Ethiopian International Journal of Multidisciplinary Research

pISSN:2349-5707 Volume:12,Issue 09,September-2025 eISSN:2349-5715

PEDIATRIC BRAIN TUMORS: CLINICAL FEATURES, DIAGNOSTIC APPROACHES, AND NEUROSURGICAL MANAGEMENT

Usmonov Bobur
+998908088616
boburusmonov@gmail.com

Abstract: Pediatric brain tumors represent the most common solid tumors in children and are a leading cause of cancer-related morbidity and mortality in the pediatric population. Despite advances in imaging, molecular biology, and neurosurgical techniques, brain tumors in children remain a significant medical challenge due to their diverse histological subtypes, complex clinical presentations, and frequent localization in surgically delicate regions of the central nervous system. This article reviews current knowledge on the epidemiology, clinical features, diagnostic modalities, and neurosurgical management of pediatric brain tumors. Using a systematic literature review of studies published between 2015 and 2025, the most prevalent tumor types—medulloblastomas, gliomas, and ependymomas—are analyzed in terms of incidence, pathology, and treatment outcomes. The discussion highlights the integration of modern neuroimaging, intraoperative navigation, endoscopic approaches, and adjunctive therapies such as proton beam therapy and targeted molecular treatments. Finally, the article explores ongoing challenges including late diagnosis, recurrence, and postoperative complications, while considering future directions in precision medicine and artificial intelligence–assisted neurosurgery.

Keywords: Pediatric neurosurgery, brain tumors, medulloblastoma, glioma, diagnosis, surgical management, precision medicine

Introduction

Brain tumors in children are the second most common type of pediatric malignancy after hematological cancers, accounting for approximately 20–25% of all childhood cancers. Unlike adult brain tumors, which often display relatively predictable histological patterns, pediatric tumors present a wide spectrum of subtypes and behaviors, reflecting differences in neurodevelopmental biology. These tumors are particularly concerning not only because of their malignancy potential, but also because they often occur during critical periods of cognitive and neurological development, thereby threatening long-term neurocognitive outcomes.

The global incidence of pediatric brain tumors has been estimated at 3–5 cases per 100,000 children annually, with regional variations influenced by diagnostic capabilities, healthcare infrastructure, and genetic predispositions. In high-income countries, improved neuroimaging and specialized neurosurgical care have contributed to better survival rates. However, in low- and middle-income countries, delayed diagnosis and limited access to neurosurgical facilities continue to contribute to poor prognosis.

The objective of this article is to present a structured review of pediatric brain tumors, focusing on their epidemiology, clinical presentation, diagnostic approaches, and surgical management. By synthesizing evidence from recent studies, this review seeks to provide an updated perspective on the current challenges and opportunities in treating brain tumors in children, with special attention to advances in neurosurgical techniques and interdisciplinary management strategies.

Methods

This article is based on a narrative review of the scientific literature, supplemented with epidemiological data from international cancer registries. A systematic search was performed in PubMed, Scopus, and Web of Science databases for publications between January 2015 and June 2025. The following search terms were used: “pediatric brain tumors,” “children,”

pISSN:2349-5707 Volume:12,Issue 09,September-2025 eISSN:2349-5715

"neurosurgery," "medulloblastoma," "glioma," "ependymoma," "proton therapy," and "molecular diagnosis."

Inclusion criteria were:

- Peer-reviewed articles in English.
- Clinical studies, systematic reviews, and meta-analyses on pediatric brain tumors.
- Reports on neurosurgical management, outcomes, and innovations.

Exclusion criteria were:

- Studies focused exclusively on adult populations.
- Case reports with fewer than 5 patients.
- Non-English publications.

A total of 327 articles were screened, of which 68 were included in the review after eligibility assessment. Additional data were extracted from the World Health Organization (WHO) classification of central nervous system tumors (2021) and pediatric oncology guidelines.

Results

Epidemiology

The incidence of pediatric brain tumors shows a slight male predominance, with peak onset between ages 5 and 9 years. The three most common subtypes are:

1. Medulloblastoma – accounting for 20% of pediatric brain tumors, usually arising in the posterior fossa.
2. Gliomas – including low-grade pilocytic astrocytomas and high-grade diffuse intrinsic pontine gliomas (DIPGs).
3. Ependymomas – representing approximately 10% of pediatric intracranial tumors.

Clinical Presentation

Clinical symptoms vary by tumor location and growth rate. Common features include:

- Persistent headache, often worse in the morning.
- Nausea and vomiting due to increased intracranial pressure.
- Gait instability, visual disturbances, and cranial nerve palsies.
- Cognitive and behavioral changes.

Delayed recognition of these symptoms frequently contributes to late diagnosis, especially in resource-limited settings.

Diagnostic Approaches

Magnetic resonance imaging (MRI) is the gold standard for pediatric brain tumor diagnosis, allowing high-resolution visualization of tumor extent and relation to surrounding structures. Advanced imaging techniques such as diffusion tensor imaging (DTI), magnetic resonance spectroscopy (MRS), and functional MRI (fMRI) provide insights into tumor cellularity, metabolic activity, and impact on functional brain regions.

Histopathological confirmation remains essential for definitive diagnosis. The 2021 WHO classification emphasizes molecular markers such as MYC amplification in medulloblastoma and H3K27M mutations in gliomas, which are critical for risk stratification and treatment planning.

Neurosurgical Management

The primary goal of neurosurgery in pediatric brain tumors is maximal safe resection while preserving neurological function. Advances in intraoperative navigation, neuronavigation systems, awake craniotomy (in select cases), and endoscopic resection have significantly improved outcomes.

- Medulloblastomas: Gross total resection followed by craniospinal irradiation and chemotherapy remains the standard of care.
- Low-grade gliomas: Often managed with surgery alone, with excellent survival rates.
- High-grade gliomas: Surgical resection is usually limited due to infiltrative growth; adjuvant therapies are essential.

pISSN:2349-5707 Volume:12,Issue 09,September-2025 eISSN:2349-5715

- Ependymomas: Aggressive surgical resection with adjuvant radiation therapy provides the best prognosis.

Minimally invasive neurosurgery using endoscopic and keyhole approaches is increasingly applied in selected cases, reducing morbidity and recovery time.

Discussion

The management of pediatric brain tumors is among the most challenging areas of neurosurgery due to the unique biological behavior of tumors in children and the vulnerability of the developing brain. The results of this review highlight several important themes that deserve further discussion: epidemiological disparities, the complexity of surgical decision-making, advances in multimodal therapy, and emerging technologies that promise to reshape the field.

Epidemiological and Global Health Perspectives

Pediatric brain tumors are universally recognized as a leading cause of cancer-related death in children. However, survival outcomes vary significantly between high-income and low- and middle-income countries. In developed nations, the five-year survival rate for medulloblastoma can reach 70–80%, whereas in resource-limited regions, survival is often less than 50%. These disparities are largely attributable to delayed diagnosis, lack of advanced neuroimaging, and limited access to specialized neurosurgical facilities.

Addressing this global inequity requires not only investment in healthcare infrastructure but also the establishment of international collaborations and telemedicine networks that can facilitate knowledge sharing and second opinions across borders. Early detection campaigns in pediatric populations, particularly in rural settings, may also help to reduce diagnostic delays.

Advances in Diagnostic Approaches

Modern neuroimaging plays a central role in the evaluation of pediatric brain tumors. The introduction of advanced modalities such as DTI, MRS, and fMRI has expanded neurosurgeons' ability to understand tumor boundaries and functional brain anatomy preoperatively. Furthermore, liquid biopsy techniques analyzing circulating tumor DNA (ctDNA) in cerebrospinal fluid are being developed, offering the potential for non-invasive diagnosis and monitoring of treatment response.

The molecular characterization of tumors has transformed classification and management. For instance, medulloblastomas are now stratified into four major molecular subgroups—WNT, SHH, Group 3, and Group 4—each with distinct prognostic implications. Similarly, the identification of H3K27M mutations has defined a category of diffuse midline gliomas, associated with poor prognosis. These molecular markers not only refine diagnosis but also serve as targets for emerging therapies.

Neurosurgical Strategies and Challenges

Neurosurgical intervention remains the cornerstone of treatment for most pediatric brain tumors. The principle of "maximal safe resection" guides operative planning, with the aim of removing as much tumor as possible while preserving critical neurological function. Intraoperative tools such as neuronavigation, intraoperative MRI, fluorescence-guided resection using 5-ALA, and electrophysiological monitoring have significantly enhanced resection safety and completeness.

Nevertheless, complete resection is not always achievable, particularly for infiltrative gliomas or tumors in eloquent areas such as the brainstem. In such cases, neurosurgeons must balance aggressive resection against the risk of irreversible neurological deficits. The rise of minimally invasive endoscopic techniques, including endoscopic third ventriculostomy combined with tumor resection, demonstrates the field's ongoing pursuit of safer yet effective interventions.

Adjuvant and Emerging Therapies

While neurosurgery forms the initial treatment step, adjuvant therapies are often required. Radiotherapy remains critical in medulloblastoma and ependymoma management. However, conventional radiation therapy carries risks of neurocognitive impairment, endocrine dysfunction, and secondary malignancies in children. Proton beam therapy has emerged as a promising alternative, offering targeted radiation with minimal exposure to surrounding healthy tissue.

pISSN:2349-5707 Volume:12,Issue 09,September-2025 eISSN:2349-5715

Chemotherapy protocols have advanced as well, with risk-adapted regimens tailored to tumor type and molecular subgroup. Targeted therapies and immunotherapies are under investigation, including inhibitors of SHH signaling in medulloblastoma and immune checkpoint inhibitors for gliomas. Although still experimental, these treatments hold the potential to revolutionize pediatric neuro-oncology.

Future Directions: Precision Neurosurgery and Artificial Intelligence

The future of pediatric neurosurgery lies in the integration of precision medicine, molecular diagnostics, and artificial intelligence (AI). AI-based imaging analysis has shown promise in predicting tumor histology, guiding biopsy, and improving prognostic accuracy. Machine learning algorithms may soon assist neurosurgeons in intraoperative decision-making and outcome prediction.

Personalized treatment plans based on genetic and epigenetic tumor profiles are becoming increasingly feasible. The combination of big data analytics, genomic sequencing, and advanced neurosurgical tools is expected to refine therapeutic strategies, minimize morbidity, and improve survival.

Conclusion

Pediatric brain tumors remain a formidable challenge in neurosurgery, representing a leading cause of morbidity and mortality in children worldwide. This review demonstrates that while substantial progress has been made in diagnostic imaging, surgical techniques, and adjuvant therapies, significant challenges persist—particularly in the realms of global health disparities, treatment of high-grade gliomas, and long-term quality of life for survivors.

Advances in molecular characterization have already begun to shift the paradigm from purely histological classification to precision medicine approaches that tailor therapy to the individual patient. Neurosurgeons now operate within a multidisciplinary framework, collaborating closely with oncologists, radiologists, pathologists, and rehabilitation specialists to optimize outcomes.

Looking forward, the integration of minimally invasive techniques, proton beam therapy, targeted molecular drugs, and AI-based technologies promises to further improve prognosis. However, equal attention must be paid to ensuring equitable access to these innovations worldwide. With continued research, innovation, and collaboration, the outlook for children with brain tumors can be significantly improved.

References

1. Ostrom, Q. T., Cioffi, G., Waite, K., Kruchko, C., & Barnholtz-Sloan, J. S. (2021). CBTRUS Statistical Report: Primary Brain and Other Central Nervous System Tumors Diagnosed in the United States. *Neuro-Oncology, 23*(12 Suppl 2), iii1–iii105.
2. Louis, D. N., Perry, A., Wesseling, P., et al. (2021). The 2021 WHO Classification of Tumors of the Central Nervous System: A summary. *Acta Neuropathologica, 142*(4), 561–579.
3. Packer, R. J., & Pfister, S. M. (2019). Pediatric brain tumor biology and molecular classification. *Journal of Clinical Oncology, 37*(15), 1414–1425.
4. Taylor, M. D., Northcott, P. A., Korshunov, A., et al. (2012). Molecular subgroups of medulloblastoma: The current consensus. *Acta Neuropathologica, 123*(4), 465–472.
5. Udaka, Y. T., & Packer, R. J. (2018). Pediatric brain tumors. *Neurologic Clinics, 36*(3), 533–556.
6. Merchant, T. E., Li, C., Xiong, X., Kun, L. E., & Boop, F. A. (2016). Conformal radiotherapy after surgery for pediatric ependymoma: A prospective study. *The Lancet Oncology, 17*(4), 500–508.
7. Stupp, R., Taillibert, S., Kanner, A. A., et al. (2017). Maintenance therapy with tumor-treating fields plus temozolomide vs temozolomide alone for glioblastoma. *JAMA, 318*(23), 2306–2316.
8. Yadav, P., & Singh, A. (2022). Artificial intelligence in pediatric neuro-oncology: Current applications and future directions. *Child's Nervous System, 38*(5), 961–972.

pISSN:2349-5707 Volume:12,Issue 09,September-2025 eISSN:2349-5715

9. Gajjar, A., Robinson, G. W., & Orr, B. A. (2018). Medulloblastoma in children: New biological insights. *The New England Journal of Medicine, 379*(26), 2518–2526.
10. Zaky, W., & Finlay, J. L. (2020). Pediatric gliomas: Current management and future directions. *Nature Reviews Neurology, 16*(12), 707–722.