DOI: https://doi.org/10.32345/2664-4738.3.2024.17
УДК: 616.831-006.484-089.873:616-036.8

CLINICAL UTILITY OF MULTIMODAL IMAGING AND NEURO-MONITORING IN AWAKE CRANIOTOMY FOR LOW-GRADE GLIOMA: A CASE REPORT AND LITERATURE REVIEW

Dipak Chaulagain, *https://orcid.org/0000-0001-6428-8371*
Volodymyr Smolanka, *https://orcid.org/0000-0001-7296-8297*
Andriy Smolanka, *https://orcid.org/0000-0002-6582-9472*
Taras Havryliv, *https://orcid.org/0000-0003-0271-8983*

Regional Clinical Center of Neurosurgery and Neurology, Uzhhorod National University, Uzhhorod, Ukraine

neurodipak@gmail.com

Insular gliomas pose a therapeutic challenge due to their intricate anatomy and proximity to eloquent brain regions. Functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI) tractography are useful ways to learn about the insular region's neuronal connections and how they work before surgery. The purpose of this case report is to show how awake craniotomy, with intraoperative neuromonitoring (IONM), can be used to remove low-grade gliomas, especially from the insular region. By carefully drawing functional boundaries using fMRI and DTI data collected before surgery, surgical methods were created to protect important brain areas as much as possible while removing as much of the tumor as possible. A 31-year-old male presented with a 5-month history of headaches, seizures, and right-sided numbness. Neurological examination revealed difficulty with word finding and organization but no overt speech deficits. An MRI revealed a non-enhancing lesion in the left frontotemporal region. An awake craniotomy was conducted to protect language centres and brain function during surgical resection, with guidance from DTI, fMRI, and IONM.The study underscores the importance of integrating advanced imaging modalities with intraoperative techniques to optimize surgical outcomes for insular gliomas. To maximize success and minimize postoperative complications, a comprehensive understanding of tumor biology, neuroanatomy, and patient-specific factors is imperative. Incorporating preoperative fMRI and DTI into surgical planning enhances the accuracy and efficacy of awake craniotomy procedures. Further research is warranted to validate these findings and refine treatment strategies for insular gliomas.

Keywords: awake craniotomy, Insular glioma, Glioma.

Background. There is an increased risk of neurological complications following surgical removal of insulinar gliomas, making them a typical problem in neurosurgical oncology. Because of their complex anatomy and proximity to important cerebral arteries, therapeutic approaches are complicated. New developments in neuroanesthesia, microsurgery, and functional mapping, however, have made it possible to treat these tumors in a safer and more successful manner. A lot of different brain and blood vessel structures surround the insula. These structures may lessen the effects of neurological problems, leading to fewer and milder problems in many cases [1, 2].

The surgical extraction of tumors from the brain's eloquent cortical regions presents a considerable risk of neurological impairment. Current methodologies prioritize maximally safe excision, aiming to preserve as much of the patient's neurological function as possible [3].

Complications, including edema, stroke, or fibre tract disruption, are possible outcomes of surgical treatments used to remove tumours. Brain surgery treatments that involve finding language areas are easier to do with techniques like cortex and subcortical stimulation used during surgery [4,5]. The results that people get from these methods, nevertheless, could differ. Maps of speech and their brain bases are being gradually filled in with the use of functional magnetic resonance imaging (fMRI), a noninvasive technique [6].

This study delves into optimal surgical approaches for low-grade insular gliomas. With the help of functional magnetic resonance imaging (fMRI) and diffusion tensor imaging (DTI), a low-grade insular glioma was successfully removed. Before surgery, fMRI and DTI helped stop large areas of functional and anatomical redistribution. This helped the surgeon plan the surgery so that the tumor could be removed as much as possible while important white matter pathways were kept. Language processing data revealed a left-dominant language and contralateral brain processing pattern. The investigation also scrutinized the impact of left inferior frontal gyrus (Broca's area) tumors on speech center lateralization and localization.

Case Report

A 31-year-old male presented to the neurosurgery department at the Regional Clinical Center of Neurosurgery and Neurology, Uzhhorod, Ukraine, with a five-month history of recurrent headaches and seizures. During these episodes, the patient experienced paresthesia in his right arm and leg, along with expressive aphasia characterized by difficulty in word retrieval and organization. The neurological examination revealed normal findings, with no overt speech impairments reported by the patient. Magnetic resonance imaging (MRI) revealed a non-enhancing lesion localized in the left fronto-temporal region (Fig. 1).

The surgical intervention was meticulously planned and executed, integrating sophisticated imaging modalities such as diffusion tensor imaging (DTI), functional magnetic resonance imaging (fMRI), and intraoperative neuro-monitoring (IONM). Employing an awake craniotomy approach, the surgical team aimed to preserve eloquent language centers while achieving maximal tumor resection. A precise craniotomy was performed under neuro-navigation guidance to access the left-sided insular glioma situated in the fronto-temporal region. Throughout the procedure, the patient remained awake to facilitate real-time assessment of language function and mitigate the risk of postoperative language deficits. Utilizing DTI and fMRI data, the surgical team accurately delineated eloquent brain regions and tumor boundaries. Continuous intraoperative neuromonitoring (IONM) was employed to assess and safeguard critical neurological functions during tumor resection. Despite the challenging

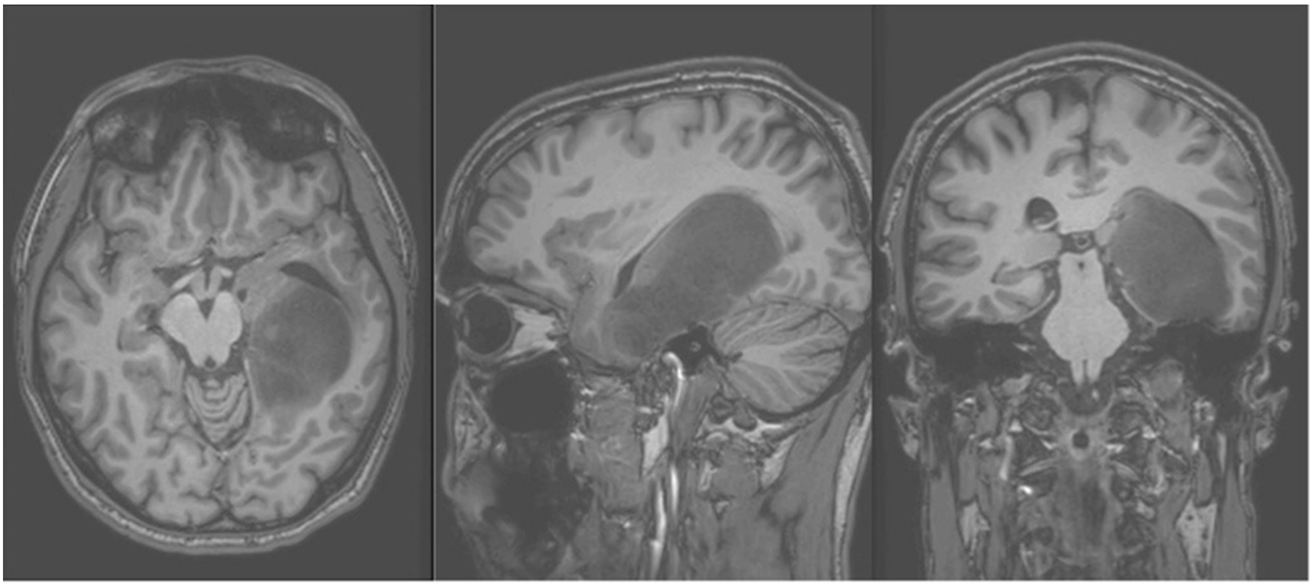

Fig. 1. Different Slices of T1 Weighted MRI of Brain showing Insular Glioma

tumor location, partial resection was successfully achieved while preserving essential neurological functions. Postoperative MRI scans confirmed partial tumor removal (Fig. 2).

Following surgery, the patient was closely monitored, and at one-month follow-up, reported resolution of previous symptoms, with no residual weakness or sensory deficits on the right side. Neurological examination revealed normal findings, indicative of successful intervention and postoperative recovery.

fMRI Analysis of Case

Furthermore, functional MRI (fMRI) analysis revealed clear left hemispheric language lateralization, with predominant activation observed in the Broca and Wernicke areas of the left hemisphere (Fig. 3).

Notably, Wernicke activations were identified superficially to the left temporal lobe tumor formations, primarily located in the parahippocampal gyrus with intraventricular extensions. The tumor was observed to be in close

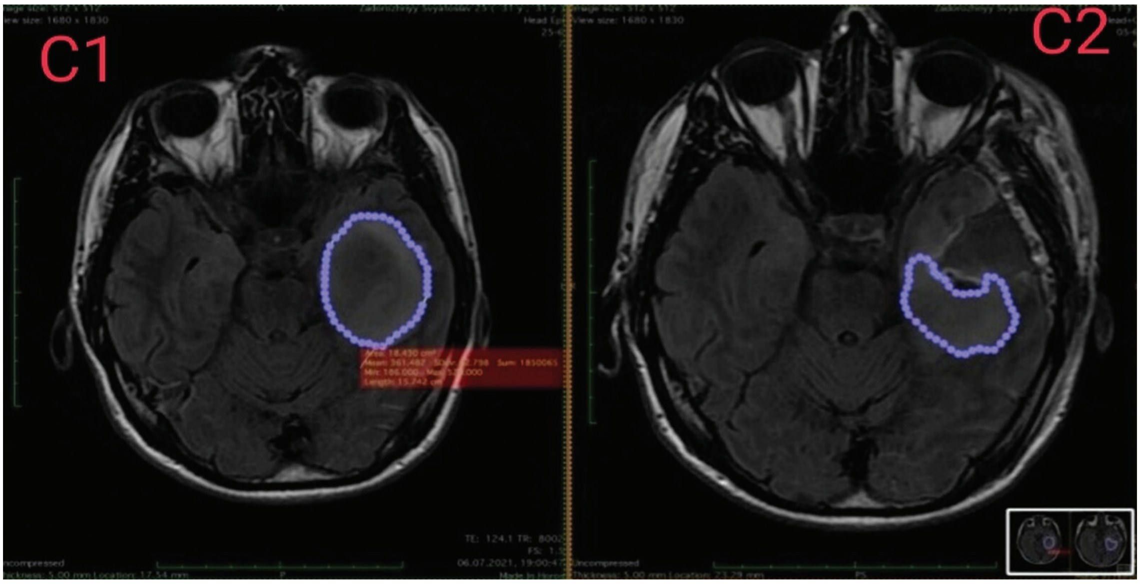

Fig. 2. Pre- and Post-operative MRI of Brain

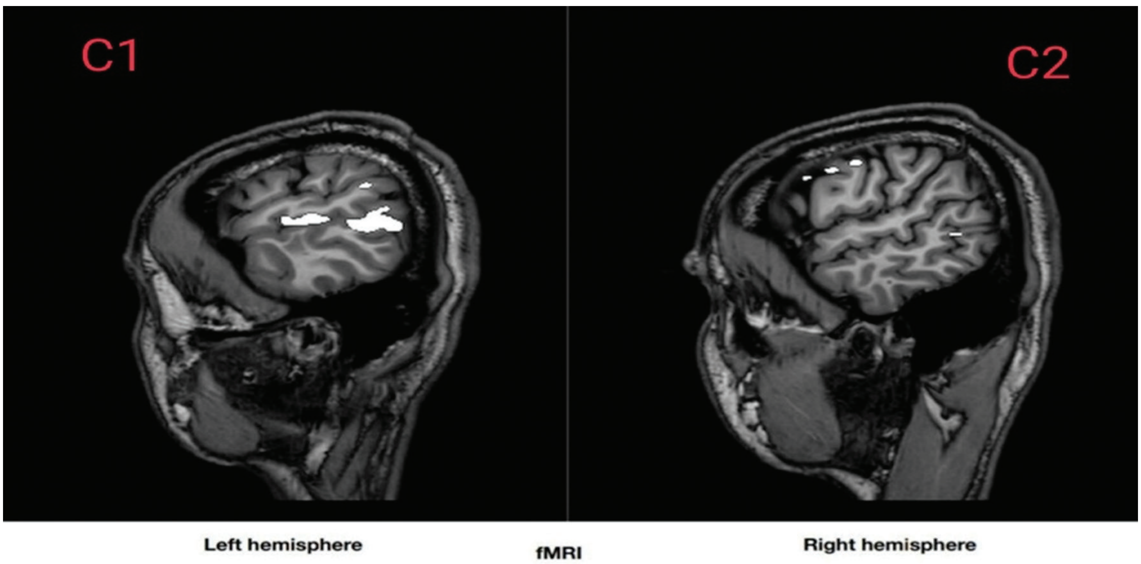

Fig. 3. fMRI of Brain shows language lateralization

proximity to the lateral temporal lobe, medially touching it (Fig. 4).

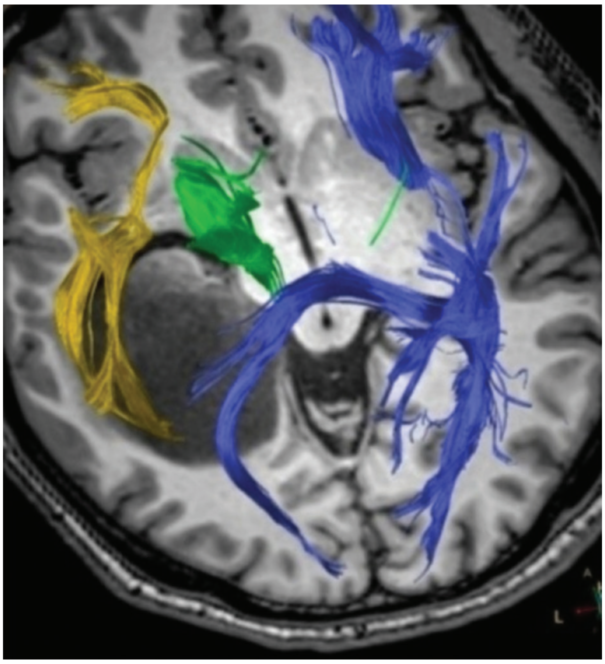

Fig. 4. DTI of Brain shows the tumor is touching the lateral temporal lobe medially

DISCUSSION

The case report presented demonstrates the effective surgical management of an insular glioma using a multimodal approach under the direction of cutting-edge imaging techniques and intraoperative neuromonitoring. Using diffusion tensor imaging (DTI), functional magnetic resonance imaging (fMRI), and intraoperative neuromonitoring (IONM) together made it easier to precisely define important brain areas and tumor boundaries. This allowed for maximum tumor removal while maintaining important neurological functions.

Because of improvements in technology and tools, somatosensory evoked potentials (SSEP) are now needed to track a lot of different neurological and vascular therapies that affect the brain [7]. Horsley pioneered the first cortical excisions using stimulation in 1886 and 1887 [8]. Cortical direct electrical stimulation (DES) has seen extensive use despite concerns about possible side effects and downsides, such as post-operative seizures. Patients with high-grade astrocytic tumours who underwent intraoperative neuromonitoring (IONM) had a lower risk of neurologic impairments and a longer overall survival time, according to research by Zhang et al. [9].

In order to eradicate gliomas, intermittent intraoperative monitoring with the use of DES is necessary. Also, it's the main way to check the language brain area's functionality in real time. Intraoperative DES technology makes use of a wide range of anaesthetic techniques, mirroring the variety of surgical procedures. Thanks to advancements in anaesthesia, individuals who want to stay conscious throughout their brain tumour surgery can now have the treatment done while they are awake.

"Regional anaesthesia" was a term used by Cushing at the tail end of the nineteenth century and served as the basis for contemporary methods [10]. The sleep-wake-alert-sleep (SAW) and awake-awake-awake (AAA) protocols are now the most used modalities of anaesthesia for awake craniotomies [10]. One of these is AAA technology, which improves intraoperative neuromonitoring (IONM) by keeping patients aware during the whole surgery [11]. For postoperative pain control to be effective, there must be preoperative patient education, specialised anesthesiologists, and surgical procedures that minimise traction on pain-sensitive brain structures [12].

By following these steps, awake brain tumour surgery may be performed with little danger and discomfort, leading to the best possible results for patients. In 1886, the first conscious craniotomy was performed by Sir Victor Horsley, who used brain electrical stimulation to localise epileptic foci [13]. Famous brain surgeon and researcher Wilder Penfield continued his work by carefully mapping brain activities in awake patients with severe epilepsy while they were under local anaesthesia (LA) [14]. It has been proposed by Sanai et al. [15] that areas of the brain where electrical stimulation does not cause language problems may be safely targeted for glioma tumour removal. Of the 250 glioma patients studied, 145 (or 58% of the total) benefited from frontal and temporal lobe mapping when it came to activities like reading aloud, number calling, and recognition.

For patients whose tumors are situated close to functioning brain areas, Chang et al. [16]

found that intraoperative mapping improves survival outcomes and decreases recurrence rates. Only 3.4% of patients in a study including 8091 procedures reported major complications after intraoperative stimulation mapping in the operating room. Complication rates were 8.3% higher in those who had preoperative simulated mapping but who did not. In addition, mapping allowed for a larger tumour to be removed [17].

As an example, in a scenario where the epileptic foci and eloquent centres were co-localized, all but one of the patients were able to keep their function while experiencing no seizures. Minor postoperative neurological deficits were seen in 12.7% of persons who underwent awake targeted resection, 49.1% who underwent persistent subdural electrode implantation, and 16.4% who underwent persistent subdural electrode implantation in non-lesional epileptic patients [18].

After surgery, 4% of 890 patients with insular gliomas had new, long-lasting problems with motor or speech, according to a meta-analysis [19]. The use of transcortical insula methods has grown in recent years due to improvements in intraoperative mapping techniques. To locate the internal capsule on the medial plane of excision for dominant-sided insular gliomas, subcortical motor mapping is used. The preservation of functional cortex and Sylvian arteries can be achieved by making several cortical windows in instances when massive gliomas involve non-functional brain [1,20].

Resection of low-grade gliomas may now be safely performed because to the combination of fMRI and diffusion tensor imaging (DTI). Functional magnetic resonance imaging (fMRI) aids in preoperative identification of the dominant hemisphere and functional language cortex by direct stimulation of the language cortex. Though fMRI has its uses, it does have its limits. The specificity and sensitivity of linguistic functional magnetic resonance imaging (fMRI) and direct brain stimulation varied from 0% to 97%, according to a meta-analysis of nine trials [21].

The presented case report illustrates the use of an awake craniotomy approach allowed for real-time assessment of language function during surgery, minimizing the risk of postoperative language deficits. Despite the challenging tumor location, the surgical team achieved partial resection while safeguarding critical language centers and maintaining brain function. Postoperative recovery was favorable, with the patient reporting resolution of previous symptoms and no residual weakness or sensory deficits on the left side at one-month follow-up. Neurological examination revealed normal findings, indicating successful intervention and postoperative recovery.

Overall, the case highlights the importance of a comprehensive and individualized surgical approach in the management of insular gliomas. By combining advanced imaging modalities with intraoperative monitoring, surgeons can optimize tumor resection outcomes while minimizing the risk of neurological deficits, ultimately improving patient outcomes and quality of life.

CONCLUSIONS

In conclusion, there are a lot of different biological, anatomical, and clinical factors that go into managing low-grade gliomas during awake craniotomy. In order to maximise patient outcomes, the surgeon's first priority is to perform the safest resection possible. Intraoperative technologies are crucial for improving surgical accuracy and reducing postoperative problems; hence, technical competence and these technologies must be integrated. When dealing with low-grade gliomas, it is crucial to have a multidisciplinary team of specialists from different areas due to the tumours' intricate nature. Neuromonitoring and imaging techniques that are up-to-date during surgery, such as awake craniotomy and tractography, along with careful motor and speech mapping, can successfully treat most cases. Improving patient prognosis and optimising therapy for low-grade gliomas can be achieved by combining state-of-the-art intraoperative technology with established surgical approaches.

Ethics approval and consent to participate: This study was approved by the Research Ethics Committee, Faculty of Medicine, Neurosurgery Department, Uzhhorod National University.

Consent for publication: Not applicable.

Availability of data and material: The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests: The authors declare that they have no competing interests.

Funding: Not applicable (No funding was received for this research).

REFERENCE

1. Sanai N, Polley M-Y, Berger MS. Insular glioma resection: assessment of patient morbidity, survival, and tumor progression. Journal of Neurosurgery [Internet]. Journal of Neurosurgery Publishing Group (JNSPG); 2010 Jan;112(1):1–9. DOI: 10.3171/2009.6.jns0952
2. Przybylowski CJ, Baranoski JF, So VM, Wilson J, Sanai N. Surgical morbidity of transsylvian versus transcortical approaches to insular gliomas. Journal of Neurosurgery [Internet]. Journal of Neurosurgery Publishing Group (JNSPG); 2020 Jun;132(6):1731–1738. DOI: 10.3171/2018.12.jns183075
3. Duffau H. Lessons from brain mapping in surgery for low-grade glioma: insights into associations between tumour and brain plasticity. The Lancet Neurology [Internet]. Elsevier BV; 2005 Aug;4(8):476–486. DOI: 10.1016/s1474-4422(05)70140-x
4. Kundu B, Penwarden A, Wood JM, Gallagher TA, Andreoli MJ, Voss J, Meier T, Nair VA, Kuo JS, Field AS, Moritz C, Meyerand ME, Prabhakaran V. Association of functional magnetic resonance imaging indices with postoperative language outcomes in patients with primary brain tumors. Neurosurgical Focus [Internet]. Journal of Neurosurgery Publishing Group (JNSPG); 2013 Apr;34(4):E6. DOI: 10.3171/2013.2.focus12413
5. Roux F-E, Boulanouar K, Lotterie J-A, Mejdoubi M, LeSage JP, Berry I. Language Functional Magnetic Resonance Imaging in Preoperative Assessment of Language Areas: Correlation with Direct Cortical Stimulation. Neurosurgery [Internet]. Ovid Technologies (Wolters Kluwer Health); 2003 Jun;52(6):1335–1347. DOI: 10.1227/01.neu.0000064803.05077.40
6. Kośla K, Pfajfer L, Bryszewski B, Jaskólski D, Stefańczyk L, Majos A. Reorganizacja funkcjonalna ośrodków językowych u pacjentów z guzami OUN w badaniu funkcjonalnego rezonansu magnetycznego. Polish Journal of Radiology [Internet]. Termedia Sp. z.o.o.; 2012;77(3):39–45. DOI: 10.12659/pjr.883373
7. Goldring S. A method for surgical management of focal epilepsy, especially as it relates to children. Journal of Neurosurgery [Internet]. Journal of Neurosurgery Publishing Group (JNSPG); 1978 Sep;49(3):344–356. DOI: 10.3171/jns.1978.49.3.0344
8. Horsley V. Remarks on Ten Consecutive Cases of Operations upon the Brain and Cranial Cavity to Illustrate the Details and Safety of the Method Employed. BMJ [Internet]. BMJ; 1887 Apr 23;1(1373):863–865. DOI: 10.1136/bmj.1.1373.863
9. Zhang N, Yu Z, Hameed NUF, Xu G, Song Y, Wu B, Zhang J, Qiu T, Zhuang D, Lu J, Wu J. Long-Term Functional and Oncologic Outcomes of Glioma Surgery with and without Intraoperative Neurophysiologic Monitoring: A Retrospective Cohort Study in a Single Center. World Neurosurgery [Internet]. Elsevier BV; 2018 Nov;119: e94–e105. DOI: 10.1016/j.wneu.2018.07.051
10. Stevanovic A, Rossaint R, Veldeman M, Bilotta F, Coburn M. Anaesthesia Management for Awake Craniotomy: Systematic Review and Meta-Analysis. Gemma M, editor. PLOS ONE [Internet]. Public Library of Science (PLoS); 2016 May 26;11(5): e0156448. DOI: 10.1371/journal.pone.0156448
11. Hansen E, Seemann M, Zech N, Doenitz C, Luerding R, Brawanski A. Awake craniotomies without any sedation: the awake-awake-awake technique. Acta Neurochirurgica [Internet]. Springer Science and Business Media LLC; 2013 Jun 28;155(8):1417–1424. DOI: 10.1007/s00701-013-1801-2
12. Meng L, McDonagh DL, Berger MS, Gelb AW. Anesthesia for awake craniotomy: a how-to guide for the occasional practitioner. Canadian Journal of Anesthesia/Journal canadien d'anesthésie [Internet]. Springer Science and Business Media LLC; 2017 Feb 8;64(5):517–529. DOI: 10.1007/s12630-017-0840-1

13. Anesthesia for Awake Craniotomy in Patients with Metastatic Brain Tumor in Ibadan, Nigeria. Journal of Anesthesia & Pain Medicine [Internet]. Opast Group LLC; 2020 Dec 11;5(2). DOI: 10.33140/japm.05.02.01
14. Dziedzic T, Bernstein M. Awake craniotomy for brain tumor: indications, technique and benefits. Expert Review of Neurotherapeutics [Internet]. Informa UK Limited; 2014 Nov 21;14(12):1405–1415. DOI: 10.1586/14737175.2014.979793
15. Sanai N, Mirzadeh Z, Berger MS. Functional Outcome after Language Mapping for Glioma Resection. New England Journal of Medicine [Internet]. Massachusetts Medical Society; 2008 Jan 3;358(1):18–27. DOI: 10.1056/nejmoa067819
16. Chang EF, Clark A, Smith JS, Polley M-Y, Chang SM, Barbaro NM, Parsa AT, McDermott MW, Berger MS. Functional mapping–guided resection of low-grade gliomas in eloquent areas of the brain: improvement of long-term survival. Journal of Neurosurgery [Internet]. Journal of Neurosurgery Publishing Group (JNSPG); 2011 Mar;114(3):566–573. DOI: 10.3171/2010.6.jns091246
17. De Witt Hamer PC, Robles SG, Zwinderman AH, Duffau H, Berger MS. Impact of Intraoperative Stimulation Brain Mapping on Glioma Surgery Outcome: A Meta-Analysis. Journal of Clinical Oncology [Internet]. American Society of Clinical Oncology (ASCO); 2012 Jul 10;30(20):2559–2565. DOI: 10.1200/jco.2011.38.4818
18. Yang T-F, Chen H-H, Liang M-L, Chen C, Chiu J-W, Wang J-C, Lai C-J, Liao K-K, Chan R-C. Intraoperative brain mapping to identify corticospinal projections during resective epilepsy surgery in children with congenital hemiparesis. Child's Nervous System [Internet]. Springer Science and Business Media LLC; 2014 May 14;30(9):1559–1564. DOI: 10.1007/s00381-014-2436-1
19.Lu VM, Goyal A, Quinones-Hinojosa A, Chaichana KL. Updated incidence of neurological deficits following insular glioma resection: A systematic review and meta-analysis. Clinical Neurology and Neurosurgery [Internet]. Elsevier BV; 2019 Feb; 177:20–26. DOI: 10.1016/j.clineuro.2018.12.013
20. Hervey-Jumper SL, Li J, Osorio JA, Lau D, Molinaro AM, Benet A, Berger MS. Surgical assessment of the insula. Part 2: validation of the Berger-Sanai zone classification system for predicting extent of glioma resection. Journal of Neurosurgery [Internet]. Journal of Neurosurgery Publishing Group (JNSPG); 2016 Feb;124(2):482–488. DOI: 10.3171/2015.4.jns1521
21. Giussani C, Roux F-E, Ojemann J, Sganzerla EP, Pirillo D, Papagno C. Is Preoperative Functional Magnetic Resonance Imaging Reliable for Language Areas Mapping in Brain Tumor Surgery? Review of Language Functional Magnetic Resonance Imaging and Direct Cortical Stimulation Correlation Studies. Neurosurgery [Internet]. Ovid Technologies (Wolters Kluwer Health); 2010 Jan;66(1):113–120. DOI: 10.1227/01.neu.0000360392.15450.c9

Article history:
Received: 18.07.2024
Revision requested: 22.07.2024
Revision received: 11.08.2024
Accepted: 25.09.2024
Published: 30.09.2024

КЛІНІЧНА КОРИСНІСТЬ МУЛЬТИМОДАЛЬНОЇ ВІЗУАЛІЗАЦІЇ ТА НЕЙРОМОНІТОРИНГУ ПРИ КРАНІОТОМІЇ У СТАНІ НЕСПАННЯ ДЛЯ ГЛІОМИ НИЗЬКОГО СТУПЕНЯ: ЗВІТ ПРО ВИПАДОК ТА ОГЛЯД ЛІТЕРАТУРИ

Діпак Чаулагайн, Володимир Смоланка, Андрій Смоланка, Тарас Гаврилів

Обласний клінічний центр нейрохірургії та неврології
Ужгородського національного університету, Ужгород, Україна

neurodipak@gmail.com

Острівкові гліоми становлять терапевтичну проблему через їх складну анатомію та близькість до яскраво виражених ділянок мозку. Функціональна магнітно-резонансна томографія (МРТ) і трактографія дифузійного тензорного зображення (DTI) є корисними способами дізнатися про нейронні зв'язки острівної області та їхню роботу перед операцією. Мета цього звіту про випадок полягає в тому, щоб показати, як краніотомію у стані неспання з інтраопераційним нейромоніторингом (IONM) можна використовувати для видалення гліом низького ступеня злоякісності, особливо в інсулярній області. Ретельно провівши функціональні межі з використанням даних фМРТ і DTI, зібраних перед операцією, було створено хірургічні методи, щоб максимально захистити важливі ділянки мозку, одночасно видаливши якомога більшу частину пухлини. 31-річний чоловік звернувся з 5-місячною історією головних болів, судом і оніміння правого боку. Неврологічний огляд виявив труднощі з пошуком і організацією слів, але жодних явних порушень мовлення. МРТ виявила ураження без збільшення в лівій лобно-скроневій ділянці. Для захисту мовних центрів і функції мозку під час хірургічної резекції була проведена краніотомія у стані неспання за рекомендаціями DTI, fMRI та IONM. Дослідження підкреслює важливість інтеграції передових методів візуалізації з інтраопераційними техніками для оптимізації результатів хірургічного втручання для інсулярних гліом. Для досягнення максимального успіху та мінімізації післяопераційних ускладнень необхідним є всебічне розуміння біології пухлини, нейроанатомії та факторів, характерних для пацієнта. Включення передопераційної фМРТ і DTI в хірургічне планування підвищує точність і ефективність процедур краніотомії у стані неспання. Для підтвердження цих висновків і вдосконалення стратегій лікування інсулярних гліом необхідні подальші дослідження.

Ключові слова: краніотомія у стані неспання, інсулярна гліома, гліома.