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Original Article

Comparative Analysis of Surgical Site Infections in Pediatric Brain Tumor Patients: Hygiene Practices, Risk Factors, and Implications for Healthcare Costs and Mortality

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Abstract

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Surgical site infections (SSIs) significantly impact pediatric central nervous system tumor outcomes. We present our data of SSIs and their influence on outcomes of pediatric brain tumor patients treated between January 2011 till December 2022. This study utilized retrospective data from patients' medical records. Chi-squared test was used for correlational analysis. Independent sample *t*-test was used for equality of means. Linear and logistic regression was done to review impact of independent variables on dependent variable. Survival analysis was done using Kaplan–Meier curves. Between 2011 and 2022, 336 pediatric patients (202 males, 134 females) were diagnosed with brain tumors. Majority patients (279; 83%) underwent surgery (91% elective). Commonest tumor site was cerebellum (84/279; 30%). Tumor resection status was gross total resection (29/279; 46%), subtotal resection (59/279; 21%), near total resection (48/279; 17%), and partial resection (20/279; 7%); while 32/279 patients (11%) had a biopsy only. Hydrocephalus was present in 166/279 patients (59%); while majority (160/166; 96%) underwent a cerebrospinal fluid (CSF) diversion procedure. SSI developed in 23/279 patients (8%), leading to delayed postoperative management in majority (15/23; 65%). SSIs were significantly associated with lower age of presentation ($p = 0.01$), less duration between symptoms and diagnosis ($p = 0.00$), performance of CSF diversion procedure ($p = 0.04$), increase in hospital stay ($p = 0.00$), delay in postoperative management (15/23; 65%) ($p = 0.01$), decline in treatment completion ($p = 0.01$), and poor survival ($p = 0.01$). Majority (171/279) of patients (61%) completed treatment. The overall survival of our cohort was 84.9% with a median follow-up time of 11 (interquartile range [IQR]: 36, 1) months. Survival was

Keywords

- neuro-oncology
- pediatric
- pediatric brain tumors
- surgical site infection

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significantly lower (56.5%) in patients with SSI ($p = 0.01$). Median time to death was 18 months. Progression-free survival was 77.4% with a median progression-free time of 8 (IQR: 28, 1) months. Median time to progression was 9 (IQR: 24, 4.5) months. The incidence of SSIs in our cohort closely resembled that of high-income countries. Risk factors for SSIs included younger age, a shorter time between symptom onset and surgery, undertaking of CSF diversion procedures. Adverse effects of SSIs included increased costs, delays in postoperative management, incomplete treatment, and higher mortality rates. This study emphasizes the substantial impact of SSIs on healthcare resources and patient well-being.

Introduction

Significant variation exists between the incidence of primary central nervous system tumors between high- and low- to middle-income countries (LMICs).[1] More than 90% of children at risk of developing childhood cancer each year live in LMICs.[2] Outcomes of these children are relatively good in high-income countries (HICs); however, in LMICs, outcomes are notably less optimistic.

For pediatric brain tumors, surgical resection remains the primary step of treatment.[3] However, neurosurgery is associated with morbidity and mortality due to surgical site infections (SSIs).

The objectives of this study are to conduct an internal quality control, and to compare our findings with international outcomes. We aim to establish benchmark parameters for institutional practices that can be adopted by smaller, less specialized centers in the field.

Methods

This study involved retrospective review of patients' charts, diagnosed and treated for brain tumor, 0 to 18 years, from January 2011 till December 2022. Magnetic resonance imaging brain with contrast was used for initial confirmation of diagnosis, with a standardized formula of length x width x thickness x 0.523 to calculate tumor volumes.[4] Those who did not opt for surgery were removed from the analysis list. Tumors were classified according to World Health Organization (WHO) classification of tumors.[5]

All patients received postoperative dexamethasone to manage peritumoral edema and perioperative parenchymal swelling.[6] Resection status was described following the guidelines provided by Karschnia et al as follows: Gross total resection (GTR; removal of 100% of the tumor), near total resection (NTR; removal of >95% of the tumor), subtotal resection (STR; removal of ≥80% of the tumor), partial resection (PR; removal of 1-79% of the tumor), and biopsy (performed solely for diagnostic purposes).[7]

Files were systematically reviewed, encompassing postoperative notes, daily progress notes, and lab results, to identify patients who developed SSI. SSI was defined as any infection occurring near or at the incision site and/or deeper underlying tissue spaces and organs within 30 days of a surgical procedure.[8] SSIs included suppuration of wounds, scalp abscess, meningitis, ventriculitis, and intracerebral abscess. Meningitis was diagnosed on the basis of cerebrospinal fluid (CSF) detailed report and culture and sensitivity (CS).[9] Patients with deep infections were initially treated empirically with ceftriaxone and vancomycin, with adjustment of antibiotics guided by CSF CS reports. In case of deterioration in the patient's condition, an escalation of antibiotics to include meropenem, vancomycin, and colistin was implemented. Criteria of stopping antibiotics were total 14 days of treatment, with at least 10 days post-negative CSF and blood cultures, given that the patient achieved afebrile status and there was observable clinical improvement.[10]

Qualitative data included gender, residence, site of tumor, completion of treatment; presence, type, site of SSI, sensitivity of organisms, type of treatment received, prophylactic antibiotics received, acute postsurgical complications, and long-term sequalae. Continuous data included age, height, weight at diagnosis, volume of tumor, duration between symptoms onset and surgery, length of surgery, length of hospital stay, and dose of radiation therapy. Last date of follow-up was used to calculate survival time. Progression was confirmed radiologically.

Statistical Analysis

Since our data was not normally distributed, median and frequencies were calculated for quantitative and qualitative variables, respectively. Pearson chi-squared test was used to calculate correlation between qualitative variables. Independent sample t-test was used to calculate difference between means of two groups. Regression (linear and logistic) analysis was performed on variables that showed significant ($p \leq 0.05$) correlation. Kaplan–Meier survival curves were used to calculate survival analysis. Log-rank test was used to compare survival between two groups. A p-value of less than or equal to 0.05 was considered significant. All data was analyzed using Statistical Package for the Social Sciences (SPSS) v22.

Results

From 2011 to 2022, 339 pediatric patients (202 males, 134 females) were diagnosed with brain tumors, with a median age of 108 (IQR: 170, 60) months (9 years) and a median duration between symptom onset and surgery of 60 (IQR: 180, 21) days (►Table 1). Out of the total, 279 patients (83%) underwent neurosurgery and were included in the study.

Cerebellum was the commonest site of tumor presentation (101/339; 30%; ►Fig. 1). Median primary tumor volume was

Table 1 Patients' characteristics

	n (%)	Symptoms (*n* = 279)	*n* (%)
Total patients diagnosed (*n* = 336)		Headache	184 (66%)
Males	202 (60%)	Nausea/vomiting	139 (50%)
Females	134 (40%)	Walking/gait problems	278 (42%)
Total patients operated (*n* = 279/336; 83%)		Vision problems	56 (20%)
Males	168 (60%)	Seizures	47 (17%)
Females	111 (40%)	Behavioral changes	42 (15%)
	Median (range)	Cranial nerve palsies	36 (13%)
Age of presentation (months)	108 (0.5–341)		
Duration between symptoms onset and surgery (days)	60 (2–3285)	**Site of tumor (*n* = 279)**	*n* (%)
Tumor volume (mL)	37 (1–402)	Cerebellum	84 (30%)
Presurgery hemoglobin (g/dL)	166 (59%)	Supratentorial/cerebral hemispheres/ventricle	77 (27.5%)
Length of surgery (hours)	4 (0.5–36)	Fourth ventricle	60 (21.5%)
Length of in-hospital stay (days)	8 (2–85)	Sellar/suprasellar/third ventricle	19 (7%)
Duration between surgery and XRT (days)	54 (5–210)	Thalamus/basal nuclei	16 (6%)
Dose of XRT (Gys)	54 (0–59.4)	Brain stem	14 (5%)
Overall survival time (months)	11 (0.1–135)	CP angle	6 (2%)
Progression-free survival time (months)	8 (0.1–135)	Pineal region	3 (1%)
Time to progression (months)	9 (0.7–89)		
Site of XRT (*n* = 63)	*n* (%)	**Hydrocephalus (*n* = 279)**	*n* (%)
Brain	30	Yes	166 (59%)
Brain + spine	27	No	113 (41%)
Type of CSF diversion (*n* = 160)	*n* (%)	**Metastasis (*n* = 20)**	*n* (%)
Extraventricular drain	108 (67%)	Brain	2 (10%)
Ventriculoperitoneal shunt	50 (31%)	Spine	7 (35%)
Ventriculostomy	2 (1.2%)	Both	11 (55%)

Abbreviations: CP, cerebellopontine; CSF, cerebrospinal fluid; XRT, radiation therapy

36.85 (IQR: 86.5, 20) mL. Metastatic disease was present in 20/279 patients (7%). Hydrocephalus was present in half of the patients (166/279; 59%). Most frequent pathological diagnosis was circumscribed astrocytic glioma (74/279; 26%) (►Table 2). Cancer predisposition syndrome testing was conducted in 74 out of 279 patients, with 30 testing positive (p53 mutation 29, constitutional mismatch repair deficiency [CMMRD] 1); the majority (73.3%) of positive cases were identified in diffuse high-grade gliomas (►Table 3).

All patients received presurgery prophylactic antibiotics. Majority underwent elective surgery (255/279; 91%) (►Table 2), with a median surgery duration of 4 (interquartile range [IQR]: 5.5, 2.5) hours. Craniotomy was the predominant procedure (275/279; 99%), with the commonest surgical approach being occipital (144/279; 52%). Resection status was GTR (129/279; 46%), STR (59/279; 21%), NTR (48/279; 17%), PR (20/279; 7%); while 32/279 (11%) patients underwent a biopsy only.

Majority with hydrocephalus (160/166; 96%) underwent a CSF diversion procedure (extraventricular drain [EVD] commonest 108/160; 67%), with majority (116/160; 72%) having CSF diversion at the time of tumor resection/biopsy. Thirty-nine (39/108; 36%) patients with EVD underwent subsequent ventriculoperitoneal shunting procedure, at a median time of 8 (range: 2–28) days.

Acute postsurgical complications developed in 107/279 (38%) patients, commonest being neurological (69/107; 64%). The incidence of other complications was; infections other than SSI (35/107; 33%), electrolytes imbalance (15/107; 14%), endocrinological (13/107; 12%), postoperative hematoma (10/107; 9%), CSF leak from wound site (10/107; 9%), and posterior fossa syndrome (10/107; 9%; ►Table 3).

The incidence of SSIs was 23/279 (8%; ►Table 3). Notably, all cases of SSI were deep-seated infections. Only 8/23 (35%) patients had a positive growth in CSF culture. The infective organisms identified were *Staphylococcus aureus* 2, Acinetobacter 2, *Escherichia coli* 1, *Klebsiella pneumoniae* 1, *Aspergillus flavus* 1, and *Candida albicans* 1. Average duration of hospitalization for patients who developed SSI was 20 days, in contrast to 8 days in those without SSI (P = 0.004).

Majority patients in our cohort (171/279; 61%) completed treatment for their cancer. Treatment abandonment was observed in 82/279 patients (29%), while 26/279 (9%) patients were unable to complete treatment due to postsurgical complications. Seventy-one (71/171; 41%) and (63/171;

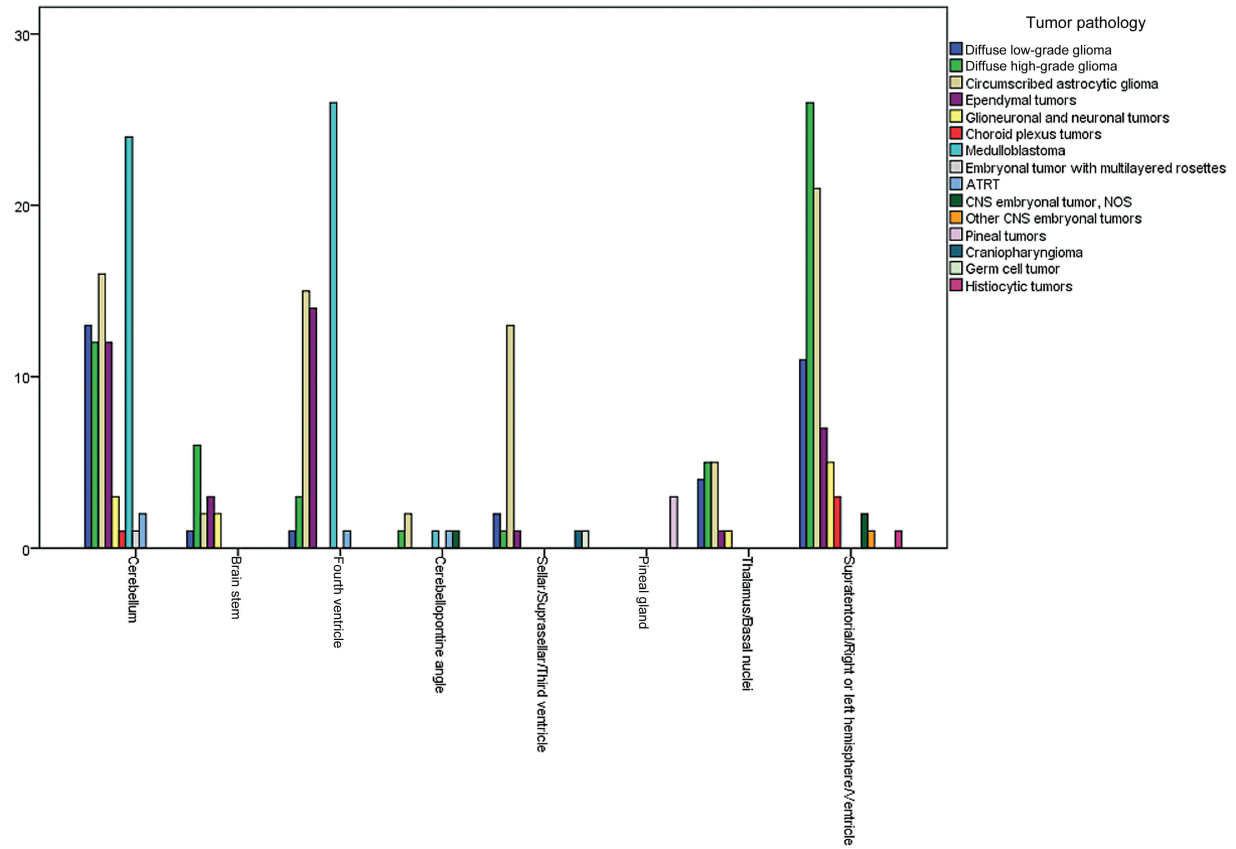

Fig. 1 Distribution of tumor according to site. ATRT, atypical teratoid rhabdoid tumor; CNS, central nervous system; NOS, not otherwise specified.

Table 2 Surgery characteristics and tumor pathology

Tumor pathology ($n = 279$)		**Approach to surgery ($n = 279$)**	
Circumscribed astrocytic glioma	74 (26%)	Occipital	144 (52%)
Diffuse high-grade glioma	54 (19%)	Supratentorial	75 (27%)
Medulloblastoma	51 (18%)	Temporoparietal	46 (16%)
Ependymal tumors	38 (14%)	Frontal	12 (4%)
Diffuse low-grade glioma	32 (11%)	Retrosigmoid	2 (1%)
Glioneuronal and neuronal tumors	11 (4%)	**Mode of surgery ($n = 279$)**	
Choroid plexus tumors	4 (1.4%)	Elective	255 (91%)
Atypical teratoid rhabdoid tumor	4 (1.4%)	Emergency	24 (9%)
Pineal tumors	3 (1.1%)	**Type of surgery ($n = 279$)**	
CNS embryonal tumor, NOS	3 (1.1%)	Craniotomy	275 (99%)
Other CNS embryonal tumors	1 (0.4%)	Craniectomy	4 (1%)
Craniopharyngioma	1 (0.4%)	**Resection status ($n = 279$)**	
Germ cell tumor	1 (0.4%)	Gross total resection	129 (46%)
Histiocytic tumors	1 (0.4%)	Subtotal resection	59 (21%)
Embryonal tumor with multilayered rosettes	1 (0.4%)	Near total resection	48 (17%)
		Only biopsy	32 (11%)
		Partial resection	20 (7%)

Abbreviations: CNS, central nervous system; NOS, not otherwise specified.

Table 3 Postsurgical complications

Acute postsurgical complication ($n = 107$)		**Long-term sequelae ($n = 58$)**	
Neurological	69 (64%)	Seizure disorder	20 (34%)
Infectious	35 (33%)	Gait/posture/movement disorder	14 (24%)
Electrolytes imbalance	15 (14%)	Electrolytes imbalance	11 (19%)
Endocrinological	13 (12%)	Other endocrine deficits	9 (15%)
Postoperative hematoma	10 (9%)	Vision problems	8 (14%)
CSF leak	10 (9%)	Hypothyroidism	7 (12%)
Posterior fossa syndrome	10 (9%)	Cerebellar mutism	6 (10%)
Surgical site infection ($n = 23$)		Growth hormone deficiency	2 (3%)
Deep	23 (100%)	Cognitive disorders	2 (3%)
Superficial	0 (0%)		
Delay in postoperative management due to SSI ($n = 23$)		**Cancer predisposition syndrome ($n = 30$)**	
Yes	15 (65%)	p53 mutation	29 (96%)
No	8 (35%)	CMMRD	1 (4%)

Abbreviations: CMMRD, constitutional mismatch repair deficiency; CSF, cerebrospinal fluid; SSI, surgical site infection.

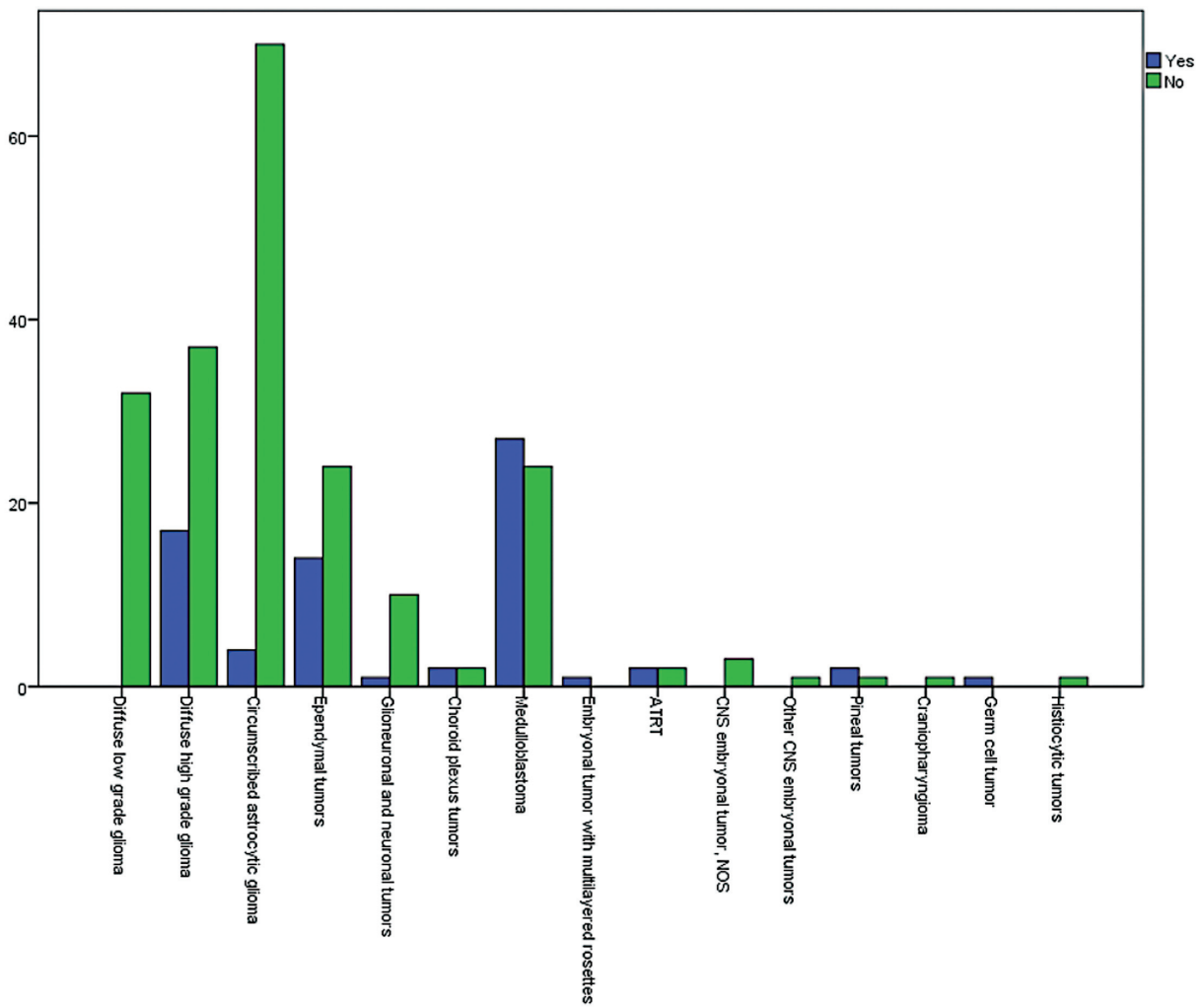

Fig. 2 Chemotherapy status according to tumor pathology. ATRT, atypical teratoid rhabdoid tumor; CNS, central nervous system.

37%) received chemotherapy and radiation therapy, respectively (►Table 1, ►Figs. 2 and 3).

SSIs were significantly associated with presence of hydrocephalus (hazard ratio [HR]: 1.124; 95% confidence interval [CI]: 1.029–1.542; $p = 0.050$), performance of CSF diversion procedure (HR: 1.053; 95% CI: 1.007–1.400; $p = 0.040$), CSF leakage from wound site (HR: 1.886, 95% CI: 1.561–1.970, $p = 0.002$), increase in in-hospital stay of patients (HR: 1.143; 95% CI: 1.09–1.192; $p = 0.000$), delay in postoperative management (15/23; 65%) (HR: 1.983; 95% CI: 1.938–1.995; $p = 0.010$), decline in treatment completion (HR: 0.179; 95% CI: 0.837–0.915; $p = 0.015$), as well as poor survival (HR: 5.385; 95% CI: 2.181–13.294; $p = 0.010$); while there was inverse correlation between age of diagnosis and SSI (HR: 0.991; 95% CI: 0.984–0.999; $p = 0.018$; ►Table 4).

The overall survival of our cohort was 84.9% with a median follow-up time of 11 (IQR: 36, 1) months (►Fig. 4). Survival was significantly lower (56.5%) in patients with SSI ($p = 0.010$; ►Fig. 5). Median time to death was 18 months. Primary disease progressed in (63/279;22%) patients. The progression-free survival was 77.4% with a median progression-free time of 8 (IQR: 28, 1) months (►Fig. 6). Median time to progression was 9 (IQR: 24, 4.5) months.

Discussion

SSIs represent a potentially preventable source of postoperative complications, mortality, and financial strain particularly in LMICs. The heightened occurrence of SSIs in LMICs is attributed to factors such as inadequate sterility, environmental pollution, compromised immunity, antibiotic resistance, and suboptimal vaccination coverage.[11] The incidence reported from other centers in Pakistan is approximately 29 to 35%.[12] Our study reports an SSI incidence of 8%.

Our data highlights that the performance of CSF diversion procedures is associated with an elevated risk of SSIs. Same has been identified in other studies.[13,14] This highlights the importance of avoiding CSF diversion procedures unless necessary. Implementation of a preshunt surgery checklist for infection control can effectively reduce the SSI rate attributable to this preventable cause, as reported by Lee et al.[15]

Inverse correlation was observed between age and the risk of SSI, aligning with the findings by Boethun et al.[16] However, contrasting results have been reported by others. The conflicting findings highlight the need for further studies to establish a more definitive understanding of the relationship between age and the risk of SSI.

The incidence CSF leakage (3.7%) was higher in those undergoing infratentorial surgery compared to those with supratentorial surgeries (6 vs. 4) (►Table 5); this, however, was not statistically significant ($p = 0.434$). Notably, no significance was found between craniotomy and craniectomy concerning CSF leakage, as the majority of our patients underwent craniotomy.

A significant association was observed between SSI and disease progression ($p = 0.007$). SSIs understandably result

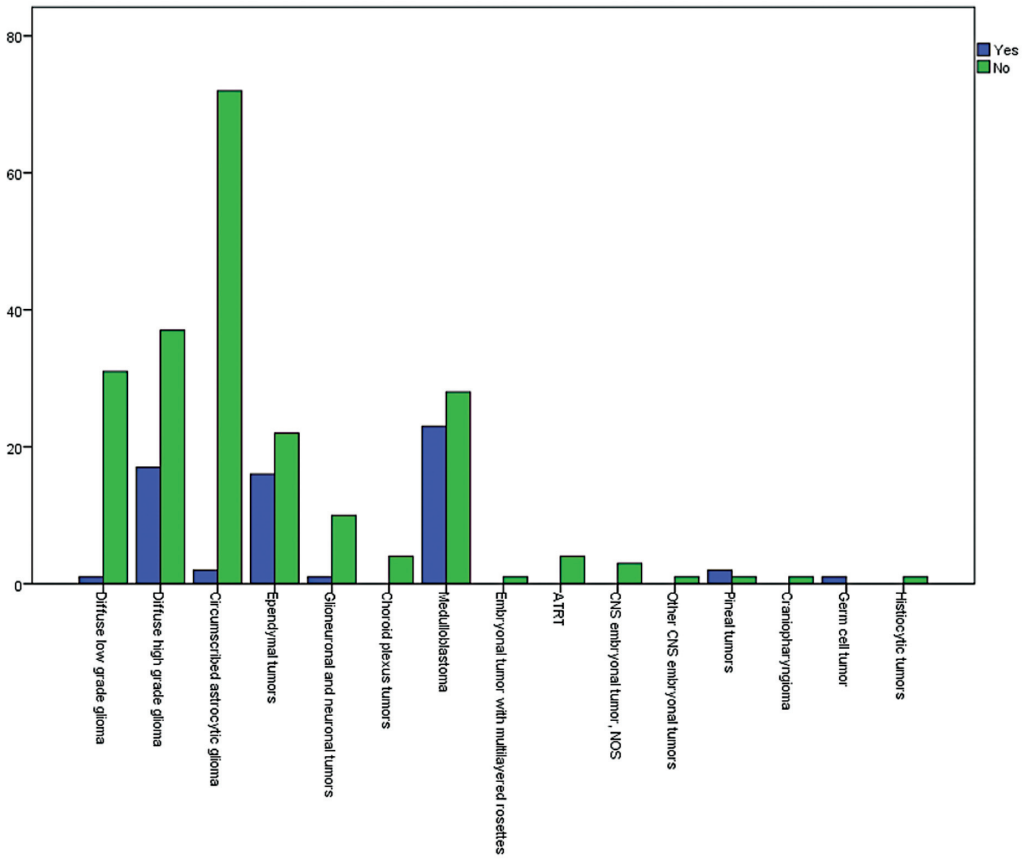

Fig. 3 Radiation therapy status according to tumor pathology. ATRT, atypical teratoid rhabdoid tumor; CNS, central nervous system.

Table 4 Regression analysis

	HR	95% CI	*p*-Value
Hydrocephalus → SSI	1.124	1.029–1.542	0.050
CSF diversion procedure → SSI	1.053	1.007–1.400	0.040
CSF leak → SSI	1.886	1.561–1.970	0.002
Age of diagnosis → SSI	0.991	0.984–0.999	0.018
SSI → In-hospital stay	1.143	1.09–1.192	0.000
SSI → Delay in postoperative management	1.983	1.938–1.995	0.010
SSI → Treatment completion	0.179	0.837–0.915	0.015
SSI → Decreased survival	5.385	2.181–13.294	0.010
Delay in postoperative management → decreased survival	10.500	3.511–31.402	0.000

Abbreviations: CI, confidence interval; CSF, cerebrospinal fluid; HR, hazard ratio; SSI, surgical site infection.

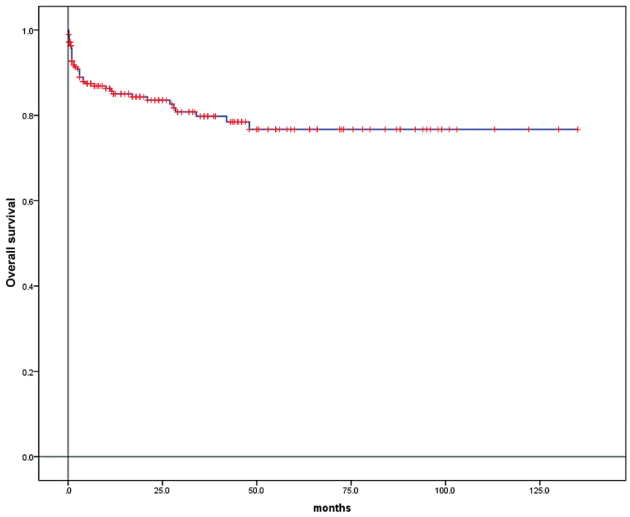

Fig. 4 Overall survival.

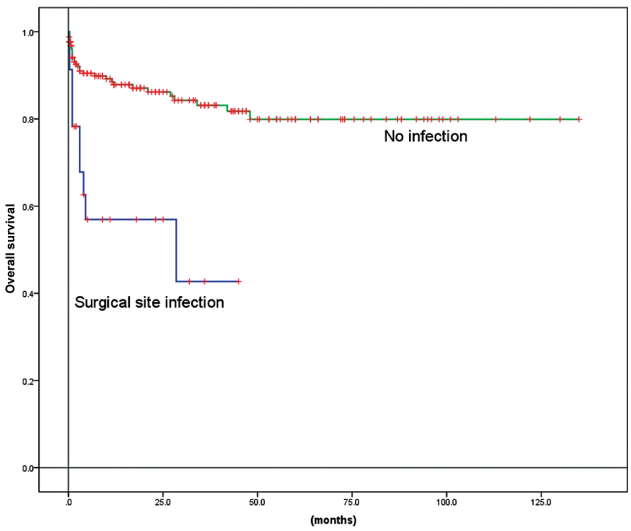

Fig. 5 Surgical site infection-dependent survival ($p = 0.01$).

in delays in postsurgical management, including the administration of chemotherapy and radiation therapy. These delays ultimately contribute to disease progression.

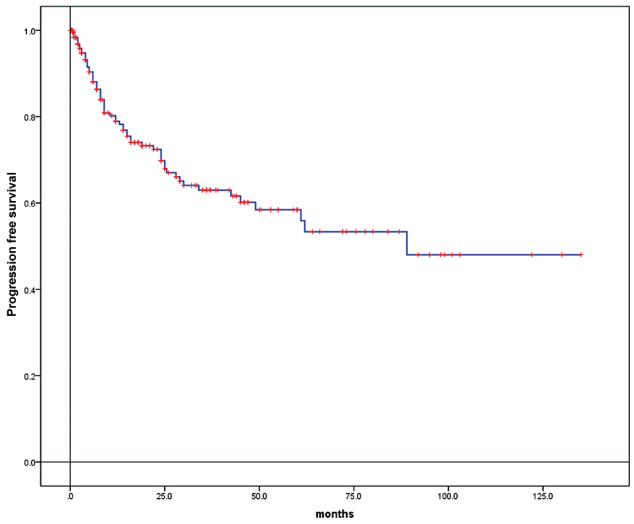

Fig. 6 Progression-free survival.

An interesting finding in our study was the significant influence of the duration between symptom onset and surgery on the incidence of SSI. Notably, individuals with a longer duration of symptoms before surgery (229 vs. 80 days) exhibited a decreased incidence of SSIs ($p = 0.000$). High-grade tumors often prompt early presentation and the development of hydrocephalus.[17,18] Individuals who underwent CSF diversion had a shorter duration between symptom onset and surgery (127 vs. 339 days; $p = 0.00$). Similarly, those with poorer survival outcomes also demonstrated a shorter duration between symptoms and surgery (79 vs. 242 days; $p = 0.00$; ►Table 6).

Positive antimicrobial growth was observed in 35% (8/23) of our patients with SSI. Consistent with literature, mixed flora, encompassing both gram-positive and gram-negative organisms, was identified. Notably, fungal species growth was detected in two patients, a noteworthy finding as fungal growth is infrequently reported.

SSIs contribute to a spectrum of adverse effects, including prolonged hospital stays,[19] which also elevates the risk of hospital-acquired infections, further prolonging the stay. In our study, the average extra length of stay due to SSI was 11.5

Table 5 Crosstabs

		Type of CSF diversion procedure			
		EVD	VPS	Ventriculostomy	Total
Surgical site infection	Yes	16	6	0	22
	No	92	44	2	138
Total		108	50	2	160
		CSF leakage			
		Yes	No		Total
Surgical approach	Supratentorial	4	129		133
	Infratentorial	6	140		146
Total		10	269		279

Abbreviations: CSF, cerebrospinal fluid; EVD, extraventricular drain; VPS, ventriculoperitoneal shunt.

Table 6 t-test for equality of means

	Grouping variable	t	*p*-Value	Mean difference	95% Confidence interval	
					Lower	Upper
	t-test for equality of means of gender					
Presurgery hemoglobin (g/dL)	Males: 12.89 Females: 11.81	5.275	0.000	1.0775	.6754	1.4797
	t-test for equality of means of mode of surgery					
Duration between symptoms and surgery (days)	Elective: 234.35 Emergency: 36.59	6.829	0.000	197.76	140.744	254.779
	t-test for equality of means of "performance of CSF diversion procedure"					
Duration between symptoms and surgery (days)	Yes: 127.82 No: 339.21	−3.790	0.000	−211.381	−321.617	−101.145
Length of stay (days)	Yes: 11.69 No: 7.30	5.445	0.000	4.391	2.803	5.979
	t-test for equality of means of SSI					
Duration between symptoms and surgery (days)	Yes: 80.45 No: 229.91	−4.497	0.000	−149.460	−215.122	−83.798
Length of stay (days)	Yes: 20.35 No: 8.88	3.226	0.004	11.473	4.104	18.841
SSI-free survival (days)	Yes: 4.17 No: 714.97	−13.136	0.000	−710.799	−817.363	−604.234
Overall survival (months)	Yes: 11.309 No: 23.961	−3.787	0.000	−12.6519	−19.3890	−5.9147
Length of surgery (hours)	Yes: 18 No: 206	0.215	0.830	0.1604	−1.3128	1.6335
	t-test for equality of means of postsurgical complications					
Length of stay (days)	Yes: 13.59 No: 7.48	5.903	0.000	6.112	4.062	8.162
SSI-free survival (days)	Yes: 513.13 No: 745.49	−2.231	0.026	−232.358	−437.407	−27.308
	t-test for equality of means of "delay in postsurgical management"					
Presurgery hemoglobin (g/dL)	Yes: 11.513 No: 12.520	−2.183	0.030	−1.0067	−1.9144	−0.0991
SSI-free survival (days)	Yes: 49.27 No: 690.87	−10.741	0.000	−641.605	−759.465	−523.744

Table 6 (*Continued*)

Length of stay (days)	Yes: 26.27 No: 8.89	3.578	0.003	17.380	6.970	27.791
Overall survival (months)	Yes: 8.553 No: 23.734	−4.361	0.000	−15.1804	−22.3484	−8.0123
	t-test for equality of means of "treatment completion status"					
Duration between symptoms and surgery (days)	Yes: 276.14 No: 123.15	3.436	0.001	152.993	65.313	240.672
SSI-free survival (days)	Yes: 968.53 No: 162.14	10.084	0.000	806.387	648.900	963.875
Length of stay (days)	Yes: 8.54 No: 11.85	−3.218	0.002	−3.314	−5.349	−1.279
Overall survival (months)	Yes: 33.609 No: 5.989	10.544	0.000	27.6205	22.4620	32.7789
	t-test for equality of means of survival outcomes					
Duration between symptoms and surgery (days)	Alive: 242.22 Dead: 79.78	4.587	0.000	162.442	92.660	232.223
SSI-free survival (days)	Alive: 736.63 Dead: 203.52	6.626	0.000	533.105	374.084	692.125
Length of stay (days)	Alive: 9.09 Dead: 13.95	−2.331	0.024	−4.864	−9.070	−0.657
Overall survival (months)	Alive: 25.586 Dead: 7.860	6.595	0.000	17.7266	12.4122	23.0409
	t-test for equality of means of disease progression					
Presurgery hemoglobin (g/dL)	Yes: 11.941 No: 12.619	−2.738	0.007	−0.6777	−1.1650	−0.1904
SSI-free survival (days)	Yes: 881.30 No: 590.77	2.402	0.017	290.528	52.402	528.655
Overall survival (months)	Yes: 30.971 No: 20.569	2.613	0.009	10.4029	2.5657	18.2402
	t-test for equality of means of long-term sequalae					
Presurgery hemoglobin (g/dL)	Yes: 12.900 No: 12.352	2.137	0.033	.5480	.0433	1.0526
SSI-free survival (days)	Yes: 1109.40 No: 537.48	3.914	0.000	571.912	280.748	863.077
Overall survival (months)	Yes: 40.052 No: 18.421	4.677	0.000	21.6309	12.4171	30.8447

Abbreviation: SSI, surgical site infection.

days ($p = 0.004$), representing a substantial wastage of healthcare resources.

Lastly, SSIs resulted in delays in postoperative care and a decline in the completion of treatment. These factors collectively had a detrimental impact on the overall survival of our cohort, with statistically significant differences observed in survival durations: (8.5 vs. 23.7 months; $p = 0.00$) and (5.98 vs. 33.60 months; $p = 0.00$), respectively.

Based on the above findings, we advocate strict adherence to the WHO guidelines for SSI prevention.[20] These guidelines encompass the following key measures: I) Whenever possible, consider the use of oral/enteral nutrient-enhanced formulas for underweight patients to ensure adequate nutritional status before surgery. II) Patients should undergo a preoperative bath or shower, utilizing either plain soap or an antimicrobial soap. III) Consider perioperative intranasal applications of mupirocin 2% ointment, either alone or in combination with chlorhexidine gluconate (CHG) bodywash. IV) Avoid hair removal whenever possible. If necessary, use clippers instead of shaving, as shaving is strongly discouraged both preoperatively and in the operating room. V) Administer antibiotic prophylaxis within 120 minutes before incision. VI) Utilize alcohol-based antiseptic solutions containing CHG for surgical site skin preparation. VII) Refrain from using antimicrobial sealants following surgical site skin preparation. VIII) Minimize the utilization of CSF diversion procedures whenever feasible.

Conclusion

The occurrence of SSIs in our cohort mirrored that of HICs. Identified risk factors for SSIs included younger age, a shorter interval between symptom onset and surgery, the presence of hydrocephalus, and the performance of CSF diversion procedures.

Notably, SSIs in our study were linked to substantial additional costs and elevated mortality rates. Delays in postoperative management and incomplete treatment significantly contributed to these outcomes, underscoring the multifaceted impact of SSIs on healthcare resources and patient well-being.

Limitations and Strengths

Our study is retrospective in nature, and it may not fully address the gaps in patient records. Several confounding factors, such as variations in tumor pathology, could have potentially influenced the outcomes. Treatment protocols were not standardized across all patients, and surgeries were conducted by different surgeons with varying levels of expertise, potentially contributing to variations in SSIs. However, this study offers valuable insight into the causes and consequences of SSI in children with brain tumors, and serves as a catalyst for further endeavors aimed at reducing the occurrence of such infections.

Ethical Approval

Ethical review committee approval was obtained via letter number 2023-9316-26871, dated October 23rd, 2023.

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Conflict of Interest

None declared.

References

1 Hossain MJ, Xiao W, Tayeb M, Khan S. Epidemiology and prognostic factors of pediatric brain tumor survival in the US: evidence from four decades of population data. Cancer Epidemiol 2021;72:101942
2 Bhakta N, Force LM, Allemani C, et al. Childhood cancer burden: a review of global estimates. Lancet Oncol 2019;20(01):e42–e53
3 Udaka YT, Packer RJ. Packer RJJNc. Pediatric brain tumors. Neurol Clin 2018;36(03):533–556
4 Bathla G, Policeni B, Hansen MR, Berbaum K. Calculating the tumor volumes in vestibular schwannomas: are the ABC/2 and volumetric methods comparable? Otol Neurotol 2017;38(06): 889–894
5 Louis DN, Perry A, Wesseling P, et al. The 2021 WHO classification of tumors of the central nervous system: a summary. Neuro-oncol 2021;23(08):1231–1251
6 Palombi L, Marchetti P, Salvati M, Osti MF, Frati L, Frati A. Interventions to reduce neurological symptoms in patients with GBM receiving radiotherapy: from theory to clinical practice. Anticancer Res 2018;38(04):2423–2427
7 Karschnia P, Vogelbaum MA, van den Bent M, et al. Evidence-based recommendations on categories for extent of resection in diffuse glioma. Eur J Cancer 2021;149:23–33
8 Borchardt RA, Tzizik D. Update on surgical site infections: the new CDC guidelines. JAAPA 2018;31(04):52–54
9 Brouwer MC, Tunkel AR, van de Beek D. Epidemiology, diagnosis, and antimicrobial treatment of acute bacterial meningitis. Clin Microbiol Rev 2010;23(03):467–492
10 Kimberlin DW. Red Book: 2018–2021 report of the committee on infectious diseases. American Academy of Pediatrics; 2018
11 Haque M, McKimm J, Godman B, Abu Bakar M, Sartelli M. Initiatives to reduce postoperative surgical site infections of the head and neck cancer surgery with a special emphasis on developing countries. Expert Rev Anticancer Ther 2019;19(01):81–92
12 Sattar F, Sattar Z, Zaman M, Akbar S. Frequency of post-operative surgical site infections in a Tertiary care hospital in Abbottabad, Pakistan. Cureus 2019;11(03):e4243
13 Sáenz A, Badaloni E, Grijalba M, Villalonga JF, Argañaraz R, Mantese B. Risk factors for surgical site infection in pediatric posterior fossa tumors. Childs Nerv Syst 2021;37(10):3049–3056
14 Sneh-Arbib O, Shiferstein A, Dagan N, et al. Surgical site infections following craniotomy focusing on possible post-operative acquisition of infection: prospective cohort study. Eur J Clin Microbiol Infect Dis 2013;32(12):1511–1516
15 Lee RP, Venable GT, Vaughn BN, Lillard JC, Oravec CS, Klimo P Jr. The impact of a pediatric shunt surgery checklist on infection rate at a single institution. Neurosurgery 2018;83(03):508–520
16 Boethun A, Vissing NH, Mathiasen R, Skjøth-Rasmussen J, Foss-Skiftesvik J. CNS infection in children with brain tumors: adding ventriculostomy to brain tumor resection increases risk more than 20-fold. Childs Nerv Syst 2023;39(02):387–394
17 Alther B, Mylius V, Weller M, Gantenbein A. From first symptoms to diagnosis: Initial clinical presentation of primary brain tumors. Clin Transl Neusci 2020;4(02):17. Doi: 2514183X20968368
18 Roth J, Constantini S. Hydrocephalus and brain tumors. Cerebrospinal Fluid Disorders SpringerLink; 2019
19 Paoli CJ, Reynolds MA, Sinha M, Gitlin M, Crouser E. Epidemiology and costs of sepsis in the United States—an analysis based on timing of diagnosis and severity level. Crit Care Med 2018;46(12):1889–1897
20 Allegranzi B, Bischoff P, de Jonge S, et al; WHO Guidelines Development Group. New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. Lancet Infect Dis 2016;16(12):e276–e287

