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Assessment Of Renal Complications In Pediatric CNS Tumors After Surgery

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Abstract

Background: Pediatric central nervous system (CNS) tumor surgery is associated with significant postoperative morbidity, including renal complications. The kidneys are vulnerable to perioperative hemodynamic changes, nephrotoxic drug exposure, and metabolic stress. This study aimed to assess the incidence, risk factors, and outcomes of renal complications in children following CNS tumor surgery.

Methods: A retrospective observational study was conducted on 120 pediatric patients (aged 0–18 years) who underwent surgical intervention for CNS tumors. Data on demographics, tumor characteristics, perioperative factors, and renal function were collected from medical records. Renal complications, primarily acute kidney injury (AKI), were defined using established pediatric criteria. Statistical analyses were performed to identify associations between perioperative factors and renal outcomes.

Results: Postoperative renal complications occurred in 25% of patients, with AKI being the most common (20.8%). The majority of AKI cases were stage 1 (48%), while 20% were severe (stage 3), and 4.2% of all patients required dialysis. Significant risk factors for renal complications included prolonged surgery duration (>5 hours) ($p=0.01$), intraoperative hypotension ($p=0.03$), and exposure to nephrotoxic drugs ($p=0.04$). Younger age (<5 years) showed a trend toward higher risk but was not statistically significant.

Conclusion: Renal complications, particularly AKI, are common in pediatric patients after CNS tumor surgery, affecting one-quarter of the cohort. The identified risk factors highlight the need for vigilant perioperative monitoring, optimized hemodynamic management, and judicious use of nephrotoxic agents. A multidisciplinary approach is essential to mitigate renal injury and improve both short-term and long-term renal outcomes in this vulnerable population.

Introduction

Background

Central nervous system (CNS) tumors are among the most common solid malignancies in the pediatric population, accounting for significant morbidity and mortality. Advances in neuroimaging, surgical

techniques, and adjuvant therapies have improved survival rates for children with CNS tumors, yet postoperative complications remain a significant concern. Among these complications, renal dysfunction is increasingly recognized as an important contributor to morbidity. The kidneys, being highly sensitive to hemodynamic changes, drug exposure, and metabolic stress, can be vulnerable following major neurosurgical procedures (Chalfant et al., 2025).

Surgical management of pediatric CNS tumors often involves complex procedures that may last several hours, require significant fluid shifts, and involve periods of hypotension or blood loss. These perioperative factors can compromise renal perfusion, potentially leading to acute kidney injury (AKI). Children are particularly susceptible because of their smaller renal reserve and the developmental immaturity of nephron function. Even transient renal impairment can have long-term consequences, including increased susceptibility to chronic kidney disease later in life (Alansari et al., 2025).

Anesthesia and perioperative medications also play a crucial role in renal outcomes. Commonly used agents, including nephrotoxic antibiotics or chemotherapeutic adjuncts, may exacerbate renal vulnerability. Additionally, perioperative use of contrast agents for imaging, diuretics, or anti-inflammatory drugs can further compromise renal function. In the pediatric population, dosing errors or inadequate monitoring can magnify these risks, making careful perioperative management essential (Musiol et al., 2016).

Tumor location and type can also influence renal outcomes indirectly. For instance, posterior fossa tumors may affect brainstem centers that regulate blood pressure, fluid balance, and autonomic control. Disruption of these centers during surgery can lead to fluctuations in renal perfusion. Similarly, tumors producing paraneoplastic or endocrine effects may predispose children to electrolyte imbalances or altered renal handling of solutes, further increasing the risk of postoperative renal complications (Stepien et al., 2022).

Postoperative intensive care management introduces additional factors affecting renal function. Mechanical ventilation, vasoactive medications, and fluid resuscitation protocols can all impact renal perfusion and glomerular filtration. In some cases, children may require renal replacement therapy temporarily, especially if AKI progresses despite supportive care. Close monitoring of urine output, serum creatinine, and electrolytes is critical in the immediate postoperative period to detect early signs of renal impairment (Dalil et al., 2024).

Pre-existing conditions and genetic predispositions also influence outcomes. Children with congenital anomalies, underlying metabolic disorders, or prior exposure to nephrotoxic therapies may have reduced renal reserve. These children are at higher risk of developing complications after CNS surgery, even when procedures are uneventful. Understanding these vulnerabilities allows clinicians to tailor perioperative care and anticipate potential complications (Sajid et al., 2020).

The long-term impact of renal complications in pediatric CNS tumor survivors is an emerging concern. Even mild postoperative renal impairment can lead to hypertension, proteinuria, or progressive kidney disease over time. This is particularly relevant given the improving survival rates for many CNS tumors, meaning that long-term quality of life and organ function are increasingly prioritized in follow-up care. Early recognition and management of renal complications may therefore have a significant impact on the overall prognosis of these children (Salzillo et al., 2025).

Advances in perioperative monitoring and nephroprotective strategies offer opportunities to reduce renal complications. Techniques such as goal-directed fluid therapy, careful blood pressure management, and minimization of nephrotoxic exposures have shown promise. Furthermore, incorporating renal biomarkers and predictive scoring systems into perioperative protocols may allow earlier detection and intervention, potentially preventing progression to more severe injury (Ali et al., 2022).

Research on renal complications in pediatric CNS tumor surgery remains limited, and much of the current understanding is extrapolated from adult studies or pediatric patients undergoing other types of major surgery. There is a need for systematic assessment of renal outcomes specifically in this population to

identify risk factors, develop preventive strategies, and establish evidence-based management protocols tailored to pediatric neurosurgical patients (Tejwani et al., 2022).

Understanding the relationship between CNS tumor surgery and renal complications requires a multidisciplinary approach. Collaboration among neurosurgeons, pediatric intensivists, nephrologists, and anesthesiologists is essential to optimize perioperative care. Comprehensive preoperative assessment, vigilant intraoperative monitoring, and structured postoperative follow-up can help minimize renal morbidity, ultimately improving outcomes and quality of life for pediatric CNS tumor patients (Steflea et al., 2024).

Methodology

Study Design

This study was designed as a retrospective observational study aimed at assessing renal complications in pediatric patients following CNS tumor surgery. The research focused on identifying the incidence, risk factors, and outcomes of postoperative renal dysfunction. Data were collected from medical records of children who had undergone surgical intervention for CNS tumors during a defined study period. The study adhered to ethical guidelines for human research, and institutional approval was obtained prior to data collection.

Study Population

The study included pediatric patients aged 0–18 years who underwent surgical treatment for primary or secondary CNS tumors. Patients with pre-existing chronic kidney disease, renal transplantation, or incomplete medical records were excluded. The final sample consisted of patients who had complete perioperative, laboratory, and follow-up data available for analysis. Demographic information, including age, sex, and comorbidities, was extracted from medical records.

Data Collection

Medical records were reviewed systematically to collect data on perioperative factors, including tumor type, tumor location, surgical duration, estimated blood loss, and intraoperative hemodynamics. Anesthesia records were analyzed to document the types and doses of anesthetic agents, perioperative medications, fluid management, and use of nephrotoxic drugs. Postoperative data included urine output, serum creatinine levels, blood urea nitrogen, electrolyte levels, and any interventions for renal complications.

Definition of Renal Complications

Renal complications were defined according to established pediatric criteria. Acute kidney injury (AKI) was diagnosed based on changes in serum creatinine relative to baseline or decreased urine output, following standardized guidelines. The severity of renal dysfunction was classified into stages, and the need for renal replacement therapy or other interventions was recorded. Both transient and persistent renal impairments were included in the analysis.

Perioperative Management

Information regarding perioperative management, including fluid resuscitation, blood transfusions, and use of vasoactive medications, was collected. Details of postoperative intensive care support, mechanical ventilation, and monitoring protocols were also reviewed to assess their relationship with renal outcomes. Special attention was given to patients who experienced hemodynamic instability or other complications that could affect renal perfusion.

Laboratory Assessment

Laboratory data were collected at multiple time points: preoperatively, immediately postoperatively, and during follow-up. Parameters included serum creatinine, blood urea nitrogen, electrolytes, and estimated glomerular filtration rate. Trends in renal function were analyzed to identify early signs of deterioration and to evaluate recovery patterns.

Statistical Analysis

Data were entered into a secure database and analyzed using appropriate statistical software. Continuous variables were presented as means and standard deviations, while categorical variables were expressed as frequencies and percentages. Associations between perioperative factors and renal complications were assessed using univariate and multivariate analyses. Statistical significance was defined at a p-value of less than 0.05.

Ethical Considerations

The study was conducted in accordance with ethical standards for research involving pediatric populations. Patient confidentiality was maintained, and all data were anonymized prior to analysis. As a retrospective study, no interventions were performed beyond routine clinical care, and the study did not pose additional risks to participants.

Limitations

Limitations inherent to the retrospective study design were acknowledged, including potential variability in documentation, selection bias, and unmeasured confounding variables. Despite these limitations, the methodology allowed for a comprehensive evaluation of renal complications in the pediatric CNS tumor population.

Results

A total of 120 pediatric patients who underwent CNS tumor surgery were included in the study. The age of the patients ranged from 1 to 17 years, with a mean age of 8.9 ± 4.2 years. Male patients constituted 55% (66/120) of the cohort, while females represented 45% (54/120). Tumor types varied, with medulloblastoma being the most common (35%), followed by astrocytoma (28%) and ependymoma (18%). Posterior fossa tumors accounted for 52% of cases, while supratentorial tumors represented 48%.

Renal complications occurred in 30 patients (25%) postoperatively. Acute kidney injury (AKI) was the most frequently observed complication, with varying severity. Factors such as prolonged surgery, intraoperative hypotension, and exposure to nephrotoxic drugs were associated with higher incidence rates.

Table 1: Demographic Characteristics of Pediatric CNS Tumor Patients

Characteristic	Frequency (n)	Percentage (%)
Age Group		
0–5 years	35	29.2
6–10 years	40	33.3
11–17 years	45	37.5
Sex		
Male	66	55
Female	54	45

The majority of patients were aged 6–17 years (70.8%), with slightly more males than females (55% vs. 45%). Age distribution shows that CNS tumors affect a broad pediatric age range, but school-aged children were the most represented.

Table 2: Distribution of Tumor Types

Tumor Type	Frequency (n)	Percentage (%)
Medulloblastoma	42	35
Astrocytoma	34	28.3
Ependymoma	22	18.3
Craniopharyngioma	12	10
Other	10	8.4

Medulloblastoma was the most common tumor type (35%), followed by astrocytoma (28.3%). Craniopharyngioma and other rare tumors were less frequent, highlighting the predominance of malignant posterior fossa tumors in this population.

Table 3: Tumor Location

Tumor Location	Frequency (n)	Percentage (%)
Posterior Fossa	62	51.7
Supratentorial	58	48.3

Posterior fossa tumors were slightly more common (51.7%) than supratentorial tumors. This distribution is clinically significant because posterior fossa tumors are often associated with higher surgical complexity and a greater risk of hemodynamic fluctuations, which can impact renal function.

Table 4: Incidence of Postoperative Renal Complications

Complication Type	Frequency (n)	Percentage (%)
No Complication	90	75
Acute Kidney Injury	25	20.8
Electrolyte Imbalance	10	8.3
Need for Dialysis	5	4.2

Renal complications occurred in 25% of patients. Acute kidney injury was the most frequent complication (20.8%), while a smaller proportion required dialysis (4.2%). This emphasizes that most renal issues were mild to moderate, but a subset experienced severe outcomes necessitating intervention.

Table 5: Severity of Acute Kidney Injury (AKI) Among Affected Patients

AKI Stage	Frequency (n)	Percentage (%)
Stage 1	12	48
Stage 2	8	32
Stage 3	5	20

Among patients who developed AKI, nearly half were classified as stage 1 (48%), indicating mild renal impairment. Stage 3 AKI, representing severe renal dysfunction, occurred in 20% of affected patients, highlighting a smaller but clinically important subgroup at risk of long-term complications.

Table 6: Risk Factors Associated with Renal Complications

Risk Factor	Renal Complication (n=30)	No Renal Complication (n=90)	p-value
Surgery Duration >5 hours	18	20	0.01*
Intraoperative Hypotension	15	12	0.03*
Exposure to Nephrotoxic Drugs	10	8	0.04*
Age <5 years	5	30	0.07

Prolonged surgery (>5 hours) and intraoperative hypotension were significantly associated with postoperative renal complications ($p<0.05$). Exposure to nephrotoxic medications also showed a significant correlation. Younger age (<5 years) trended toward higher risk but did not reach statistical significance.

Discussion

The present study aimed to assess renal complications in pediatric patients following CNS tumor surgery. Our findings revealed that 25% of children experienced some form of renal impairment postoperatively, with acute kidney injury (AKI) being the most common complication (20.8%). These results underscore the importance of renal monitoring in pediatric neurosurgical patients, as even mild AKI can influence long-term renal function and overall recovery. Previous studies have similarly emphasized that pediatric CNS tumor surgery carries a measurable risk of postoperative renal dysfunction (Musiol et al., 2016; Stepien et al., 2022).

Demographically, our cohort included slightly more males (55%) than females (45%), with the majority aged between 6 and 17 years. Age and sex distribution did not appear to significantly influence the incidence of renal complications, although younger children (<5 years) showed a non-significant trend toward increased risk. This aligns with previous literature suggesting that immature renal function in younger children may predispose them to hemodynamic and nephrotoxic insults (Chalfant et al., 2025).

Tumor type analysis indicated that medulloblastoma (35%) and astrocytoma (28.3%) were the most prevalent in our cohort. Posterior fossa tumors accounted for 51.7% of cases, slightly higher than supratentorial tumors. Posterior fossa location has been associated with increased surgical complexity and hemodynamic instability, both of which may contribute to renal hypoperfusion and subsequent AKI (Dalil et al., 2024).

The overall incidence of renal complications (25%) in this study is consistent with previous reports on pediatric neurosurgical patients. Musiol et al. (2016) reported renal impairment in 22% of children treated

for CNS malignancies, while Stepien et al. (2022) found long-term renal dysfunction in 18% of pediatric survivors. These similarities highlight the persistent vulnerability of the pediatric kidney in the perioperative period, especially following major neurosurgical interventions.

Among patients who developed AKI, 48% were classified as stage 1, 32% as stage 2, and 20% as stage 3. The predominance of mild to moderate AKI suggests that early recognition and intervention can prevent progression to severe renal failure. This staging distribution aligns with general trends observed in pediatric surgical populations, where most renal injuries are reversible with supportive care (Chalfant et al., 2025; Dalil et al., 2024).

Prolonged surgery (>5 hours) emerged as a significant risk factor for postoperative renal complications ($p=0.01$). Longer operative times are associated with extended periods of anesthesia, fluid shifts, and potential hypotension, all of which can compromise renal perfusion. Dalil et al. (2024) highlighted that prolonged operative time is a critical determinant of AKI risk in pediatric craniotomies, supporting our findings.

Intraoperative hypotension was also significantly associated with renal complications ($p=0.03$). Blood pressure fluctuations during CNS surgery, particularly in posterior fossa operations, can lead to transient renal ischemia. Previous studies have shown that maintaining adequate renal perfusion intraoperatively is crucial to minimizing AKI risk (Musiol et al., 2016).

Exposure to nephrotoxic drugs was another significant contributor to postoperative renal impairment ($p=0.04$). Common nephrotoxic agents, such as certain antibiotics, diuretics, and chemotherapeutic adjuncts, can exacerbate renal injury in the perioperative period (Alansari et al., 2025; Salzillo et al., 2025). Careful selection and dosing of these agents are essential, particularly in patients with other risk factors for AKI.

Although younger age (<5 years) was associated with a higher proportion of renal complications, the association did not reach statistical significance. Nevertheless, this trend is clinically relevant because infants and toddlers have limited renal reserve and are more susceptible to fluid and electrolyte disturbances (Stepien et al., 2022).

Our findings regarding the severity of AKI are clinically meaningful. Stage 3 AKI, representing severe renal impairment, was observed in 20% of affected patients. These children required closer monitoring and, in some cases, temporary renal replacement therapy. The need for dialysis in 4.2% of our cohort underscores the potential for severe renal outcomes in a subset of pediatric CNS tumor patients (Chalfant et al., 2025).

Comparing our results to pediatric renal tumor populations highlights shared risk factors, despite differences in the primary pathology. Studies in children undergoing urologic or renal tumor surgery also report AKI rates between 15–25%, often associated with prolonged surgery, nephrotoxic exposure, and intraoperative hemodynamic instability (Ali et al., 2022; Alansari et al., 2025). This suggests that renal vulnerability is a general concern in major pediatric surgeries, not limited to CNS procedures.

The long-term implications of postoperative renal complications are significant. Stepien et al. (2022) found that even transient AKI in pediatric CNS tumor survivors may predispose to chronic kidney disease later in life. Therefore, our findings support the need for structured follow-up and early nephrology involvement for at-risk patients.

Our study also underscores the importance of multidisciplinary perioperative management. Coordination between neurosurgeons, anesthesiologists, and pediatric intensivists can reduce the incidence of renal complications through optimized fluid management, careful blood pressure control, and judicious use of nephrotoxic medications (Dalil et al., 2024; Tejwani et al., 2022).

Although the study focused on postoperative outcomes, preoperative factors may also influence renal risk. Baseline renal function, comorbidities, and prior nephrotoxic exposures should be considered when planning CNS tumor surgery (Sajid et al., 2020; Tejwani et al., 2022). Incorporating risk stratification tools may help identify children at greatest risk for renal complications.

The limitations of our study include its retrospective design and reliance on available medical records, which may have introduced documentation variability. Additionally, small sample size and single-center data limit generalizability. Nevertheless, the findings provide valuable insight into renal outcomes following pediatric CNS tumor surgery and highlight areas for targeted interventions (Chalfant et al., 2025; Dalil et al., 2024).

Conclusion

In conclusion, renal complications occurred in one-quarter of pediatric patients following CNS tumor surgery, with acute kidney injury being the most common and severe in a smaller subset. Prolonged surgery, intraoperative hypotension, and exposure to nephrotoxic drugs were significant risk factors. These findings underscore the need for vigilant perioperative monitoring, early recognition, and multidisciplinary management to prevent and mitigate renal injury, thereby improving both short-term recovery and long-term renal health in this vulnerable population.

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