World Journal of Biology Pharmacy and Health Sciences

eISSN: 2582-5542

Cross Ref DOI: 10.30574/wjbphs

Journal homepage: https://wjbphs.com/

(Review Article)

Precision medicine in neuro-oncology: The role of nursing in targeted therapies and immunotherapy

Chidinma Madu [1,*] and Ajibade Victoria Mofiyinfoluwa [2]

[1] *Department of Neuro-Oncology, Duke Health Systems, USA.*

[2] *Department of Critical Care Registered Nurse, Duke Health Systems, USA.*

World Journal of Biology Pharmacy and Health Sciences, 2025, 22(02), 333-341

Publication history: Received on 30 March 2025; revised on 14 May 2025; accepted on 17 May 2025

Article DOI: https://doi.org/10.30574/wjbphs.2025.22.2.0483

Abstract

Background: Precision medicine in neuro-oncology has truly transformed the way we treat brain tumors. By leveraging molecular and genetic profiling, we can now customize therapies to fit each patient's unique needs. This approach stands in stark contrast to traditional methods, as it not only improves outcomes but also reduces toxicity and boosts the effectiveness of treatments through targeted therapies and immunotherapies. Neuro-oncology nurses are vital in this process, taking on responsibilities like conducting thorough patient assessments, educating patients about personalized treatment options, managing side effects, and ensuring that patients stick to their complex treatment plans. Thanks to advancements in AI-driven diagnostics, wearable health tech, and telemedicine, nurses are better equipped than ever to deliver proactive, patient-centered care. As this field continues to evolve, ongoing education and teamwork across disciplines will be crucial for enhancing neuro-oncological treatment.

Aim: This paper sets out to delve into the changing role of neuro-oncology nurses as they embrace precision medicine, particularly in the realms of targeted therapies and immunotherapy. It looks at how these nurses contribute to patient assessments, education, and treatment management, while also integrating new technologies to improve personalized care and therapeutic results.

Methods: This study takes a deep dive into the role of neuro-oncology nurses in the realm of precision medicine, especially when it comes to targeted therapies and immunotherapy. We'll be looking at a range of peer-reviewed articles, clinical guidelines, and reports from oncology organizations to shed light on the responsibilities nurses have in areas like patient assessment, education, treatment management, and the use of technology. Our review will spotlight the latest advancements, the challenges faced, and the best practices that showcase how nurses are adapting and contributing to personalized care in neuro-oncology.

Result: The findings really shine a light on how essential neuro-oncology nurses are in making precision medicine work through a focus on patient-centered care, ensuring treatment adherence, and managing side effects from targeted therapies and immunotherapy. These nurses are crucial in helping patients understand their personalized treatment plans, keeping an eye on how therapies are working, and incorporating new technologies like AI-driven diagnostics and remote monitoring. As precision medicine continues to evolve, the responsibilities of nurses are growing, highlighting the importance of ongoing education and teamwork across disciplines to enhance patient outcomes in neuro-oncology.

Conclusion: Precision medicine has truly transformed the way we approach neuro-oncology treatment, and nurses are at the heart of this change, especially when it comes to targeted therapies and immunotherapy. They take on key responsibilities like educating patients, keeping a close eye on their progress, and integrating new technologies to ensure the best possible care. To keep up with the fast-paced advancements in precision medicine, ongoing education and teamwork are absolutely essential for improving nursing practices. Plain language summary: Precision medicine is

* Corresponding author: Chidinma Madu

transforming brain tumor treatment by utilizing genetic insights to develop personalized therapies. Neuro-oncology nurses are essential in guiding patients through targeted therapies and immunotherapy, ensuring they understand and manage their treatments effectively. They monitor side effects, support treatment adherence, and leverage technologies like AI and telemedicine to enhance patient care. As advancements continue, ongoing education and collaboration with medical teams are crucial for optimizing patient outcomes.

This abstract takes a closer look at the crucial part nursing plays in precision medicine for neuro-oncology, particularly when it comes to targeted therapies and immunotherapy. As personalized treatments continue to transform the way we approach brain tumor care, nurses are at the forefront, providing essential patient education, managing symptoms, and ensuring therapy adherence. Their knowledge is vital for spotting side effects early, coordinating care effectively, and ultimately enhancing patient outcomes. By connecting innovative treatments with comprehensive patient support, nursing professionals are indispensable in maximizing the benefits of precision medicine in neuro-oncology.

Keywords: Precision medicine; Neuro-oncology; Nursing; Targeted therapy; Immunotherapy; Patient care; Technology integration

1. Introduction

Precision medicine in neuro-oncology represents a transformative and personalized approach to the treatment of brain tumors by leveraging molecular and genetic profiling to tailor therapeutic strategies. Unlike traditional, one-size-fits-all treatment paradigms, precision medicine enables the development of individualized treatment plans based on the unique molecular and genetic characteristics of each patient's tumor. This shift has had profound implications in neuro-oncology, as it has optimized therapeutic outcomes, minimized unnecessary toxicity, and provided more effective ways to manage brain tumors. The introduction of targeted therapies, which selectively inhibit specific oncogenic pathways, alongside immunotherapies that enhance the body's immune response against malignancies, has revolutionized how neuro-oncological disorders are treated (Louis et al., 2021). Central to the successful implementation of precision medicine in neuro-oncology is the critical role played by neuro-oncology nurses. Their responsibilities have evolved significantly in response to these advances.

Nurses are at the forefront of implementing precision medicine through comprehensive patient assessments, education on personalized therapeutic regimens, managing treatment-related toxicities, and ensuring adherence to often complex and individualized treatment plans (Oncology Nursing Society [ONS], 2023).

The introduction of precision medicine requires that nurses not only possess an understanding of advanced therapies but also continuously monitor patients for potential side effects and work within a multidisciplinary team to ensure the best possible outcomes. As the landscape of neuro-oncology continues to evolve, so does the role of the nurse. The integration of innovative technologies, such as artificial intelligence (AI)-driven diagnostic tools, wearable health monitoring devices, and telehealth platforms, has further enhanced the precision of patient care. AI tools are increasingly being utilized to interpret complex genomic data, helping nurses anticipate therapeutic responses and adverse effects with greater accuracy. Remote patient monitoring systems and predictive analysis integrated into electronic health records have streamlined nursing workflows, providing real-time clinical decision support and improving the efficiency of care delivery. Additionally, telemedicine has expanded the reach of neuro-oncology nurses, enabling virtual assessments and ongoing support for patients, particularly those undergoing neuro-oncological procedures. These technological advancements empower nurses to adopt a more active and patient-centered approach, ensuring that patients receive timely interventions and continuous monitoring, no matter their location.

2. Nurse Assessment and Patient Selection

Neuro-oncology nurses are central to the initial assessment and patient selection for precision medicine-based treatments. Their responsibilities include comprehensive patient history collection, evaluation of eligibility for targeted therapies and immunotherapy, and coordination of genetic and biomarker testing (Weller et al., 2021). Genomic profiling has become a cornerstone in neuro-oncology, enabling the identification of actionable mutations such as EGFR amplification, IDH mutations, and BRAF alterations that guide targeted treatment decisions

(Stupp et al., 2020). Nurses play a key role in educating patients and families about the implications of genomic testing, ensuring informed decision-making. The integration of AI-driven genomic analysis has enhanced the speed and accuracy of identifying candidates for targeted therapies, allowing for more precise patient stratification (National Cancer Institute [NCI], 2023). As precision medicine advances, nurses must stay informed about emerging biomarkers and evolving therapeutic guidelines to optimize patient care. This requires continuous education, hands-on training, and collaboration with interdisciplinary teams to implement the latest evidence-based practices. By staying updated on emerging biomarkers and treatment innovations, nurses can better personalize patient care and improve outcomes. Their proactive role ensures that precision medicine remains effective, safe, and accessible for neuro-oncology patients.

3. Administration and Monitoring of Targeted Therapies

Targeted therapies such as tyrosine kinase inhibitors (TKIs) and monoclonal antibodies have significantly improved outcomes in neuro-oncology by specifically targeting dysregulated signaling pathways in tumor cells (Parsons et al., 2022). However, these therapies require meticulous administration and monitoring due to their potential toxicities, including hepatotoxicity, cardiotoxicity, and dermatologic reactions (Brastianos et al., 2020). Neuro-oncology nurses ensure proper administration of targeted therapies while closely monitoring patients for adverse effects. They assess laboratory parameters, evaluate clinical symptoms, and collaborate with oncologists for timely dose adjustments (Warren et al., 2019).

The utilisation of wearable technology and mobile health applications enables real-time tracking of patient responses, allowing nurses to intervene early in case of toxicity and optimize treatment outcomes (Dana-Farber Cancer Institute, 2023).

4. Immune Therapy Management

The advent of immune checkpoint inhibitors (ICIs), such as PD-1/PD-L1 inhibitors and CTLA-4 antagonists, has marked a significant shift in the treatment of brain tumors by enhancing the body with immune response to cancer (Reardon et al., 2021). However, immunotherapy is associated with unique immune-related adverse events (irAEs), including pneumonitis, colitis, endocrinopathies, and neurologic complications, which require vigilant nursing assessment and intervention (Lah et al., 2022).

Nurses are absolutely vital when it comes to spotting and managing immune-related adverse events (irAEs) early on. Their work helps prevent serious complications and keeps treatment on track. This means they need to monitor patients regularly, quickly identify any symptoms, and work closely with the healthcare team to ensure timely interventions. Plus, educating patients about possible side effects and teaching them how to monitor themselves is crucial for enhancing safety and sticking to immunotherapy plans.

Neuro-oncology nurses are crucial in monitoring early signs of irAEs and coordinating prompt management strategies. This involves patient education on symptom recognition, initiation of supportive care measures, and collaboration with multidisciplinary teams to adjust treatment regimens as necessary (ONS, 2023). AI-powered patient monitoring systems have improved nurses ability to detect subtle symptom changes, reducing complications and hospitalisations (PMC, 2023).

5. Interdisciplinary Collaboration, Ethical, Challenges and Future Perspectives

The implementation of precision medicine in neuro-oncology necessitates strong interdisciplinary collaboration among oncologists, radiologists, geneticists, neurosurgeons, and palliative care specialists. Nurses act as vital communicators, facilitating seamless coordination of care, treatment modifications, and patient advocacy (Stupp et al., 2020). Through case management, neuro-oncology nurses identify treatment-related complications early and contribute to therapeutic decision-making. Telehealth has further enhanced interdisciplinary collaboration by allowing virtual consultations and remote patient monitoring, minimizing patient travel burdens while maintaining high-quality care (Oncology Nurse Advisor, 2023). Such collaborative approaches are essential in addressing the complexities of precision medicine and ensuring comprehensive patient-centered care. Precision medicine presents several ethical and psychosocial challenges, particularly concerning patient autonomy, genetic privacy, and equitable access to innovative treatments. Nurses play a critical role in addressing these concerns by providing clear, compassionate communication about the benefits and risks of precision therapies (Brastianos et al., 2020).

Additionally, neuro-oncology nurses support patients in coping with the psychological burden of a cancer diagnosis, guiding them to counseling resources and advocacy organisations. The use of AI-driven counseling tools and digital mental health applications has supplemented traditional psychosocial support, offering patients real-time assistance with symptom management and emotional distress (Personalized Onco-Genomics, 2023). The literature underscores the essential contributions of neuro-oncology nurses in precision medicine, from patient selection and treatment administration to toxicity management and interdisciplinary collaboration. By enhancing treatment adherence, improving early detection of adverse effects, and facilitating communication within healthcare teams, nurses significantly impact patient survival and quality of life (Louis et al., 2021).

Despite these advancements, challenges such as the need for ongoing education in rapidly evolving therapies, the complexity of managing treatment-related toxicities, and healthcare disparities remain. The integration of AI, telehealth, and wearable technology in precision medicine nursing holds promise for addressing these challenges and optimizing patient care. Future research should focus on expanding nursing education in precision oncology and establishing standardized guidelines to enhance nursing contributions in this field.

6. Advancement In Genomics and Molecular Biology In Glioma Diagnosis and Treatment

The past decade has seen unprecedented developments in genomics and molecular biology that have transformed the discipline of neuro-oncology, particularly in the diagnosis and treatment of gliomas. Gliomas, a heterogeneous group of brain tumors from low-grade astrocytomas to highly aggressive glioblastomas, have classically been defined by histopathological criteria. With the emergence of molecular profiling, tumor classification has been revolutionized, providing more precise diagnostic categories and guiding targeted therapeutic interventions. The emergence of next-generation sequencing (NGS), genome-wide methylation profiling, and single-cell transcriptomics has revolutionized our understanding of glioma pathophysiology. By defining the key genetic changes and molecular signatures, these technologies have unlocked the potential of precision medicine approaches—tailored therapies based on the molecular characteristics of a patient's tumor.

This article discusses the transformative impact of molecular diagnostics, genomic profiling in everyday clinical practice, the development of targeted therapy, and potential future directions for glioma treatment. By reviewing the available current research evidence and examining clinical practice, we aim to determine the key contribution of precision medicine to the better prognosis of glioma patients

7. The Evolution of Molecular Diagnostics in Gliomas

Molecular diagnostics have significantly revolutionized the classification and understanding of gliomas, overturning traditional approaches that relied primarily on histological examination of cell morphology and growth patterns. Historically, gliomas, which are primary brain tumors originating in glial cells, were classified using basic histopathological methods. These classifications were based on the appearance of the tumor cells under the microscope—such as their shape, size, and arrangement—as well as their growth patterns. For example, gliomas were categorized into grades I to IV, with grade I being the least aggressive and grade IV representing the most malignant form, glioblastoma multiforme.

While this system provided valuable insights, it had significant limitations. Most notably, histopathological classifications could not reliably predict the tumor's biological behavior, its potential for aggressive growth, or how the tumor would respond to different therapeutic interventions. One of the key challenges with histopathological methods is that they provide only a snapshot of the tumor’s characteristics at a specific point in time. They fail to capture the complex molecular heterogeneity that exists within gliomas, which can influence not only the tumor's progression but also its responsiveness to various therapies.

This limitation has prompted the shift toward molecular profiling, a more dynamic and precise approach that has profoundly transformed how gliomas are understood and managed. Molecular profiling involves analyzing the genetic and epigenetic alterations present within tumor cells, which provides much deeper insights into the biological underpinnings of gliomas. Genetic mutations, such as alterations in key genes like IDH1/2, TP53, and EGFR, have been found to play a central role in glioma pathogenesis. For example, gliomas harboring mutations in the IDH1 gene tend to have a better prognosis and a more favorable response to certain treatments compared to those without this mutation. In contrast, gliomas with EGFR amplification or MGMT promoter methylation status may have distinct responses to therapies such as temozolomide.

In addition to genetic mutations, the epigenetic landscape of gliomas—changes in gene expression that do not involve alterations in the underlying DNA sequence—also plays a significant role in tumor behavior. Epigenetic changes, such as DNA methylation patterns and histone modifications, can influence how genes are expressed or silenced, which in turn affects the growth and spread of the tumor.

By examining these molecular features, clinicians can now stratify gliomas into more refined subgroups, not solely based on the traditional histological classification but on the underlying molecular characteristics of the tumor. This new approach has been critical for better understanding the prognosis of glioma patients and optimizing treatment strategies. The shift from histological to molecular classification has witnessed phenomenal improvements in the accuracy of glioma diagnosis. Tumors that might have been clustered similarly on the basis of their morphology can now be differentiated more accurately on the basis of their molecular and genetic features. This enables clinicians to predict the behavior of the tumor more accurately and select the most appropriate treatment modalities, whether it is targeted therapy, immunotherapy, or traditional chemotherapy. Moreover, molecular profiling facilitates the identification of unique biomarkers that can identify patients who would benefit most from a particular therapy independent of employing the guess-and-check methodology that was typical of traditional therapeutic interventions. Overall, molecular profiling not only took glioma diagnosis to a higher level of precision but also opened up more personalized and targeted therapies.

The ability to tailor therapeutic strategies based on the genetic and epigenetic makeup of the tumor has been found to enhance patient prognosis and holds the promise of more efficient intervention. This new era in glioma classification is a significant step toward the ultimate aim of knowing, treating, and ultimately eliminating these clever and often calamitous brain tumors.

8. Milestones In Molecular Classification

The classification of central nervous system (CNS) tumors underwent a major transformation in 2016 when the World Health Organization (WHO) introduced molecular markers into its classification system. This shift represented a departure from the traditional reliance on histological classification alone, moving toward a genotype-phenotype approach, particularly for glioma subtyping. One of the most significant molecular markers identified was the presence of mutations in the IDH1 and IDH2 genes, which encode isocitrate dehydrogenase enzymes. These mutations became key prognostic indicators, distinguishing IDH-mutant gliomas, which generally have better outcomes, from IDH-wildtype glioblastomas, which exhibit highly aggressive behavior and poorer prognosis.

Another pivotal discovery was the 1p/19q co-deletion, referring to the loss of chromosomal arms 1p and 19q. This genetic alteration became a defining characteristic of oligodendrogliomas, tumors known for their increased sensitivity to chemotherapy and significantly improved survival rates compared to other gliomas.

Additionally, the TERT promoter mutation emerged as a crucial molecular marker, particularly in glioblastomas. Mutations in the promoter region of the TERT gene, which encodes telomerase reverse transcriptase, were linked to a poorer prognosis, reinforcing their importance in tumor classification and prognostication. Building upon these advances, the 2021 WHO classification further refined the molecular subtyping of CNS tumors, integrating novel findings from DNA methylation profiling and transcriptomics analysis. One of the most notable updates was the incorporation of genome-wide DNA methylation profiling, which significantly improved diagnostic accuracy by identifying specific glioma subtypes based on their epigenetic signatures.

Furthermore, the classification recognized the H3 K27M mutation as a defining feature of diffuse midline gliomas, an aggressive tumor subtype with distinct molecular and clinical characteristics. This mutation, affecting histone H3, set these tumors apart from other high-grade gliomas, underscoring its diagnostic and therapeutic relevance. Epigenetic markers also gained prominence, with particular attention to MGMT promoter methylation, a crucial biomarker in determining the sensitivity of gliomas to alkylating agents such as temozolomide. The methylation status of this promoter became an essential predictor of treatment response, further refining personalized therapeutic strategies for glioma patients.

The evolution of CNS tumor classification between 2016 and 2021 highlights the growing role of molecular diagnostics in neuro-oncology. By integrating genetic and epigenetic markers into tumor classification, WHO has enhanced the accuracy of glioma diagnosis, prognosis, and treatment stratification, paving the way for more tailored and effective therapeutic approaches.

9. Integration of Genomic Profiling into Clinical Practice

With the rapid advancement of genomic technologies, the integration of molecular diagnostics into clinical practice has become increasingly feasible. These advancements have revolutionized glioma classification and management, allowing for more precise patient stratification and the development of personalized treatment strategies. Several sophisticated techniques are now routinely used to examine gliomas at the molecular level, improving diagnostic accuracy and therapeutic decision-making. One of the most powerful technologies in glioma genomics is Next-Generation Sequencing (NGS). This technique enables a comprehensive analysis of glioma genomes, identifying key mutations, copy number variations, and structural rearrangements. Clinically significant genetic alterations, such as mutations in IDH1, BRAF, FGFR, and EGFR, can be detected through NGS, allowing for more targeted and individualized treatment approaches.

Another transformative advancement is Whole-Genome Methylation Profiling, which provides an exceptionally accurate classification system based on epigenetic signatures. This technique has proven particularly valuable in distinguishing histologically similar tumors that exhibit distinct molecular behaviors. By analyzing genome-wide methylation patterns, clinicians can refine diagnoses and predict tumor progression more accurately. Single-Cell RNA Sequencing (scRNA-seq) represents a major breakthrough in understanding glioma heterogeneity.

By examining gene expression at the level of individual cells, this technology allows researchers to identify distinct tumor subpopulations, including glioma stem-like cells, which play a crucial role in tumor recurrence and treatment resistance. Understanding the cellular diversity within gliomas can help in designing more effective therapeutic strategies. A major advancement in non-invasive glioma monitoring is Liquid Biopsy, specifically the analysis of circulating tumor DNA (ctDNA). Unlike traditional brain biopsies, which are invasive and carry risks, liquid biopsy provides a minimally invasive alternative for tracking tumor evolution and therapeutic response. By detecting tumor-specific genetic mutations in blood samples, this technique enables real-time monitoring of glioma progression and helps clinicians adjust treatment strategies accordingly. The integration of these genomic profiling tools into clinical practice has significantly enhanced glioma diagnosis, prognosis, and treatment planning. As these technologies continue to evolve, they offer new possibilities for improving patient outcomes through more precise, personalized, and dynamic approaches to glioma management.

10. The Emergence of Targeted Glioma Therapies

As we dive deeper into the world of glioma molecular subtypes, targeted therapies are stepping into the spotlight as a revolutionary approach in neuro-oncology. Unlike traditional treatments like chemotherapy and radiation, which tend to indiscriminately harm both tumor and healthy brain tissue, targeted therapies are crafted to specifically block the oncogenic pathways that fuel tumor growth and progression. This precision medicine strategy aims to reduce unnecessary side effects while enhancing treatment effectiveness. Gliomas, especially glioblastomas (GBMs), have long been some of the toughest tumors to tackle due to their genetic diversity, resistance to treatment, and aggressive nature.

However, advances in molecular characterization have uncovered crucial genetic mutations that can be targeted for therapy. Key pathways involved in glioma development include the IDH mutation pathway, the RTK/PI3K/AKT/mTOR signaling pathway, the BRAF mutation pathway, and various mechanisms that help tumors evade the immune system. One of the most exciting classes of targeted therapies is IDH inhibitors, like Ivosidenib and Vorasidenib, which specifically target mutant IDH1/IDH2 enzymes. These medications work by lowering the levels of 2-hydroxyglutarate, an oncometabolite that encourages tumor growth, thus helping to slow down glioma progression.

Another significant advancement is in treating gliomas with BRAF mutations, particularly the BRAF V600E mutation found in a subset of these tumors. Targeted therapies such as Dabrafenib and Trametinib effectively inhibit the faulty BRAF signaling, leading to remarkable tumor shrinkage in patients. FGFR inhibitors, like Erdafitinib, focus on abnormal signaling within the fibroblast growth factor receptor (FGFR) pathway, which plays a role in the growth of certain glioma subtypes. By blocking this pathway, these drugs can help slow tumor growth and enhance patient outcomes for glioblastomas that show EGFR amplification.

11. Future Prospects in Glioma Management

The treatment of gliomas has a rosy future in store, with the continuous advancement of precision medicine methods. With our understanding of the molecular and genetic underpinnings of gliomas constantly growing, the treatment methods are becoming increasingly sophisticated, tailored to the unique tumor profile of each patient. This is being facilitated by the convergence of cutting-edge technologies and novel therapies, holding out the promise of novel means of improving patient outcomes and extending survival. One of the major areas of ongoing research entails the optimization of genomic and transcriptomic profiling methods, which enhance tumor classification with greater precision. The combination of next-generation sequencing (NGS) [6] and single-cell RNA sequencing offers a better understanding of tumor heterogeneity complexity through the identification of subclonal populations that confer drug resistance. By identifying these distinct molecular features, clinicians can design more targeted treatment regimens, selecting therapies specifically designed to target the specific genetic and epigenetic alterations driving tumor development. With this increased understanding of glioma biology, scientists are also better positioned to identify new biomarkers that can predict response to therapy, allowing active realignment of therapeutic strategies based on evolving features over time. Another promising area in glioma therapy is maximizing targeted therapies.

The introduction of small-molecule inhibitors for primary oncogenic drivers such as IDH mutations, BRAF V600E mutation, and EGFR amplifications has already begun to show clinical promise. But resistance mechanisms are still a big challenge. Next steps are the use of combination therapies, where targeted drugs are paired with conventional treatments like chemotherapy and radiation or combined with other precision medicines. By attacking gliomas along multiple fronts simultaneously, these regimens can prevent the development of resistant populations of tumor cells. Researchers are also examining novel drug delivery mechanisms, such as nanoparticle-based carriers and blood-brain barrier (BBB) modulation techniques, to enhance penetration of targeted medications into gliomas, hence their potency.

Immunotherapy is another area of exploration in glioma therapy. While glioblastomas have been considered immunologically "cold" tumors with limited sensitivity to immune checkpoint inhibitors in the past, novel approaches are currently being developed to enhance anti-tumor immunity. Personalized cancer vaccines, based on the use of neoantigen profiling to design tumor-specific immune activation, are promising in initial trials. In addition, CAR T-cell therapy is also being enhanced to target more specifically glioma-specific antigens such as EGFRvIII and IL-13Rα2. Scientists are also investigating how to modulate the tumor microenvironment to render gliomas susceptible to immune attack, for example, by the use of myeloid checkpoint inhibitors and oncolytic viruses. The future of immunotherapy for the treatment of glioma will likely be a combination of these methods, employing multiple immune-modulating strategies to achieve more long-term responses.

Advances in artificial intelligence (AI) and machine learning are also on the way to changing the future of glioma therapy. AI-based diagnosis platforms are refining the accuracy of tumor classification through the integration of imaging data and molecular profiling information, leading to more precise and earlier diagnoses. Machine learning software is being developed to predict treatment outcomes from large collections of patient results, allowing personal treatment plans to be optimized. The AI products also have the potential to contribute to real-time decision-making throughout neurosurgery, assisting neurosurgeons in more accurate marking of the boundaries of the tumor and minimization of trauma to normal tissue. As these technologies evolve, they will result in better and more efficient clinical decision-making, eventually improving patient outcomes.

The employment of multi-modal therapeutic approaches is also becoming more prominent in the treatment of gliomas. Combining radiation therapy with novel radiosensitizers, such as molecular inhibitors of DNA damage repair pathways, is being explored to enhance radiotherapy with reduced toxicity. Tumor-treating fields (TTFields), a recently engineered non-surgical therapy, utilizing electric fields to disrupt glioma cell division, has already proven advantageous in survival rates in patients with glioblastoma and is being tried in combination with other therapies.

These multi-modality treatments signify the growing concordance that a single agent is likely to be insufficient in the treatment of gliomas and that the utilization of complementary modalities is the best choice for long-term control of disease. Another area of interest is the development of liquid biopsy technologies for glioma treatment. Traditional biopsies are invasive and difficult to perform on deeply seated or surgically inaccessible cancers. Liquid biopsies, which quantify circulating tumor DNA (ctDNA), extracellular vesicles, and other biomarkers in blood or cerebrospinal fluid, offer a non-invasive platform for tumor monitoring. These techniques are being refined to enable real-time assessment of treatment response and early identification of recurrence, providing clinicians with an active instrument for the modulation of therapeutic plans as the disease evolves. Incorporation of liquid biopsy strategies into the routine clinical toolkit could have a profound impact on glioma management by facilitating more intensive and accurate disease monitoring.

In the future, treatment of glioma will likely be dominated by extremely personalized treatment protocols that include molecular profiling, targeted therapy, immunotherapy, and advanced imaging techniques. Personalized combination therapies based on each patient's tumor characteristics, combined with real-time monitoring through liquid biopsies and AI-driven data analysis, will enable a more adaptive and focused treatment approach. Further, continued studies into novel drug delivery systems, including intratumoral therapy and gene editing tools, have the ability to continue enhancing treatment outcomes.

With developing precision medicine, it will be crucial that molecular biologists, bioinformaticians, neurosurgeons, and oncologists collaborate to translate these advances into the clinical setting. Current clinical trials testing new targeted therapies and immunotherapies will play a crucial role in further advancing these approaches and defining the most useful approaches to glioma treatment. While these difficulties do lie, particularly in the challenge of overcoming therapeutic resistance as well as increased drug delivery across the blood-brain barrier, future management of gliomas increasingly is moving toward a precision, personalization, and innovation model.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Marino, S., Bowden, S. G., Han, S. J., Yeboa, D. N., Sulman, E. P., Roach, M., ... & Berghoff, A. S. (2017). World Federation of Neuro-Oncology Societies.

[2] Villaruz, L. C., Socinski, M. A., & Weiss, J. (2023). Guidance for clinicians and patients with non-small cell lung cancer in the time of precision medicine. Frontiers in Oncology, 13, 1124167.

[3] Fischer, C., Petriccione, M., Donzelli, M., & Pottenger, E. (2016). Improving care in pediatric neuro-oncology patients: an overview of the unique needs of children with brain tumors. Journal of child neurology, 31(4), 488-505.

[4] BEACH, F. L. (2022). PRECISION MEDICINE.

[5] Cipri, S., Del Baldo, G., Fabozzi, F., Boccuto, L., Carai, A., & Mastronuzzi, A. (2023). Unlocking the power of precision medicine for pediatric low-grade gliomas: molecular characterization for targeted therapies with enhanced safety and efficacy. Frontiers in Oncology, 13, 1204829.

[6] Cipri, S., Del Baldo, G., Fabozzi, F., Boccuto, L., Carai, A., & Mastronuzzi, A. (2023). Unlocking the power of precision medicine for pediatric low-grade gliomas: molecular characterization for targeted therapies with enhanced safety and efficacy. Frontiers in Oncology, 13, 1204829.

[7] Walker, D., Liu, J. F., Rahman, R., Campbell, E., Wilne, S., MacArthur, D., ... & Grundy, R. (2018). EPID-07. A PRECISION MEDICINE STRATEGY TO AVOID THE HARM OF BRAIN INJURY IN SURVIVORS OF CHILDHOOD

[8] BRAIN TUMOURS.

[9] Neuro-Oncology, 20(suppl_2), i81-i81.

[10] Wick, W., Dettmer, S., Berberich, A., Kessler, T., Karapanagiotou-Schenkel, I., Wick, A., ... & Platten, M. (2019). N2M2 (NOA-20) phase I/II trial of molecularly matched targeted therapies plus radiotherapy in patients with newly diagnosed non-MGMT hypermethylated glioblastoma. Neuro-oncology, 21(1), 95-105.

[11] Helland, Å., Russnes, H. G., Fagereng, G. L., Al-Shibli, K., Andersson, Y., Berg, T., ... & Smeland, S. (2022). Improving public cancer care by implementing precision medicine in Norway: IMPRESS-Norway. Journal of translational medicine, 20(1), 225.

[12] Kessler, T., Berberich, A., Casalini, B., Drüschler, K., Ostermann, H., Dormann, A., ... & Wick, A. (2020). Molecular profiling-based decision for targeted therapies in IDH wild-type glioblastoma. Neuro-oncology advances, 2(1), vdz060.

[13] Lundy, J., Harris, M., Zalcberg, J., Zimet, A., Goldstein, D., Gebski, V., ... & Croagh, D. (2021). EUS-FNA biopsies to guide precision medicine in pancreatic cancer: results of a pilot study to identify KRAS wild-type tumours for targeted therapy. Frontiers in Oncology, 11, 770022.

[14] Del Baldo, G., Carai, A., Abbas, R., Cacchione, A., Vinci, M., Di Ruscio, V., ... & Mastronuzzi, A. (2022). Targeted therapy for pediatric diffuse intrinsic pontine glioma: a single-center experience. Therapeutic Advances in Medical Oncology, 14, 17588359221113693.

[15] MARKO, M., FEYEN, O., SPRENGER, K., SCHIRRMACHER, V., & STUECKER, W. (2020). PERSONALISED MEDICINE IN GLIOBLASTOMA MULTIFORME STEFAAN W. VAN GOOL,* JENNIFER MAKALOWSKI,* MATTHIAS P. DOMOGALLA.

[16] Challenges and Solutions of Oncological Hyperthermia, 126.

[17] Nandu, H., Wen, P. Y., & Huang, R. Y. (2018). Imaging in neuro-oncology. Therapeutic advances in neurological disorders, 11, 1756286418759865.

[18] Nandu, H., Wen, P. Y., & Huang, R. Y. (2018). Imaging in neuro-oncology. Therapeutic advances in neurological disorders, 11, 1756286418759865.

[19] Pellerino, A., Bertero, L., Rudà, R., & Soffietti, R. (2018). Neoplastic meningitis in solid tumors: from diagnosis to personalized treatments. Therapeutic Advances in Neurological Disorders, 11, 1756286418759618.

[20] Pellerino, A., Bertero, L., Rudà, R., & Soffietti, R. (2018). Neoplastic meningitis in solid tumors: from diagnosis to personalized treatments. Therapeutic Advances in Neurological Disorders, 11, 1756286418759618.

[21] Pellerino, A., Bertero, L., Rudà, R., & Soffietti, R. (2018). Neoplastic meningitis in solid tumors: from diagnosis to personalized treatments. Therapeutic Advances in Neurological Disorders, 11, 1756286418759618.

[22] Brant, J. M., Cope, D. G., & Saria, M. G. (Eds.). (2023). Core Curriculum for Oncology Nursing-E-Book. Elsevier Health Sciences.

[23] Coleman, N., Ameratunga, M., & Lopez, J. (2018). Development of molecularly targeted agents and immunotherapies in glioblastoma: a personalized approach. Clinical Medicine Insights: Oncology, 12, 1179554918759079