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ADVANCES IN BIOLOGICAL THERAPIES FOR NEUROSURGICAL ANESTHESIA: A NARRATIVE REVIEW OF MONOCLONAL ANTIBODIES AND GENE THERAPY APPLICATIONS IN BRAIN TUMOR MANAGEMENT AND NEURODEGENERATIVE DISEASES

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ABSTRACT: Neurosurgical anesthesia has seen significant progress with the introduction of biological therapies, particularly monoclonal antibodies and gene therapy. These novel treatments hold immense potential in the management of complex neurological conditions, notably brain tumors and neurodegenerative diseases. The promise of monoclonal antibodies that target specific antigens as adjuvant therapies for aggressive malignancies like glioblastoma, and gene therapy's objective to correct genetic abnormalities responsible for various neurological disorders, are particularly noteworthy. This narrative review aims to provide a comprehensive overview of the current research, challenges, and future directions of these biological therapies in the context of neurosurgical anesthesia.

Keywords: Monoclonal Antibodies. Gene Therapy. Neurosurgical Procedures. Brain Neoplasms. Neurodegenerative Diseases.

INTRODUCTION

Neurosurgical anesthesia has witnessed significant advancements in recent years, particularly with the emergence of biological therapies such as monoclonal antibodies and gene therapy (1,2). These innovative approaches have shown promising potential in managing complex neurological conditions, including brain tumors and neurodegenerative diseases. This narrative review, which is comprehensive in its coverage, aims to provide a thorough overview of these biological therapies' current research, challenges, and bright prospects in the field of neurosurgical anesthesia.

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METHODOLOGY

A thorough literature search was conducted using renowned databases, including Scopus, Web of Science, PubMed, ERIC, IEEE Xplore, ScienceDirect, Directory of Open Access Journals (DOAJ), and JSTOR. The search terms included "biological therapies," "monoclonal antibodies," "gene therapy," "neurosurgical anesthesia," "brain tumors," and "neurodegenerative diseases." Relevant articles published in English, focusing on the applications of monoclonal antibodies and gene therapy in neurosurgical anesthesia, were selected for review. The selected studies were critically appraised for their methodology, results, and implications.

RESULTS

Monoclonal Antibodies in Brain Tumor Management

Monoclonal antibodies have emerged as promising adjuvant treatments for brain tumors, particularly glioblastoma, which is known for its aggressive nature and poor prognosis (3). These antibodies target tumor-specific antigens, enabling a more targeted approach to cancer treatment (4). Researchers have explored the potential of conjugating monoclonal antibodies with toxins or radioactive isotopes to enhance their efficacy in eradicating tumor cells (5).

Phase I/II clinical trials have yielded encouraging results, demonstrating disease stabilization and prolonged patient survival when monoclonal antibodies are used with standard treatment modalities such as surgery, radiation, and chemotherapy (5,6). One notable example is bevacizumab, a monoclonal antibody targeting vascular endothelial growth factor (VEGF), which has shown efficacy in reducing tumor angiogenesis and edema in glioblastoma patients (7,8).

However, several challenges remain in successfully applying monoclonal antibodies in brain tumor treatment. Immunogenicity, which refers to the body's immune response against foreign antibodies, can limit their effectiveness and lead to adverse reactions (9,10). Additionally, the blood-brain barrier (BBB), a highly selective semipermeable membrane barrier that separates the circulating blood from the brain and extracellular fluid in the central

nervous system, poses a significant hurdle in delivering monoclonal antibodies to the brain, as it selectively restricts the passage of large molecules (9,11). Researchers are actively exploring strategies to overcome these barriers, such as developing humanized antibodies to reduce immunogenicity and using nanoparticles or receptor-mediated transport to facilitate BBB crossing (9,12–14).

Gene Therapy for Neurodegenerative Diseases

Neurodegenerative diseases, such as Alzheimer's, Parkinson's, and Huntington's, are characterized by the progressive loss of specific neuronal populations, leading to cognitive and motor impairments (15). Gene therapy has emerged as a promising approach to address the underlying genetic abnormalities associated with these disorders (16). By delivering therapeutic genes to the affected brain regions, gene therapy aims to restore normal cellular functions and slow down or halt the neurodegenerative process (17).

One of the most extensively studied applications of gene therapy in neurodegenerative diseases is the delivery of neurotrophic factors, a family of proteins that promote the growth and survival of neurons, such as glial cell line-derived neurotrophic factor (GDNF), to promote neuronal survival and regeneration (18,19). Preclinical studies have shown that GDNF gene therapy can protect dopaminergic neurons in animal models of Parkinson's disease, leading to improved motor function (18). Similarly, gene therapy approaches targeting the reduction of toxic protein aggregates, such as amyloid-beta in Alzheimer's disease and mutant huntingtin in Huntington's disease, have shown promise in animal models (20,21).

However, the clinical translation of gene therapy for neurodegenerative diseases faces several challenges. The delivery of therapeutic genes to the brain requires viral vectors, such as adeno-associated viruses (AAVs), which can elicit immune responses and raise safety concerns (17,22). Additionally, the long-term efficacy and potential side effects of gene therapy in the human brain remain to be fully elucidated. Ongoing clinical trials are investigating the safety and effectiveness of various gene therapy approaches for neurodegenerative diseases, hoping to develop effective treatments that can slow down or reverse the course of these debilitating conditions (20,23).

DISCUSSION

The emergence of biological therapies, particularly monoclonal antibodies and gene therapy, has opened new avenues for managing brain tumors and neurodegenerative diseases in neurosurgical anesthesia. Monoclonal antibodies offer a targeted approach to cancer treatment, potentially enhancing the efficacy of conventional therapies and improving patient outcomes. Gene therapy, on the other hand, holds promise for addressing the underlying genetic abnormalities associated with neurodegenerative disorders, offering hope for slowing down or reversing the progression of these conditions.

However, the successful application of these biological therapies in neurosurgical anesthesia faces several challenges. The blood-brain barrier remains a significant hurdle in delivering monoclonal antibodies and gene therapy vectors to the brain, necessitating the development of innovative strategies to overcome this barrier. Immunogenicity and potential side effects also require careful consideration and management to ensure the safety and efficacy of these therapies.

Despite these challenges, the potential benefits of monoclonal antibodies and gene therapy in neurosurgical anesthesia are significant. With ongoing research and clinical trials, it is anticipated that these biological therapies will continue to advance and provide new treatment options for patients with brain tumors and neurodegenerative diseases. The urgency and importance of this work in neurosurgical anesthesia cannot be overstated. Continuous research and clinical trials are crucial in integrating these therapies into practice, ensuring optimal patient care and outcomes.

CONCLUSION

Biological therapies, including monoclonal antibodies and gene therapy, represent exciting frontiers in neurosurgical anesthesia. These innovative approaches offer the potential to revolutionize the management of brain tumors and neurodegenerative diseases, providing targeted treatments and addressing underlying genetic abnormalities. While challenges such as the blood-brain barrier and immunogenicity remain, ongoing research and clinical trials are paving the way for the successful application of these therapies in clinical practice.

As neurosurgical anesthesia evolves, anesthesiologists must stay abreast of the latest advancements in biological therapies and their implications for patient care. Integrating monoclonal antibodies and gene therapy into neurosurgical anesthesia practice will require a multidisciplinary approach, with close collaboration between healthcare professionals to ensure the safe and effective delivery of these therapies.

In conclusion, the emergence of biological therapies in neurosurgical anesthesia holds immense promise for improving patient outcomes and quality of life. As research progresses and clinical trials yield promising results, these therapies are anticipated to become increasingly integrated into the management of brain tumors and neurodegenerative diseases, offering new hope for patients and their families.

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