Typically, patients are transferred to the ICU for a single stay to stabilize them.[26] Postoperative CT scans are conducted when patients show new neurological deficits or signs of raised ICP. The delicate skin and flexible skull bones increase the risk of postoperative CSF leaks and infection.[5]

A common delayed issue for surgeons is delayed hydrocephalus or shunt malfunction in previously shunted cases. Risk factors include infratentorial tumors, periventricular tumors, breach of the ventricular pathway, and large tumors literature.[10, 40] Malignant tumors and uncontrolled intraoperative bleeding predict shunt malfunction. While cohort heterogeneity prevents identifying specific histopathologies as predictors of delayed hydrocephalus, various studies show some tumors predispose patients to develop hydrocephalus if not shunted earlier.[33] Shunt malfunction and need for shunt revision have significantly affected the surgical outcome in our cohort ($p = 0.038$)

The overall time to shunt failure was 30 days for benign tumors and seven days for malignant tumors in our cohort, with malignant tumors being more common. Shunt failure rates are generally higher in pediatric patients (up to 20%) than in adults (13.5–15%), partly due to factors such as growth, smaller ventricular systems, and a higher risk of infection in infants. Similarly, the average time to shunt failure after brain tumor surgery in infants is 20 days as compared to 3 months in adults.[23]

OVERALL SURVIVAL AND LONG-TERM NEUROLOGICAL OUTCOME.

It is essential to evaluate patient survival based on tumor grade rather than grouping them together. The mean follow-up duration was 33.89 months, which was significantly lower than that of comparable studies.

In our cohort, 33 were classified as benign tumors; the overall survival rate was 90%, with a median progression-free survival of 12 months. The survival rates were 96.96%, 93.33%, and 89.28% at 6, 12, and 24 months of follow-up, respectively. Whereas in malignant tumors (108), the overall survival rates were 66.6%, 51.4%, and 41.6% at 6, 12, and 24 months, respectively, with a median survival of 18 months and a median progression-free survival of 6 months (overall). Although the survival rates are similar to those reported in other studies, malignant tumors generally have less favorable outcomes.[6, 15, 19, 27] In contrast to our research, Isikay et al. reported an exceptionally favorable overall survival of 177.6 months, with a remarkably low mortality rate of 27.1%, findings likely driven by a cohort enriched for benign histology and the deliberate exclusion of patients undergoing subtotal resection (< 80%) or biopsy

alone—key methodological differences from our study—while even among malignant tumors, the 5-year survival in their series reached 54%.[19]

Compared with other studies, long-term follow-up is limited, as most patients underwent surgery within the last 5 years. All but one surviving patient had recovered from the neurological deficits post-surgery. Antiepileptics controlled long-term seizures in one patient. One had permanent vision loss, which had improved only slightly. Still, long-term follow-up (> 5 years) was available for 38 patients, all of whom achieved satisfactory outcomes and independent living. Even though the overall survival in our study for malignant tumors appears slightly worse than in other studies, the long-term neurological outcome has been commendable. Studies like Geber et al and Shih-Shan Lang et al. have reported mild to severe neurological sequelae in patients suffering from CBT.[14, 25]

CONCLUSION

Effective management of infant brain tumors requires timely, precise decisions supported by surgery, chemotherapy, and radiation. Balancing gross total resection against intraoperative risks may involve staged surgery to reduce blood loss and complications. Early diagnosis, ideally pre- or at birth, enables prompt intervention and better outcomes. New research links advanced paternal age and consanguineous marriage, prompting further study. Careful staging and tailored adjuvant therapy optimize survival and quality of life. Parental education empowers families to participate actively and make informed decisions. Overall, multidisciplinary strategies and family engagement are key to the best outcomes.

LIMITATION

Retrospective studies face data attrition despite careful follow-up, and tumor diversity complicates analysis, highlighting the need for larger, subtype-specific studies. Most cases were treated within 5 years, so longer follow-up is needed to assess neuropsychological outcomes.

Abbreviations

AT/RT	Atypical teratoid rhabdoid tumor
CSF	Cerebrospinal fluid
GTR	Gross total resection
Non-GTR	Non-Gross total resection
Pre-op	Preoperative
Intra-op	Intraoperative
Post-op	Postoperative
MRI	Magnetic resonance imaging
VP	Ventriculo-peritoneal
ETV	Endoscopic third ventriculostomy
NIMHANS	National Institute of Mental Health and Neurosciences
SPSS	Statistical Package for the Social Sciences
WHO	World health organization

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Authors contribution: Authors: MS: Data collection, draft, analysis, review, SKK: Concept, draft, Review, DS: Review, NS: Review, NBN: Review, GJSB,HD,ARP: Review, AA: Review.

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Figures

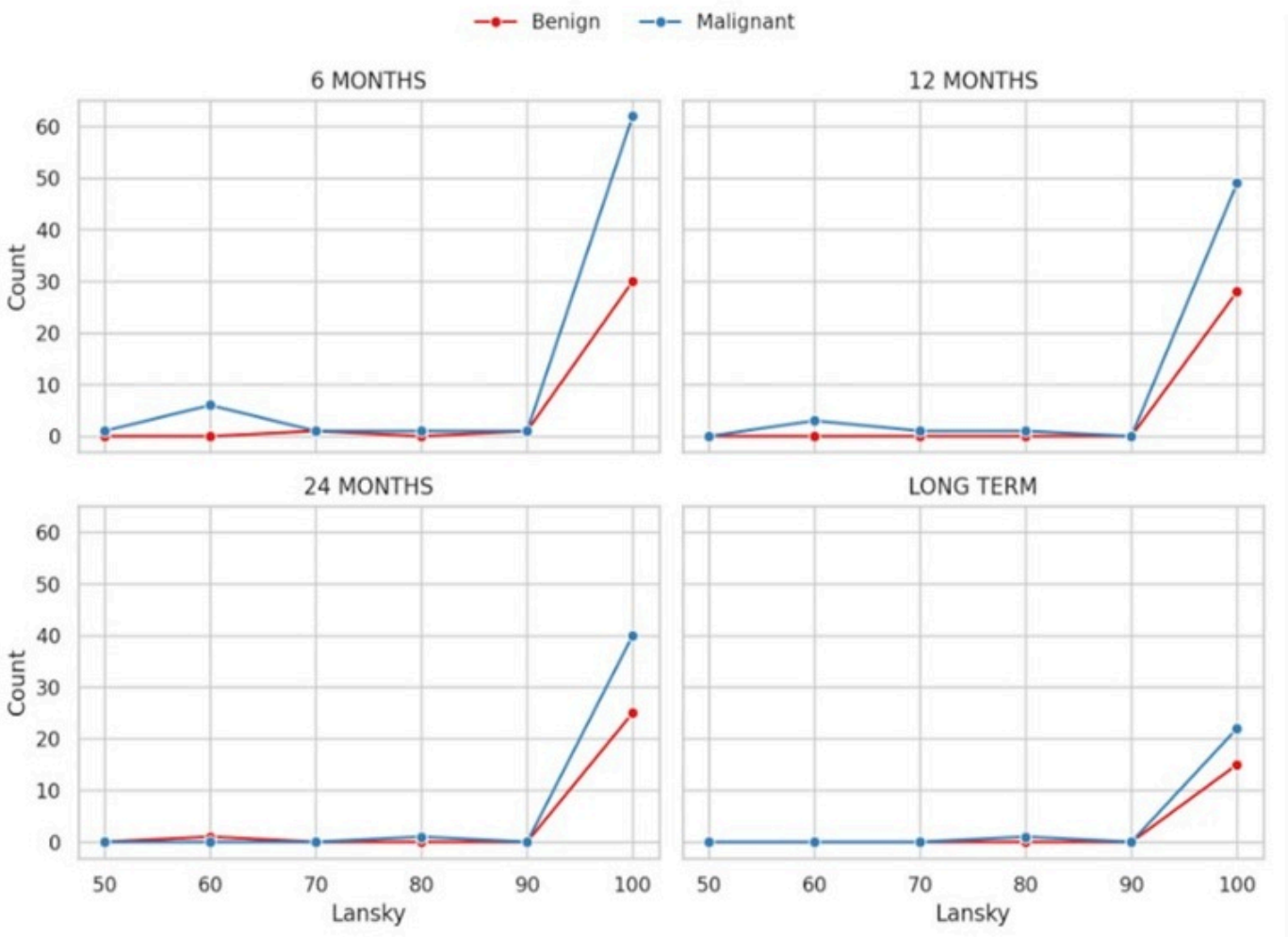


Figure 1

Presenting the neurological status at 6, 12, 24 months, and during longterm follow-up.

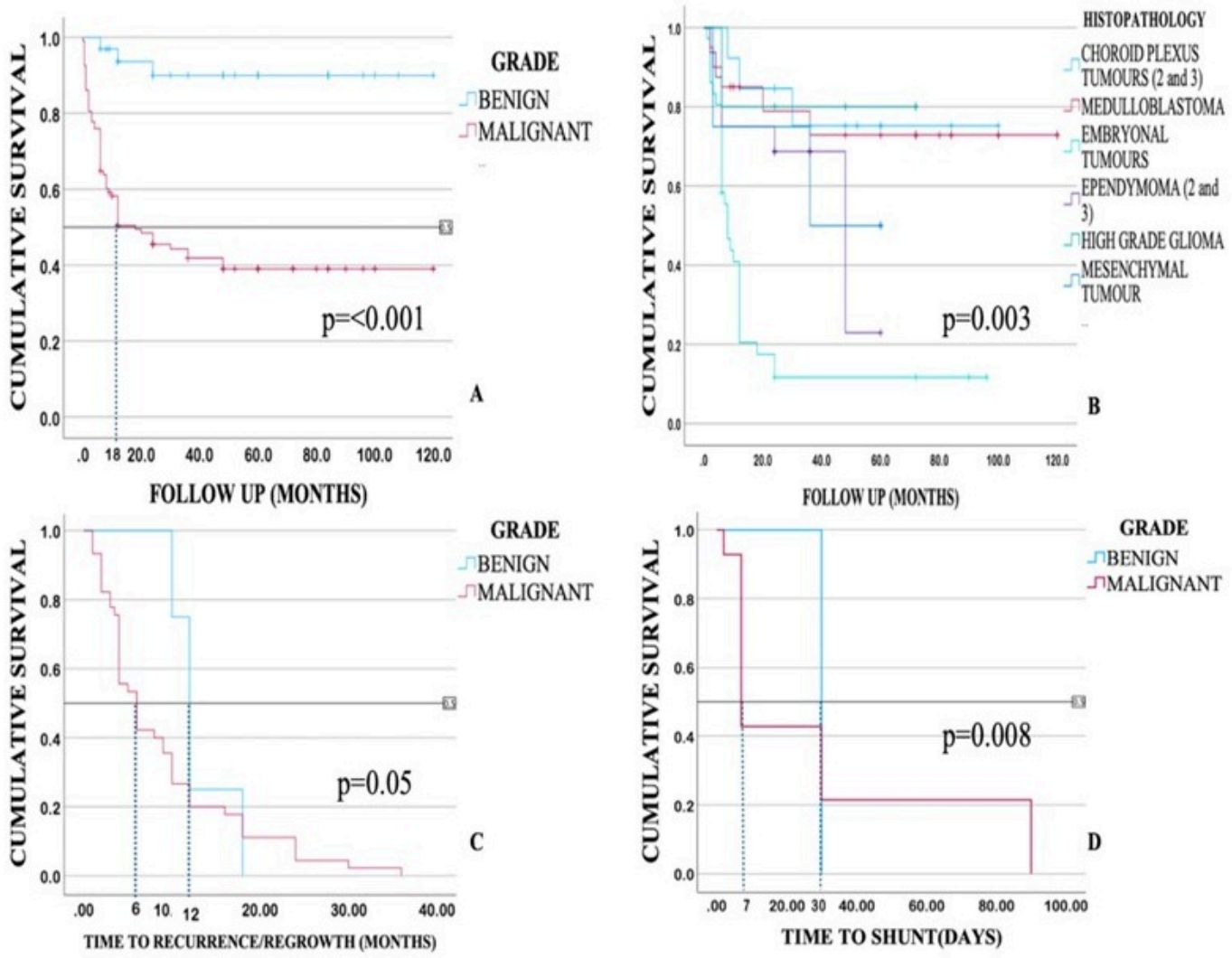


Figure 2

A showing the survival curve of benign and malignant lesions with median survival of 109 months for benign tumours and 18 months for malignant lesions, B showing the varying survival of different malignant pathologies noted in the cohort, with embryonal tumours having the worst prognosis; C showing median time to recurrence with PFS for benign as 12 months malignant as 6 months; D showing the survival curve for time to shunt revision with median time to failure for benign as 30 days and for malignant as 7 days.

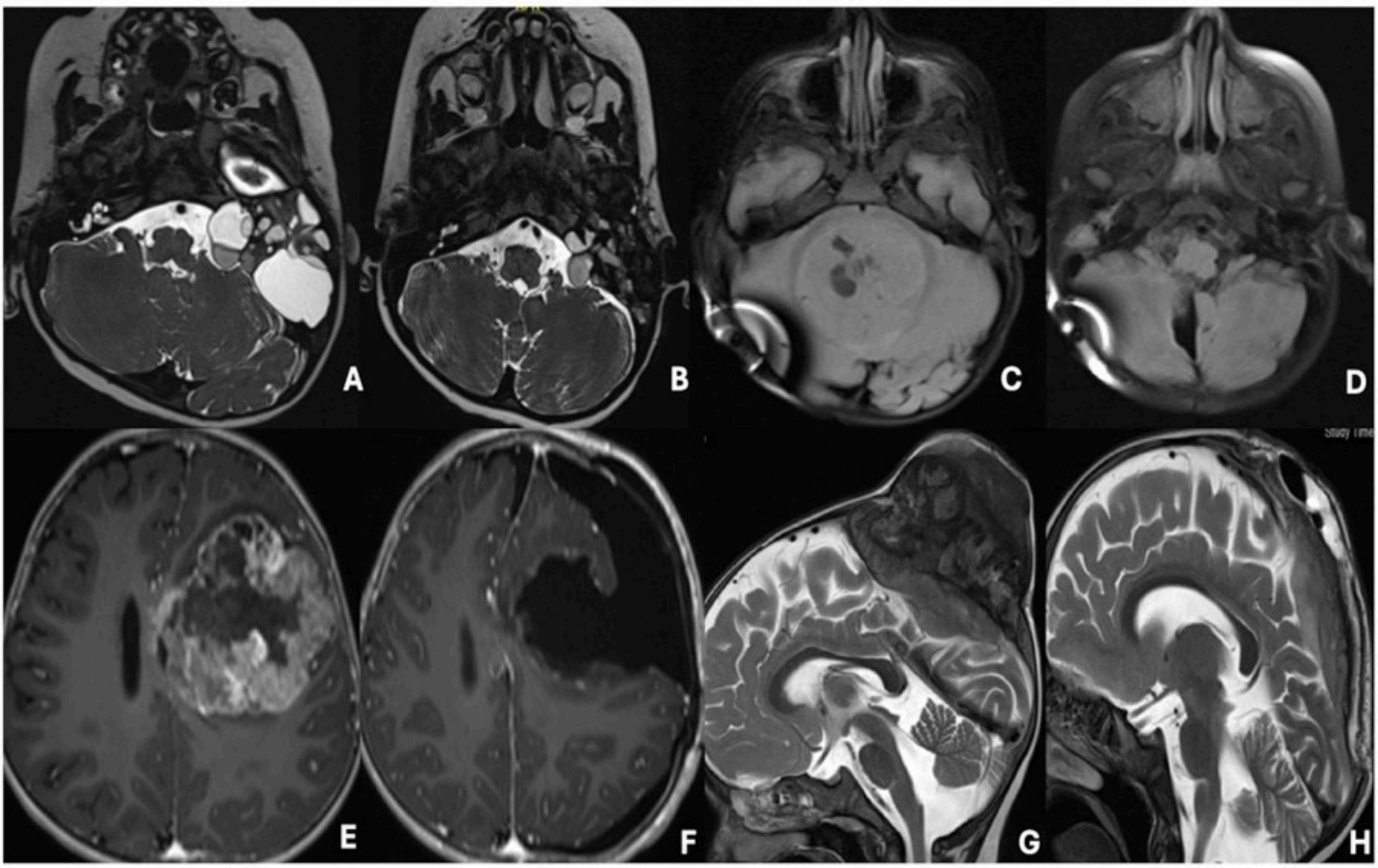


Figure 3

showing A T2W ciss 3D axial MRI of an 8-month-old baby with a left petrous solid cystic Ependymoma presenting with facial palsy, B: shows a T2W ciss 3d axial MRI follow-up scan after 3 years showing stable disease with subtotal resection; C: T2W FLAIR axial MRI of a 8 month old baby with a fourth ventricular medulloblastoma with right side VP shunt in situ, D: T2W FLAIR axial MRI follow up scan after two years showing no e/o recurrence; E: T1W contrast image of a 6 month old baby with a left frontal AT/RT presenting with increasing head size and developmental delay, F: T1W contrast axial post operative MRI of gross total resection of tumor; G: T2W sagittal MRI of 9 month of child presenting with enlarging head mass with parasagittal embryonal tumor with divergent differentiation, H: T2W sagittal image with stable disease at 3 years after subtotal resection.