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Review Paper

Glioblastoma Multiforme: Navigating the Complexity of an Aggressive Brain Tumor

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Abstract

Glioblastoma multiforme (GBM) represents the most aggressive and common primary malignant brain tumor in adults. Characterized by rapid proliferation, diffuse infiltration, and resistance to conventional therapies, GBM poses significant clinical and therapeutic challenges. This article explores the molecular biology, epidemiology, clinical presentation, diagnostic strategies, and current treatment modalities associated with GBM. Advances in genomics and targeted therapies are also discussed, highlighting emerging approaches that aim to improve patient outcomes. Despite progress, GBM remains associated with poor prognosis, underscoring the urgent need for innovative research and personalized treatment strategies.

Introduction

Glioblastoma multiforme is a grade IV astrocytoma, classified as the most malignant form of glioma. It originates from astrocytes, the star-shaped glial cells that support neuronal function. GBM is notorious for its heterogeneity, both at the cellular and molecular levels, contributing to its aggressive behavior and therapeutic resistance

Epidemiology

GBM accounts for approximately 45–50% of all primary malignant brain tumors. It predominantly affects adults between the ages of 45 and 70, with a slightly higher incidence in males. While most cases are sporadic, rare genetic conditions such as Li-Fraumeni syndrome and neurofibromatosis type 1 may increase susceptibility

Pathophysiology and Molecular Features

The hallmark of GBM is its rapid growth and diffuse infiltration into surrounding brain tissue. Key molecular characteristics include

- **Genetic mutations**: Alterations in genes such as *TP53*, *EGFR*, and *PTEN* are commonly observed.
- **IDH status**: Isocitrate dehydrogenase (IDH) mutations distinguish secondary GBMs from primary ones and are associated with better prognosis.
- **MGMT promoter methylation:** This epigenetic modification influences response to chemotherapy, particularly temozolomide

These molecular insights have become essential for classification and treatment planning

Clinical Presentation

Symptoms of GBM vary depending on tumor location but often include:

- Persistent headaches
- Seizures
- Cognitive or personality changes
- Focal neurological deficits (e.g., weakness, speech difficulties)
- Nausea and vomiting due to increased intracranial pressure

The rapid progression of symptoms is a distinguishing feature.

Diagnosis

Diagnosis typically involves a combination of imaging and histopathological evaluation

- **Magnetic Resonance Imaging (MRI)**: The gold standard for detecting GBM, often showing a ring-enhancing lesion with central necrosis.
- **Biopsy or surgical resection**: Confirms diagnosis and allows for molecular analysis.
- **Advanced imaging techniques**: Such as MR spectroscopy and perfusion imaging, provide additional insights into tumor metabolism and vascularity.

Treatment Strategies

Management of GBM requires a multimodal approach:

1. Surgical Resection

Maximal safe removal of the tumor is the first step. However, complete resection is rarely possible due to the infiltrative nature of GBM.

2. Radiotherapy

Postoperative radiotherapy targets residual tumor cells and is a standard component of treatment.

3. Chemotherapy

Temozolomide is the most commonly used chemotherapeutic agent, often administered alongside radiotherapy and as maintenance therapy

4. Tumor Treating Fields (TTF)

A novel modality that uses alternating electric fields to disrupt cancer cell division.

Emerging Therapies

Recent research has focused on innovative approaches, including:

- **Immunotherapy**: Vaccines and checkpoint inhibitors aim to enhance the immune response against tumor cells.
- **Targeted therapy**: Drugs designed to inhibit specific molecular pathways.
- **Gene therapy**: Experimental strategies to modify **tumor genetics.**
- **Nanotechnology:** Enhancing drug delivery across the blood-brain barrier

While promising, these therapies are still under investigation and have yet to significantly improve long-term survival.

Prognosis

The prognosis for GBM remains poor, with a median survival of approximately 12–15 months despite aggressive treatment. Factors influencing prognosis include patient age, performance status, extent of resection, and molecular markers such as IDH mutation and MGMT methylation status.

Conclusion

Glioblastoma multiforme remains one of the most challenging malignancies in neuro-oncology due to its aggressive nature and resistance to treatment. Advances in molecular biology have improved our understanding of the disease, paving the way for personalized medicine. However, significant gaps remain, and continued research is essential to develop more effective therapies and improve patient survival and quality of life.

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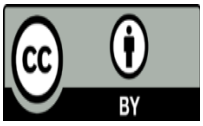

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