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Surgery of brain aneurysm in a BrainSuite® theater: A review of 105 cases

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ABSTRACT

Introduction: The BrainSuite® is a highly integrated operating theater designed mainly for brain tumor surgery. The issues concerning its routine use in vascular neurosurgery have not been discussed in literature to date.

We report our experience of surgical treatment of cerebral aneurysms in the BrainSuite®, with a view to evaluating safety, feasibility, advantages, disadvantages, and contraindications.

Material and methods: Retrospectively, we reviewed all the patients affected by ruptured and unruptured aneurysms that underwent craniotomy with clipping between January 2007 and May 2013 and a subsequent minimum 12-month follow up. Intraoperative DWI, MRA, and volumetric MRI were always performed in order to evaluate vessel patency and early ischemic lesions. The usefulness of navigation was also evaluated in terms of loss/gain of time and its effectiveness as a surgical aid to both the localization of small distal aneurysms and the preoperative planning of the clipping strategies to adopt.

Results: A total of 105 patients were included in this report. Of these, 39 and 66 were affected, respectively, by ruptured and unruptured aneurysms. The mean age was 56.1 and the male-to-female ratio was 1:2.9. The aneurysms affected, with progressively descending incidence, the MCA, ACoA, ICA bifurcation, PComA, A2, A1–A2, and C6 segment of the ICA in 40 (38.1%), 23 (22%), 15 (14.3%), 7 (6.6%), 7 (6.6%), 7 (6.6%), and 6 (5.8%) cases, respectively. The aneurysms were clipped and completely excluded from blood circulation in all cases and no difficulty was encountered in positioning and fixing the patients' heads, despite the particular head holder of the BrainSuite®. MRI created no interference or problems in cases of carotid exposure at the neck, while harvesting of the lower-limb saphenous vein was not feasible due to the vicinity of the operating field to the magnet. Intraoperative angiography was never performed since an angiogram is not compatible with the BrainSuite. Intraoperative DWI, MRA, and volumetric MRI proved to be effective tools for post-clipping evaluation of the patency of the parent vessels and their collateral branches as well as of aneurismal occlusion. This was also checked doubly by availing also of intraoperative micro Doppler ultrasonography. Intraoperative DWI also permitted us to evaluate the presence of initial ischemic lesions as possible consequences of both direct arterial occlusion and early vasospasm related to surgical manipulation. Intraoperative navigation of brain aneurysm with 3D-model reconstructions may be of some use to younger surgeons when planning the clipping strategies and localizing the aneurysm particularly in cases, respectively, of large-complex aneurysms where the sac involves collateral branches and small aneurisms affecting both distal ACA and MCA aneurysms. The outcomes for patients, evaluated according to the GOS (Glasgow outcome score), associated significantly with the preoperative HH (Hunt and Hess) scale grading. Patients with high HH scores (IV and V) in particular showed the highest incidence of unfavorable outcome (GOS = 1 or 2)

Conclusions: The BrainSuite® theater is completely suited to brain aneurysm surgery but only in cases where a combined endovascular approach may be required. It provides some advantages and few limitations compared to a normally-equipped neurosurgical operating theater; our experience shows that the technological advances of this complex operating room are useful though not essential in aneurysm surgery.

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1. Introduction

The BrainSuite® is an operating room with a high-field (1.5 T) intraoperative magnet (iMRI) integrated with surgical planning and ceiling-mounted navigation, originally designed for surgery of infiltrative malignant brain tumors aimed at helping surgeons to achieve maximal tumor resection while preserving neurological function. The development of advanced neuroimaging makes techniques, such as CT angiography (CTA), high resolution contrast-enhanced MR angiography (with the MIP sequences), perfusion and diffusion MRI (DWI) as well as angiography (DSA), potentially usable by the Navigator workstation (which is almost completely identical to a radiological workstation), although the potential advantages of this technological theater in cerebrovascular surgery are still a matter of debate [1–8].

At present, very few papers report experiences of managing cerebral aneurysms in similar scenarios and a very small number of cases has been discussed to date [8,9].

Issues, such as interference between high-intensity iMRI fields and surgical or radiological instrumentation, difficulties in positioning patients due to both custom-made operating tables and cumbersome, stiff, head-holders, are particularly relevant and need to be addressed.

We report a series of surgical interventions on cerebral aneurysms carried out by us and discuss the feasibility, the effectiveness, and the safety of these procedures in a BrainSuite®.

The purpose of this paper is to prove that brain-aneurysm surgery is possible, safe, and feasible also within the particular environment of the BrainSuite (a theater provided with an integrated navigation plus high-field intraoperative magnetic resonance imaging (iMRI) system). Some of the authors of this paper (G.D, A.R, and L.F) have had previous experience with this pathology in standard operating theaters.

At the same time, this study asks whether the peculiarities (navigation and advanced techniques of neuroimaging provided by 1.5 T iMRI) of the BrainSuite®, may be of some use to this kind of surgery.

We have ~~also~~ evaluated, in fact, both the utility of intraoperative high-field MRI techniques when verifying the patency of the parent vessels and their branches and the possible presence of early ischemic areas after clipping and the potential advantages of neuronavigation in this kind of surgery.

2. Material and Methods

We analyzed, retrospectively, the clinical records of patients with both ruptured and unruptured aneurysms who were treated surgically between 2007 and 2013 in the BrainSuite at our Institution.

The BrainSuite® is an operating theater endowed with a 1.5 T MR scan (Magnetom Sonata, Siemens, Erlangen, Germany), equipped with a non-standard operating table, which is really a radiological table adapted for surgery, and with the Noras 8-channel OR head coil (Noras MRI products GmgH, Germany) as head holder (Fig. 1).

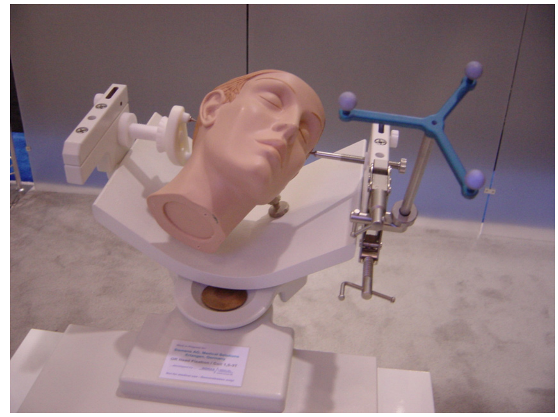

Fig. 1. The Noras 8-channel OR head coil (Noras MRI products GmgH, Germany), used both as a head holder and as a head coil for intraoperative MRI.

On the basis of the surgical notes provided, we evaluated whether this particular operating table and the cumbersome and poorly maneuverable head holder caused any limitations or delays in the positioning of patients.

Unruptured aneurysms were scheduled for elective surgery and underwent 3D-CT angiography (CTA) as the chosen radiological option after 2008, while DSA was the choice in the first 2 years of our series, even if CTA had always been performed in order to use it for navigation.

However, if CTA did not provide reliable and/or satisfactory information concerning the aneurysm and its relationship with the vessels involved, we performed standard digital subtraction angiography (DSA).

Ruptured aneurysms were operated immediately after admission to the emergency room and the same neuroradiological algorithm as that applied to unruptured aneurysms was adopted.

Patients suffering from subarachnoid hemorrhage (SAH) were clinically assessed preoperatively by using the Hunt and Hess clinical grading scale for SAH.

All patients underwent postoperative clinical follow-up assessments at 1, 6, and 12 months. Outcomes were assessed at intervals of 6 months or longer (within 1 year after discharge from the hospital) using the GOS (score 5, excellent outcome; 4, good outcome with moderate disability; 3, fair outcome with severe disability; 2, poor outcome [vegetative]; and 1, death).

Postoperative angiography, CTA, or MR angiography were performed before hospital discharge during the first 2 years of our series, while, later, only CTAs were performed. Patients who did not undergo postoperative imaging or those whose imaging reports were unavailable were excluded from the study. Before 2009, angiograms, as the final postoperative follow-up examination, were obtained at 12 months. From 2009 onwards, all patients underwent CT angiography for 12 months after surgery, supplemented with angiography only in patients where imaging documented a suspected incomplete occlusion. Minimum clinical follow-up lasted 1 year.

We never availed of the intraoperative MRI, which is usually required for navigation during brain-tumor surgery.

Instead, we used both the preoperative CT and CT angiography (CTA), which were always transferred to the planning station and to the neuronavigator. The CTA and skull CT of the patients were easily uploaded and merged into the BrainSuite workstation. Subsequently, the patient's head was matched with the radiological model, by using the Z touch or surface registration technique (a technique whereby an infrared emitting tool is pointed at several cutaneous markers on the forehead as well as on both the orbital regions and the nose).

Surgical approaches as well as microsurgical techniques of clipping were specific to each particular type of aneurysm. However, after clipping, both intraoperative micro-Doppler evaluation and MRI (DWI, MR angiography, and volumetric sequences MIP) were always performed.

We evaluated the impact of these immediate postoperative examinations on surgical or therapeutic decisions and their overall significance in this kind of surgery.

After considering the epidemiological data, we classified the aneurysms according with their location, size, HH score, and outcome, always reporting the overall and subgroup results.