MAGNETIC RESONANCE TRACTOGRAPHY INTEGRATED TO NEURONAVIGATION IN THE SURGICAL PLANNING OF A TEMPORAL ARTERIOVENOUS MALFORMATION AT THE DOS DE MAYO NATIONAL HOSPITAL. CASE REPORT

Tractografía por resonancia magnética integrada a la Neuronavegación en la planificación quirúrgica de una malformación arteriovenosa temporal en el Hospital Nacional Dos de Mayo. Reporte de caso

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ABSTRACT

Introduction: Complete resection of a cerebral arteriovenous malformation (AVM) eliminates the risk of bleeding[1]. Although AVMs that adjoin eloquent areas have been studied with functional neuroimaging or intraoperative mapping, [2] the usefulness of tractography has been limited to case reports or small series. Selecting the patient for surgery for an AVM close to an eloquent area is a challenge. [3]
Clinical case: 33-year-old man with a clinical picture of epilepsy for 8 years controlled with carbamazepine. Two years ago, after suspension of treatment, the seizures reappeared, some of the auditory hallucinations "voices asking for help." Brain tomography (CT) showed a hyperdense lesion suggestive of AVM in the left temporal region, which was confirmed with magnetic resonance imaging (MRI) and cerebral angiography. The AVM was completely resected using the tractography integrated into the Neuronavigation.
Conclusion: Magnetic resonance tractography integrated into the Neuronavigation allows to assess in real-time the proximity of the nidus of AVM to the arcuate fasciculus tract and the use of intraoperative fluorescein video angiography allows to assess vascularity in real-time. All of this makes it possible to perform total resection without causing injury to the eloquent area by avoiding compromising the fibers of the arcuate fasciculus tract.

Keywords: *Intracranial Arteriovenous Malformations, Neuronavigation, Fluoresceins (Source: MeSH NLM)*

RESUMEN

Introducción: La resección completa de una malformación arteriovenosa (MAV) cerebral elimina el riesgo de sangrado[1]. Aunque las MAVs que colindan con zonas elocuentes han sido estudiadas con neuroimágenes funcionales o mapeo intraoperatorio[2], la utilidad de la tractografía se ha limitado a reportes de casos o series pequeñas. La selección del paciente para cirugía de una MAV cercana a una área elocuente, es un reto [3].
Caso clínico: Varón de 33 años, con cuadro clínico de epilepsia desde hace 8 años controlada con carbamazepina. Hace 2 años, luego de suspensión de tratamiento las convulsiones reaparecen, algunas de tipo alucinaciones auditivas "voces pidiendo auxilio". Tomografía cerebral (TAC) mostró una lesión hiperdensa sugestiva de MAV en región temporal izquierda que se confirmó con una resonancia magnética (RMN) y una angiografía cerebral. La MAV fue resecada completamente con ayuda de la tractografía integrada al Neuronavegador.
Conclusión: La tractografía por resonancia magnética integrada a la Neuronavegación permite evaluar en tiempo real la cercanía del nido de la MAV al tracto del fascículo arcuato y el uso de la videoangiografía con fluoresceína intraoperatoria permite evaluar la vascularidad en tiempo real. Todo ello hace posible realizar la exéresis total sin ocasionar lesión del área elocuente al evitar comprometer las fibras del tracto del fascículo arcuato.

Palabras clave: *Malformaciones Arteriovenosas Intracraneales, Neuronavegación, Fluoresceínas (Fuente: DeCS Bireme)*

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The visualization of the pathways in the white matter by magnetic resonance imaging with tractography is increasingly used in neurosurgical planning. This method allows demonstrating using three-dimensional images, the tracts in relation to the lesion, being a non-invasive method in real-time that allows seeing the location and trajectory of the pathways in the white matter. Magnetic resonance tractography allows us to carry out adequate surgical planning in different pathologies, located in the gray matter or the white matter, either close to an eloquent area or to a deep functional area[4].

Tractography allows us to visualize the tracts in the white matter and we use it to identify the proximity of an eloquent area to tumors, malformations, heart attacks, and other injuries. The three-dimensional visualization of the fibers of the corticospinal (pyramidal) tract, optical radiation, and the arcuate fasciculus in relation to brain injuries is extremely useful for preoperative evaluation and intraoperative navigation.[5]

For a clearer appreciation of this modern technique and of the clinical impact of tractography, we present the first case operated in our hospital in which this technology was used in the resection of an arteriovenous malformation, where magnetic resonance tractography was used, the high-resolution microscope integrated to Neuronavigation and intraoperative fluorescein.

CLINICAL CASE

History and Exam: 33-year-old male patient, with a history of epilepsy for 8 years on treatment with carbamazepine 200 mg every 12 hours. After suspension and irregular treatment in the last 2 years, the seizures reappeared (some of them present as “voices asking for help”). A brain tomography (CT) showed a hyperdense lesion suggestive of an AVM in the left temporal region, which was confirmed with a brain MRI. Given the persistence of seizures and with the diagnosis of AVM, he went to the emergency room of our hospital. A 4-vessel digital subtraction cerebral angiography showed the presence of a temporary SM III AVM (*Fig 1*).

Surgical treatment: Due to the proximity to the language area (Wernicke's Area), surgery was planned with the use of

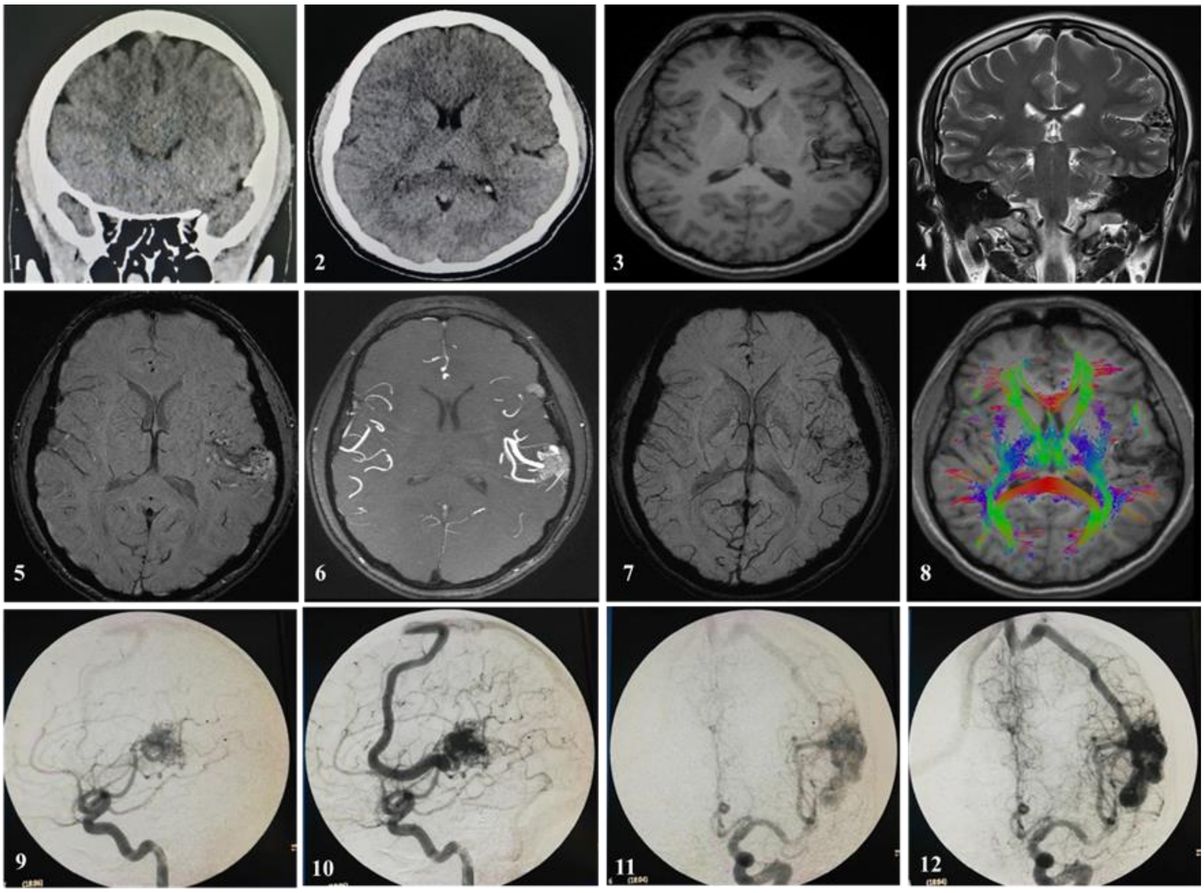

Fig. 1. (1, 2) Cerebral tomography (CT) in coronal and axial view showing a hyperdense image in relation to the nest of the arteriovenous malformation (AVM) and left temporal drainage vein with superior direction. **(3)** MRI in T1 sequence without contrast, in axial section showing, left temporal AVM. **(4)** MRI in T2 sequence, the coronal view showing temporal AVM on the lateral surface and left Silvio fissure. **(5, 6, 7)** MRI and MRI angiography in axial view showing left temporal AVM with arterial afferents from left M3 - M4 branches. **(8)** Brain MRI with tractography showing the corticospinal tract, the visual pathway, and part of the bilateral arcuate fasciculus. Contact of the AVM with the posterior part of the left arcuate fascicle is appreciated. **(9, 11)** Angiography in early arterial phase, in lateral incidence and AP, showing left temporal AVM with left M4 afferents. **(10, 12)** Late arterial phase angiography in lateral incidence showing a left temporal AVM with a fistulous draining vein to the superior longitudinal sinus.

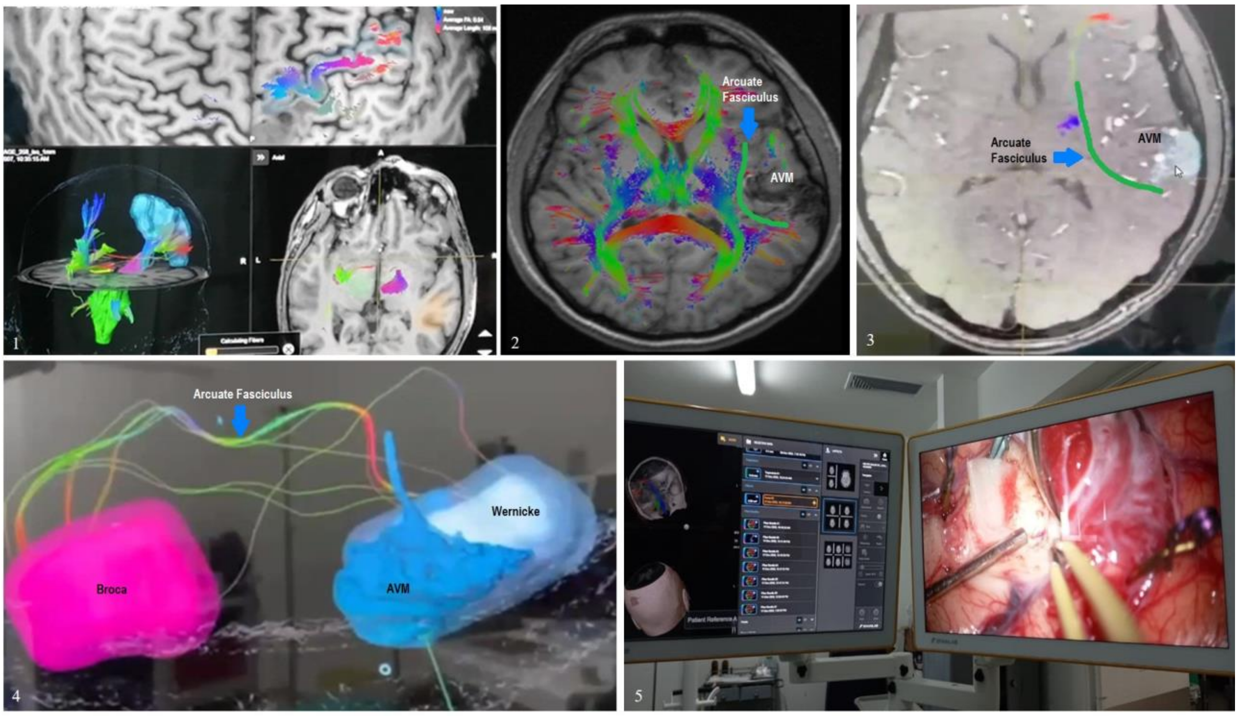

Fig. 2. (1) Image of the Neuronavigation system, surgical planning with tractography to address AVM. **(2)** MRI of the brain with tractography, showing the corticospinal tract, the visual pathway, and part of the bilateral arcuate fasciculus. Contact of the AVM with the posterior part of the left arcuate bundle is appreciated. **(3)** Brain MRI integrated to the Neuronavigator showing part of the left temporal AVM and the pyramidal pathway on the same side. **(4)** 3D representation of the Broca area (purple color), Wernicke (light blue color), AVM (blue color), and the arcuate fascicle. **(5)** Microsurgical image integrated into Neuronavigation.

a Neuronavigator (Brainlab), integrating the MRI images with the tractography, appreciating the close relationship of the temporal AVM with the arcuate fascicle and the area Wernicke (*Fig 2*).

A left frontotemporoparietal craniotomy was performed and after the dural opening the AVM nest was evidenced, feeders were identified, subarachnoid and pial dissection was performed. The Neuronavigation integrated into the microscope (*Kinevo 900*) was used as an aid and the flow in the afferent and efferent branches was evaluated in real-time by means of video angiography with fluorescein, which gave us a greater margin of surgical safety. Total excision of the temporal AVM was performed (*Fig 3*).

Clinical evolution: In the immediate postoperative period, the patient presented nominative aphasia (when he was shown a pencil, he clearly mentioned its usefulness and color, but he could not say what the name of the object shown was, that is to say, "pencil"). On the other hand, he did not present problems for the recognition of other objects and the proper pronunciation of words. In the immediate post-surgical CT, a slight hypodensity was evidenced in the surgical bed (*Fig 4*).

Later she also presented psychomotor agitation for which she was treated in the Neurocritical care unit and after a favorable evolution, she was transferred to the hospitalization area. His evolution was favorable, remaining awake, lucid, without motor or sensory deficits, and without language alterations, for which he was discharged with an outpatient control indication.

DISCUSSION

Vascular lesions are benign and non-invasive, but they can affect the function and life prognosis mainly through hemorrhagic, ischemic, and sometimes epileptogenic mechanisms. In lesions such as arteriovenous malformations and cavernomas, the surgical goal is total resection to prevent future bleeding. [4] When successful, surgery is curative, emphasizing the importance of preserving neurological function. On the other hand, arteriovenous malformations, cavernomas, and spontaneous intracerebral hemorrhages can be partially, or totally deep, so white matter identification techniques are especially useful.

There are several treatment options for arteriovenous malformations: Surgery, embolization, and radiosurgery. Each one with its advantages and disadvantages, adding a certain complexity to decision making. There are many studies available on the functional cortical and subcortical reorganization induced by AVM. [6]

This functional remodeling redefines the classic eloquent areas with which we classically evaluate arteriovenous malformations. [7] Understanding the spatial configuration of the underlying white matter tract may have a significant impact on prognostic evaluation. [8] Consequently, the proximity of an eloquent white matter tract has been associated with a decrease in long-term functional outcome. [7]

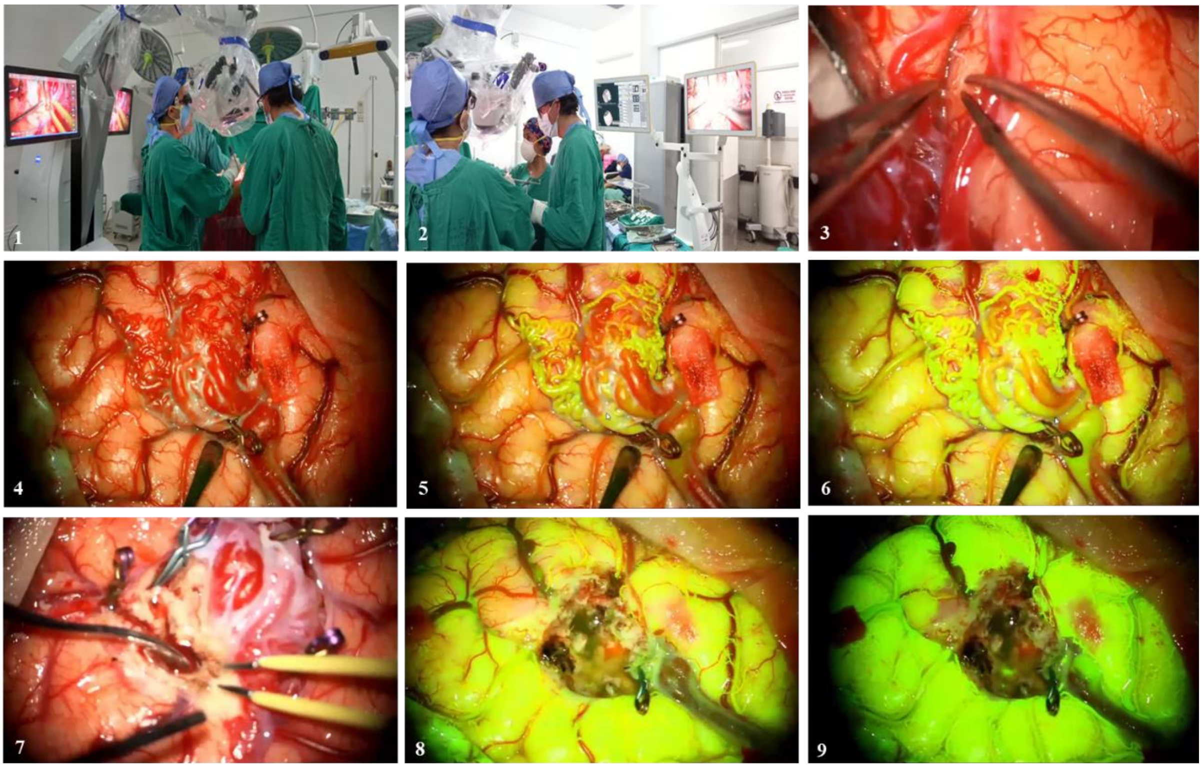

Fig. 3. **(1, 2)** *Kinevo 900* surgical microscope with intraoperative videoangiography, integrated with *Brainlab* Neuronavigator. **(3)** Microsurgical stage of subarachnoid dissection and arterial afferents. **(4)** Panoramic view of left temporal AVM with temporal clips in arterial afferents. **(5)** Intraoperative fluorescein videoangiography for the identification of arterial afferents. **(6, 7)** Pial and parenchymal dissection stage of temporal AVM. **(8, 9)** Intraoperative videoangiography with fluorescein after total resection of AVM showing the absence of vascular lesion and almost total staining of the surrounding parenchyma.

Surgery for arteriovenous malformations cannot afford to be subtotal, as could be the case in other brain lesions in eloquent areas since incomplete resection increases the risk of bleeding and therefore morbidity. Evaluation of the tract adjacent to the injury helps to decide if surgery is the safest option for a specific injury. When deciding to resect, tractography helps to demonstrate nearby pathways in superficial lesions and the safest corridor by trying to avoid eloquent fibers in deeper lesions. [9] The results of tractography may raise alternative treatment options when the configuration of the tract spatial is functionally unsafe for surgery.

The tracking of fibers in patients with arteriovenous malformation can be highly variable depending on the state of the AVM. Non-hemorrhagic ones are associated with limited perinidal disruption, leading to minimal variations, only due to local microvascular changes. Otherwise, the non-infiltrating nature of these lesions preserves the normal white matter that appears in the vicinity of the arteriovenous malformation, preserving the reliability of the Tractography. [10]

On the other hand, if there is bleeding, after the hemorrhage there is perilesional vasogenic edema, gliosis, and other interruptions that can make it difficult to track the fibers as occurs for example in the case of brain tumors. However, it was shown that fiber tracking was still feasible and useful in some of these situations. [9]

The tracking and shaping of the fibers were applied for the first time to the corticospinal pathways. [11] Progressively, with the improvement of the imaging and processing techniques, the tracking of smaller and more complex structures has become possible. The application of the mapping of the white matter tracts involved in cognitive function and specific language is a major challenge, given the relative subjectivity and complexity of the structures involved. [12] Caverzasi et al. reported, in a series of 35 patients, that the preservation of the traced left arcuate fasciculus (AF) and the temporoparietal component of the superior longitudinal fascicle (SLF-tp) were statistically correlated with the absence of postoperative language deficit.[13] Damage to these two-way was also statistically predictive of a long-term language deficit. [13]

The treatment of cerebral arteriovenous malformations is challenging. There are four available treatment modalities: Observation, radiosurgery, embolization, and microsurgery. In planning about treatment, one must consider the natural history of the injury versus the morbidity and mortality rate.

The characteristics of arteriovenous malformations of the temporal lobe, such as their location, potential deep arterial feeders, or deep venous drainage, increase the risk of early clinical presentation, hemorrhage, morbidity, and mortality; This is an additional challenge for surgeons who attempt to excise the lesion while preserving the eloquent local structures. [14]

In this study, we show our microsurgical resection technique of an arteriovenous malformation of the left temporal lobe close to Wernicke's area. To maximize access to the lesion for safe resection, a wide craniotomy was performed,

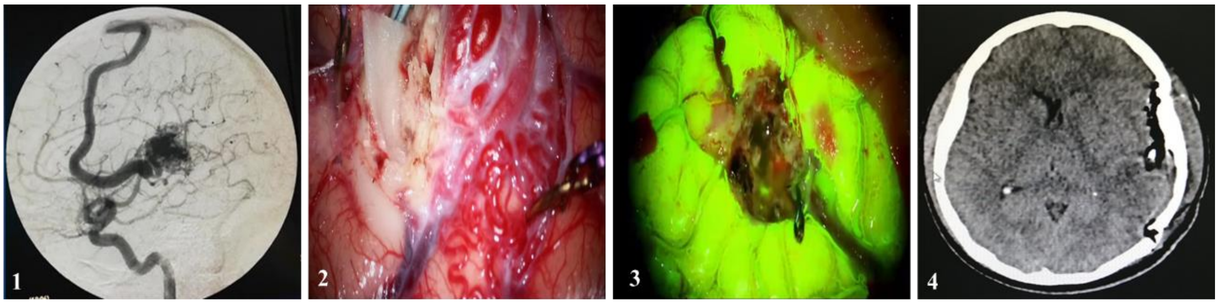

Fig. 4. (1) Late arterial phase angiography in lateral view showing left temporal AVM with left M4 afferents. **(2)** Stage of pial and parenchymal dissection of the temporal AVM. **(3)** Intraoperative videoangiography with 10% fluorescein shows total resection of the AVM, absence of vascular lesion, and almost total staining of the surrounding parenchyma. **(4)** Postoperative brain CT, without hematoma of the surgical site.

surgery was planned to use Magnetic Resonance with tractography, for which the data were entered into the Neuronavigator, which allowed us to visualize the malformation in relation to the tracts of the arcuate fasciculus, the feeding arteries branches of the middle cerebral and the underlying cortex. In addition, resection was performed under microsurgery and with the help of real-time intraoperative fluorescein videoangiography. In the end, the entire AVM nest was resected, and intraoperative videoangiography confirmed total resection.

CONCLUSION

Magnetic resonance tractography integrated into Neuronavigation makes it possible to avoid damaging the language pathways during surgery for an arteriovenous malformation near a language area, thus preserving language function. This initial result will allow us to improve our pre-surgical planning protocols, carry out intraoperative monitoring, and have less possibility of injury to eloquent areas.

Likewise, it allows predicting some language deficit, since the preservation of the dorsal language pathways has a prognostic value in the recovery of language deficit in the long term. In our case, by preserving the tract of the arcuate fasciculus, we achieved adequate preservation of language.

Progressive improvements in intraoperative scanning, tractography, Neuronavigation, and video angiography methods are helping to overcome and improve results in resection of eloquent lesions. Microsurgical resection remains an important part of the management of temporal lobe arteriovenous malformations. In carefully selected patients, this can be done with minimal morbidity.

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Disclosures
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