

Oncologic neurosurgery in the era of precision medicine and the challenges ahead

Neurocirugía oncológica en la era de la medicina de precisión y los retos pendientes

César Chong Loor 

SOLCA-Guayaquil, Ecuador

Received: 02/01/2026

Accepted: 03/31/2026

Published: 04/01/2026

Oncologic neurosurgery may be regarded as a medical subspecialty devoted to the diagnosis, surgical treatment, and follow-up of primary and metastatic tumors of the central nervous system (brain and spinal cord) in patients of all ages.

To fulfill this purpose, the oncologic neurosurgeon has to make objective use of neurosurgical techniques and procedures adapted to oncology; that is, the diagnosis and treatment of tumors involve a multidisciplinary team including neurosurgeons, neurologists, oncologists, and radiation oncologists to address both cancer and its neurological complications, using advanced imaging, genetics, and personalized therapy [1,2].

Advanced imaging techniques, artificial intelligence (AI), and molecular biology are used to maximize tumor resection and preserve brain function. Technologies such as neuronavigation, intraoperative imaging (MRI/ultrasound), and functional mapping (awake craniotomy) enable personalization, reduce sequelae, and improve survival [3-5].

Over time, through sustained and proactive effort, SOLCA-Guayaquil and its Neurosurgery Service have made these advances available to patients. Human and technological resources have also positioned them at the forefront in the country, while consistently striving to maintain a level comparable to that of referral centers in other regions. All of this with the main purpose of offering solutions for complex neuro-oncologic conditions according to the particularities of each case.

There are several factors or subsystems that interact synergistically with technology and knowledge, as well as with the results derived from their application over time, and they are reflected in accumulated experience and effort. In this regard, significant progress has been achieved, including the following subsystems [6-11]:

- **Neuronavigation and Augmented Reality:** Brain GPS-type systems integrate preoperative images with the real surgical field, thus enabling minimally invasive approaches.
- **Intraoperative Ultrasound:** It complements the accuracy of the neuronavigation system. It allows correction of the millimetric deviations that may occur with neuronavigation during surgery and confirms that tumor resection has been achieved as planned (total or partial).
- **Intraoperative Imaging and Navigation:** The use of intraoperative MRI and high-resolution ultrasound corrects the brain shift phenomenon (brain deformation after opening the skull), thus enabling more complete resections.

* **Corresponding Author:** César Chong Loor, cesar.j.chong@solca.med.ec

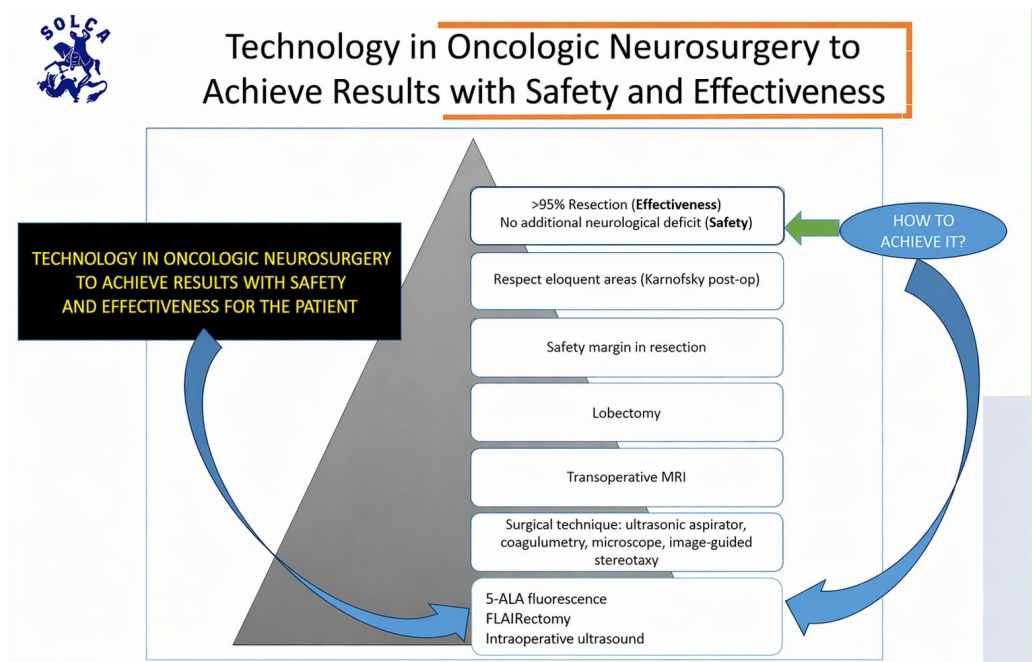
How to cite: Chong Loor C. Oncologic neurosurgery in the era of precision medicine and the challenges ahead. *Oncología* (Ecuador). 2026;36(1): 1-4. <https://doi.org/10.33821/865>

- **Awake Craniotomy and Functional Mapping:** This is used to identify eloquent brain areas (language, movement) while the patient is awake, thus reducing the risk of neurological deficits.
- **Molecular and Genomic Diagnosis:** Real-time sequencing (for example, nanopore sequencing) classifies tumors in less than one hour during surgery and helps determine the extent of resection.
- **Fluorescence-Guided Surgery:** Techniques such as the use of 5-ALA (5-aminolevulinic acid) make tumor cells “glow” under specific lights and facilitates their visual identification against healthy tissue.
- **PET Scan:** Through radioactively labeled molecules such as glucose and citicoline, PET imaging makes it possible to observe the metabolic behavior of tumors. The greater their aggressiveness and growth, the greater their metabolic activity on the study. Consequently, it helps obtain better biopsy samples in certain tumors for improved identification—higher tumor grade or malignancy. It also allows staging or assessment of tumor spread throughout the body in cases of brain metastases.
- **High-Precision Radiotherapy:** Techniques such as radiosurgery, including robotic systems and CyberKnife, or proton therapy provide high precision when delivering radiation, thereby protecting healthy brain tissue.
- **Minimally invasive spine surgery:** it substantially improves patients' quality of life.

At SOLCA-Guayaquil, resources aimed at achieving a high degree of precision are broadly available; however, intraoperative magnetic resonance imaging is not available, although in practice this limitation is reasonably offset by other previously mentioned tools and modalities. Likewise, magnetic resonance imaging is performed within the first 24 postoperative hours to establish the degree of tumor resection. Subsequently, the patient is prepared to receive adjuvant treatment with chemotherapy, radiotherapy, or both, depending on each case.

In this context, oncologic neurosurgery (Figure 1) in the era of precision medicine has evolved from a predominantly extractive approach to a model centered on molecular biology and the use of innovative technologies, aimed at maximizing tumor resection without compromising neurological functions.

Figure 1. Technology in oncologic neurosurgery to achieve results safely and effectively.



FLAIR: Fluid-Attenuated Inversion Recovery.

FLAIRectomy or resection of the peritumoral FLAIR hyperintensity

An important aspect to be considered, in addition to precision, is safety and effectiveness.

Safety is a fundamental concept because it makes it possible to minimize, to the greatest extent possible, the side effects or collateral effects derived from any intervention. In the context of oncologic neurosurgery, this implies avoiding the appearance of new neurological deficits. More importantly, the higher objective is not only to preserve neurological function, but also to improve preexisting symptoms and deficits that compromise the patient's quality of life through a precise, planned intervention supported by the best available evidence [12,13].

What lies ahead is fully personalized oncologic neurosurgery and molecular biology. This era of precision will be achieved through the genomic analysis of each patient, for instance:

- Molecular Profiling: Next-Generation Sequencing (NGS) identifies specific mutations to guide targeted therapies and predict treatment response.
- Liquid Biopsy: It enables monitoring tumor dynamics through the analysis of DNA in blood or cerebrospinal fluid in a minimally invasive manner.
- Artificial Intelligence: AI algorithms assist in rapid diagnosis and real-time tumor classification during surgery, supported by big data, Single-Cell Spatial Multiomics, and molecular imaging.

In this transformation scenario, oncologic neurosurgery is moving toward an increasingly precise, safe, and personalized model supported by the integration of molecular biology, artificial intelligence, and innovative technologies. These open a more hopeful perspective for patients with tumors of the central nervous system by translating into better outcomes and quality of life.

1. Administrative information

1.1 Author contributions

The author made all relevant contributions: conceptualization, original draft writing, review, and editing.

1.2 Funding

None.

1.3 Availability of data and materials

None.

2. Statements

2.1 Ethics committee approval

Not applicable.

2.2 Consent for publication

Not applicable, as the manuscript does not contain personal data or identifiable patient information.

2.3 Conflict of interest

The author declares that there is no conflict of interest related to the content of this editorial.

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