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Technical note

# A purely functional Imaging based approach for transcortical resection of lesion involving the dominant atrium: Towards safer, imaging-guided, tailored cortico-leucotomies

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ABSTRACT

*Background and study object:* The Dominant Atrium (DA) is a crossroad of eloquent white matter bundles difficult to preserve with a standard "anatomical" approach. The aim of this work is to evaluate the results of a cohort of patients who underwent surgery with the aid of a purely functional MRI and DTI-based approach.

*Materials and methods:* 43 patients suffering from lesions involving the DA have been included in the final cohort and studied in regards to quality of life (KPS); a special attention was lent on the incidence of new or worsening of preexisting neurological deficits, with a focus on motor, visual and speech disturbances after the surgical treatment. Patient, surgery and lesion-related data were recorded to identify the relationships with outcome. Eloquent areas fMRI and the course of Arcuate Fasciculus (AF), Inferior frontooccipital fasciculus (IFOF), Optic radiation (OR) and corticospinal tract (CST) have been investigated with preoperative MRI sequences and DTI reconstruction.

*Results:* The final cohort consisted of 43 patients, 19 males and 24 females; average age was 56.8 years. We recorded 9 transient and 3 permanent postoperative deficits, only one of those was caused by an edema interference with DTI reconstruction. Preoperative functional status, histology and volume of the lesion proved to be independent factors affecting results.

*Conclusions:* A purely functional surgical approach to the DA provided promising preliminary results. A direct DTI-fMRI visualization of the eloquent structures proximal to DA allows surgeon to conceive an ultra-precise and "tailored" cortico-leucotomy for an optimal exposure of the lesion.



## 1. Introduction

### 1.1. Background and rationale

Lesions involving the dominant atrium (DA) are challenges for neurosurgeons, this anatomically complex location [1,2] implies a severe risk of postoperative deficits, with a subsequent impairment of quality of life (QoL).

In contemporary neurosurgery [3,4], preserving higher cognitive functions is critical to preserve quality of life (QoL), and subsequently the eligibility to adjuvant therapies and, definitively influences Overall Survival [4–8].

A thorough surgical planning is the highway to a cautious and safe resection. The contemporary approaches to the DA strongly

*Abbreviations:* ASA, American society of anesthesiologists score; EOR, extent of resection; DA, dominant atrium; DTI, diffusion tensor imaging; fMRI, functional magnetic resonance imaging; QoL, quality of life; ION, intraoperative neuromonitoring; GPA, graded prognostic assessment; GTR, gross total resection; NTR, near total resection; STR, subtotal resection; Io-MRI, intraoperative MRI; MRI, magnetic resonance imaging; MPRAGE, magnetization-prepared rapid gradient-echo; KPS, Karnofsky performance status; OR, optic radiation; AF, arcuate fasciculus; CST, corticospinal tract; IFOF, inferior fronto-occipital fasciculus; MRC, medical research council.

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rely on preoperative MRI-DTI, with a direct reconstruction of the white matter bundles [3–13]; probably making the old conception of the anatomical approaches to the DA [14,15] at best "confirmatory" to the DTI findings.

The philosophy behind this approach is to gain a direct visualization of the fiber bundles and to execute intraoperatively a surgical planning characterized by a direct and safe trajectory with a minimally invasive cortico-leucotomy thus preventing postoperative sequelae.

### 1.2. Objectives

The aim of this work is therefore to retrospectively review a series of patients suffering from DA lesions operated on in a single Intraoperative-MRI equipped Neurosurgery Department in order to describe the critical role of the information provided by DTI for what concerns both the preoperative surgical planning and intraoperative surgical strategy by analyzing the effect of many patient-related, surgery-related and lesion-related variables on motor, visual and speech function outcome and quality of life after surgical resection.

## 2. Materials and Methods

### 2.1. Study design and setting

In our Department, in the period between January 2008 and July 2016 a total of 46 consecutive patients suffering from purely intraventricular dominant atrium (DA) lesions have been operated on. The database has been composed of retrospectively reviewed clinical and radiological records acquired during hospitalization and through clinical revaluations at the Neurosurgical Outpatient service of our Hospital.

### 2.2. Participants and eligibility

Patients were excluded according to the following criteria:

1. Patients presenting lesions with extra-ventricular extension (the only lesions included were purely intraventricular-atrial); only patients suffering from tumors histologically arising from the intraventricular anatomical structures have been included;
2. A preoperative KPS $\leq$ 60%;
3. In case of intraventricular metastases, an estimated overall sur vival $\leq$ 4–6 months (on the ground of GPA rankings) [16];
4. In case of multiple lesions, the patient was included only if the target lesion was the one involving DA. In such cases the target lesion was the only removed lesion;
5. Incomplete or wrong clinical, radiological and surgical records and/or patients lost to follow-up.

### 2.3. Variables: Data source and measurements

For each of the patients included we recorded: age, sex, clinical onset, histology of the lesion. The volume of the lesion (in $cm^3$, evaluated with Iplan ™ 2.6 software, BrainLAB AG, Feldkichen, Germany) was recorded either.

Performance status was evaluated through the Karnofsky performance status (KPS). This scale was recorded at admission and 30 days after surgical procedure. 36 patients underwent routine 30 postoperative days reevaluation at the Neurosurgical outpatient service of our division. In 7 cases hospitalization lasted more than 30 days so the performance status recorded in the daily medical records one month after surgical procedure was added in the final database. Patients underwent a 2 months reevaluation at the Neurosurgical Outpatient service of our Institution.

Special attention was paid to the incidence of surgery-related worsening of motor, speech and visual function.

These functions were evaluated and recorded both during the preoperative period and at 30 days from surgery as follows:

1. Speech disturbances were investigated with the aid of an ordinal 4-steps scale (No speech disturbance, Mild Speech disturbance not preventing communication, Dysphasia preventing communication, Sensory/motor aphasia).
2. Visual function was investigated with a pre and postoperative digital visual field test. The results of such investigations were coded in an ordinal 4-steps scale (No unilateral campimetric deficit, 25–50% of unilateral campimetric reduction, 50–75% of unilateral campimetric reduction, Hemianopsia)
3. Motor function was basically coded with the aid of the standard MRC (Medical Research Council) strength scale.

The presence of new postoperative deficit, as well as worsening of the preexisting was recorded as nominal variable (no other deficit/Transient/Permanent). We defined a deficit as "permanent" when we could confirm the stability or only partial recovery of the deficit at the 2 months outpatient service re-evaluation.

Furthermore, a 3-steps nominal outcome variable (worsened, stable, improved) was added and meant to work as a control variable for the previous data.

Medical and surgical complications and number of intraoperative MRI scans performed were recorded too.

### 2.4. Protocol of dominant atrium lesion management in detail

Each patient underwent a preoperative 1.5 T-MRI scan (Sonata, Siemens, Erlangen, Germany), twin to the one into our BrainSUITE, for diagnostic purposes, surgical planning and neuro-navigation. T1w, T2w, FLAIR and Gadolinium enhanced isotropic volumetric T1-weighted magnetization-prepared rapid acquisition gradient echo (MPRAGE). BOLD-fMRI imaging was carried out to localize eloquent cortices, such as motor cortex in precentral gyrus, Broca and Wernicke areas in inferior frontal gyrus and angular and supramarginal temporal gyrus respectively, and visual area proximal to the calcarine sulcus. Diffusion tensor sequences (DTI) with 3D tractography completed our protocol in order to localize arcuate fasciculus (AF), Inferior Fronto-Occipital Fasciculus (IFOF), Corticospinal Tract (CST) and Optic Radiation (OR). Radiological methodology is reported elsewhere [10,11].

Conditions like massive brain edema can reduce DTI sensibility and specificity in respect to white matter fibers therefore the proper visualization of AF, IFOF, CST and OR were recorded as dichotomous variables (0/1 – Yes/No).

All the surgical procedures were performed in BrainSUITE. Patients heads were placed in MR head-coil-frame, with integrated fiducials that were preoperatively recognized by a frame-based Neurovigation system (VectorVision, BrainLAB AG, Feldkichen, Germany). A dedicated pointer equipped with fiducials was recognized by the Neuronavigator and used to localize the lesion and the proper skin incision.

Trajectory to the tumor, or more precisely for the tailored cortico-leucotomy, was preoperatively planned on the ground of the fMRI and 3D-tractography findings, in order to avoid any damage on the eloquent structures (Figs. 1–3).

At the end of the procedure, the last MRI was performed in order to assess the extent of resection.

A total intravenous anesthesia protocol with Propofol (1mg/kg) and Remifentanil (0.5 μg/kg/min) was applied. During surgery, no muscle relaxant was administered.