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Chapter Eleven - Emerging interventional treatments in the management of pediatric brain tumors

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Abstract

Recent advancements in the molecular understanding of pediatric brain tumor biology have significantly contributed to the development of innovative therapeutic strategies aimed at improving clinical outcomes for affected children. These scientific breakthroughs have facilitated the identification of specific molecular targets and signaling pathways integral to the oncogenesis of pediatric brain tumors, thereby enabling the design of targeted therapies that disrupt these pathogenic processes. Furthermore, the incorporation of immunotherapy and precision medicine approaches has unveiled novel therapeutic avenues, offering the potential for more efficacious and less toxic treatment modalities. As research in this domain continues to progress, these cutting-edge therapeutic interventions are anticipated to enhance survival rates and improve the quality of life for pediatric patients. This review delineates emerging interventional treatments in pediatric brain tumor management and examines the persistent challenges within the field.

Introduction

Pediatric brain tumors represent a significant challenge in oncology, being the leading cause of cancer-related mortality in children (Miller et al., 2021). Despite advances in surgical techniques, radiation, and chemotherapy, the prognosis for many pediatric brain tumors remains poor, necessitating the exploration of novel therapeutic approaches (Kulubya et al., 2022).

Over the past two decades, strides in the molecular understanding of brain tumor biology have revolutionized the landscape of treatment strategies. By elucidating the genetic and epigenetic alterations driving tumorigenesis, researchers have identified distinct molecular targets and signaling pathways that are crucial in the pathogenesis of these malignancies (Kulubya et al., 2022). This has facilitated the development of targeted therapies designed to specifically disrupt oncogenic processes, offering the promise of more precise and less toxic treatment options.

Moreover, Neurosurgical innovations have included the use of laser interstitial thermal therapy, focused ultrasound and sonographic therapy for treatment of brain tumors. The principles of these innovative approaches for tissue ablation are well understood from the application of a heat or waves via radiant light energy, the associated cell death from heating, and advanced magnetic resonance imaging (MRI) to monitor and guide the ablation. However, initial response and long-term control for specific tumor types are not well established in the field. Furthermore, the unique pathologies common to pediatric brain tumors lags behind our adult counterparts in the extant literature. It is expected for these innovative approaches to play a more significant role in pediatric neuro-oncology, but if that becomes upfront therapy, limited to recurrent or residual disease, or in combination with targeted medical therapy to facilitate breaking down the blood-brain barrier for more efficacious drug deliver remains to be determined.

This chapter aims to explore the latest advancements in molecular targeting and therapeutic innovations, highlighting their implications for improving survival rates and quality of life in pediatric patients, while also addressing the ongoing challenges in this rapidly evolving field.

Section snippets

Advancements in the molecular biology of pediatric brain tumors

The 2021 World Health Organization (WHO) classification of central nervous system tumors now integrates histopathologic and molecular data, reflecting significant advancements in the molecular characterization of these tumors (Louis et al., 2021). Pediatric low-grade gliomas (pLGGs) exemplify the forefront of research into brain tumor molecular alterations. They are increasingly recognized as a “single pathway disease,” primarily driven by genetic changes that consistently activate the …

Novel therapeutic approaches in pediatric brain tumors

In recent years, substantial progress has been achieved in the development of therapeutic compounds, driven by new insights into cellular pathways, oncogenic driver mutations, and cancer cell mechanisms. These targeted therapies function by either directly inhibiting these pathways or by activating the immune system to facilitate the destruction of cancer cells. This category of therapies includes small-molecule inhibitors, monoclonal antibodies, and adoptive cellular immunotherapy. Table 1, …

Laser interstitial thermal therapy for pediatric brain tumors

Laser interstitial thermal therapy (LITT) is a minimally invasive surgical technique for the ablation of soft tissue. LITT is novel as a neurosurgical technique owing to how it leverages the principles of laser physics and tissue thermodynamics to achieve targeted tissue ablation guided by advanced MRI temperature monitoring technology (Chen et al., 2021). There are multiple platforms for LITT therapy that are FDA cleared to necrotize or coagulate soft tissue in organs of the human body …

Convection-enhanced delivery for pediatric brain tumors

Convection-Enhanced Delivery (CED) was first described in the early 1990s by Edward Oldfield and colleagues at the National Institutes of Health (Bobo et al., 1994). Developed to overcome the challenges posed by the blood-brain barrier (BBB), CED involves stereotactic placement of one or more catheters directly into the targeted brain region. These catheters are connected to an external infusion pump, which creates a pressure gradient to drive the therapeutic infusate into the extracellular …

Focused ultrasound (FUS) and sonodynamic therapy in pediatric brain tumors

Focused ultrasound (FUS) is a non-invasive therapeutic modality that utilizes high-frequency sound waves to precisely target tissues within the body. Its mechanisms and applications are diverse, ranging from thermal ablation to mechanical disruption. FUS operates by propagating ultrasound waves that create alternating cycles of compression and rarefaction within tissues. When these waves converge at a focal point, they produce a localized increase in energy density, which can be modulated to …

Conclusion

The advent of innovative treatments such as LITT, FUS, sonographic therapy, and targeted therapies, marks a significant advancement in the management of pediatric brain tumors. These techniques offer promising alternatives to traditional surgery and radiation by providing precise, minimally invasive options that minimize damage to healthy tissues. LITT employs laser-induced heat for targeted ablation, FUS utilizes sound waves for both thermal and non-thermal therapeutic effects, and sonographic …

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