Original article

Resection of cavernous angioma located in eloquent areas using functional cortical and subcortical mapping under awake conditions. Outcomes in a 50-case multicentre series

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A B S T R A C T

Introduction. – Surgical resection of supratentorial cavernous angiomas located in eloquent areas poses a significant risk to the patient of postoperative neurological impairment and justifies intraoperative functional monitoring.

Methods. – Multicentre retrospective series of adult patients with cavernous angiomas located within eloquent areas and treated with functional-based surgical resection according to functional boundaries under intraoperative functional cortico-subcortical monitoring under awake conditions.

Results. – Fifty patients (18 males, mean 36.3 ± 10.8 year-old) underwent surgical resection with intraoperative cortico-subcortical functional mapping using direct electrostimulation under awake conditions for a cavernous angioma located in eloquent areas with a mean postoperative follow-up of 21.0 ± 21.2 months. At presentation, the cavernous angioma had previously resulted in severe impairment (neurological deficit in 34%, seizures in 70%, uncontrolled seizures in 34%, reduced Karnofsky Performance Status score of 70 or less in 24%, inability to work in 52%). Functional-based surgical resection allowed complete removal of the cavernous angioma in 98% and of the haemosiderin rim in 82%. Postoperative seizures and other complications were rare, and similarly so across all centres included in this series. Postoperatively, we found functional improvement in 84% of patients (reduced Karnofsky Performance Status score of 70 or less in 6%, uncontrolled seizures in 16%, and inability to work in 11%).

Conclusion. – Functional-based surgical resection aids the safe and complete resection of cavernous angiomas located in eloquent areas while minimizing the surgical risks. Functional mapping has to be considered in such challenging cases.

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1. Introduction

Cavernous angiomas are a tangle of abnormally-formed, thin-walled capillaries without mature vessel walls, endothelium-lined caverns, and veins [1]. Cavernous angiomas represent 5 to 15% of vascular lesions [2,3], and present with epileptic seizures or
intracerebral haemorrhage in > 50% and > 35% of cases, respectively [4,5]. The high risk of seizure recurrence after the first unprovoked seizure (>90%) and of drug-resistance (>50%) together with the risk of bleeding justify radical therapeutic strategies without waiting until the rigorous criteria of medically refractory epilepsy are fulfilled and this has been concisely argued elsewhere [5].

Surgical resection remains the first line treatment for supratentorial cavernous angiomas although it does come with the risk of potential complications. The aim of surgery should be to completely resect the lesion, including the surrounding haemosiderin rim whenever feasible to improve seizure control[6]. However, any associated venous anomaly should be preserved because of the risk of venous infarction. Exploration of epileptic networks is sometimes useful for drug-resistant cavernous angiomas and can help to determine resection boundaries including any extended epileptogenic tissue [7,8]. In deep-seated cavernous angiomas that are difficult to cure surgically, radiosurgery has been proposed but it carries a morbidity risk of more than 10% and has a delayed effect [9,10]. The quality of life, neurological and neuropsychological outcomes and postoperative morbidity are a concern, particularly for cavernous angiomas located close to or within eloquent areas and some authors support the conservative treatment of such lesions [11]. If various surgical approaches and intraoperative techniques have been proposed to achieve a complete resection of cavernous angiomas [5,12,13], however a functional-based surgical resection encompassing the cavernous angioma and surrounding brain has only rarely been reported [14,15]. The intraoperative cortico-subcortical functional mapping technique using direct electrostimulation under awake conditions allows the real-time study of brain functions, helps the neurosurgeon to tailor the surgical approach to reach the cavernous angioma, as well as tailor the resecting of surrounding brain tissue infiltrated with haemosiderin. Also any extended epileptogenic tissue can be resected, if required, based on intraoperative functional findings. A team previously reported good outcomes after complete removal of cavernous angiomas located in eloquent areas [15,16]. However, this seminal series consisted of a single centre series of 9 patients with a median follow-up of 19 months, which limits the conclusions drawn.

Here, we report a large, multicentre study aiming to assess the extent of resection and the patient outcomes after surgery in a series of adult patients with a supratentorial cavernous angioma located in eloquent brain areas all undergoing surgical resection with intraoperative cortico-subcortical functional mapping using direct electrostimulation under awake conditions and applying the technique, methodology, and philosophy of the French brain surgery school to achieve a personalized functional-based brain resection.

2. Methods

2.1. Data source

This study examined a consecutive series of 50 patients who underwent functional-based surgical resection of a cerebral cavernous angioma located within or near eloquent brain areas at different neurosurgical institutions (in alphabetical order): Guıde-Chauliac Hospital (Montpellier, France), Lariboisière Hospital (Paris, France), Nice Hospital (Nice, France), Pitié-Salpêtrière Hospital (Paris, France), Poitiers Hospital (Poitiers, France), Sainte-Anne Hospital Center (Paris, France), and Roger-Salengro Hospital (Lille, France). All operations were performed by the same neurosurgeons at each institution. Inclusion criteria were:

- adult patients;
- histopathological diagnosis of cavernous angioma;
- cavernous angioma location within or close to eloquent areas, as previously defined [17];
- surgical resection using intraoperative cortico-subcortical functional mapping using direct electrostimulation under awake conditions performed from a lesionectomy perspective without additional procedure with the aim of removing a particular epileptic network;
- available clinical, imaging, functional data at diagnosis and during follow-up.

Between June 1999 and January 2016, a total of 50 patient cases were available for final analyses. Eight of these cases have been previously published [15].

2.2. Data collection

Data were centralized retrospectively from the medical records using a protocol designed for this study. Data on the following parameters was collected: gender, age at radiological diagnosis, presenting symptoms, neurological disability at surgery and at last follow-up, epileptic seizures and seizure control at surgery and at last follow-up (defined as controlled or uncontrolled seizure despite antiepileptic drug therapy without the strict application of the drug-resistant epilepsy definition according to the International League Against Epilepsy) [18], language evaluation performed using the Boston Diagnostic Aphasia Examination and the DO80 picture naming test at surgery and at last follow-up, patients’ functional status at surgery and at last follow-up evaluated by means of the Karnofsky Performance Status (KPS) scale, ability to work at surgery and at last follow-up, cavernous angioma location, time interval between radiological diagnosis and surgery, preoperative cavernous angioma and haemosiderin rim diameters, extent of surgical resection of the cavernous angioma and haemosiderin rim, duration of follow-up, functional deterioration postoperatively compared to the preoperative status.

2.3. Surgical procedure

In each neurosurgery institution the same senior neurosurgeon performed the surgery. In all cases, intraoperative functional cortical and subcortical direct electrostimulation mapping was performed using the “asleep-awake-asleep” protocol, the technique being previously described [19–22]. Cerebral sulci and gyri and cavernous angioma were first identified using intraoperative ultrasonography and/or intraoperative neuronavigation (ultrasonography alone in 13 cases, neuronavigation alone in eight cases, ultrasonography plus neuronavigation in 29 cases). Functional mapping used a bipolar electrode delivering a biphasic current (pulse frequency 60 Hz; pulse phase duration 1 ms). The entire exposed cortex was stimulated and all responsive sites were re-stimulated three times for confirmation; all the other sites were stimulated at least three times. The current intensity used for individual patients was determined by progressively increasing the amplitude in 0.5 to 1 mA increments until a functional response was elicited (baseline 1 mA). In all cases in which the central region was exposed, sensorimotor mapping was first performed to confirm the positive responses (movement and/or paraesthesia). The patient was then asked to perform language tasks: counting (regular rhythm, from 1 to 10, repetitively) and picture naming (DO80) with the goal to identify the eloquent cortical sites inhibited by stimulation. Before naming each picture, the patient was asked to read a short phrase, namely the French translation of “this is a, etc.,” to check that there were no seizures generating complete speech arrest if the patient was not able to name the picture. For the picture naming task, DO80 was used pre- and postoperatively. The patient was never informed when the brain was stimulated. The duration
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