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ORIGINAL ARTICLE

Three-dimensional rotational angiography in the assessment of the angioarchitecture of brain arteriovenous malformations

Angiographie rotationnelle tri-dimentionnelle pour l'étude de l'angioarchitecture des malformations artérioveineuses cérébrales

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Brain arteriovenous malformation;
Angioarchitecture;
3D rotational angiography;
Vascular density

Summary
Background and purpose. — The angioarchitecture of brain arteriovenous malformations (BAVM) still remains a complex subject of study despite advances in medical imaging techniques. For this reason, the present study aimed to assess whether or not 3D rotational angiography (3DXA) might improve the assessment of BAVM.
Patients and methods. — Included prospectively were 72 patients who had undergone conventional digital subtraction angiography (DSA) and 3DXA for pretherapeutic assessment of BAVM prior to radiosurgery. Dimensional criteria, arterial-feed patterns, venous drainage, points of weakness and vascular densities (VD) of the nidus and shunt zone were studied.
Results. — 3DXA detected all arteriovenous shunts by revealing abnormal venous enhancement. Post-processing tools similar to CT and MRI may also be used to make complex 3D reconstructions. In addition, the technique provided significant help for volumetric estimations, extraction of arterial feeders and origins of draining veins, and analysis of the 3D conformation of the nidus. Furthermore, 3DXA detected significantly more points of weakness, such as intranidus aneurysms and venous anomalies ($P < 0.005$). In 65% of cases, a gradient of vascular enhancement intensity was found between the arteries and draining veins surrounding or comprising the nidus. VD, or the percentages of space occupied by the enhanced vascular elements, was

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evaluated in both the nidus and shunt zone. VD in the shunt zone was highest in untreated patients with no history of bleeding ($P < 0.005$).
Conclusion. — 3DXA offers a useful approach to BAVM exploration and can improve our knowledge of lesional angioarchitecture, necessary for the planning of therapeutic strategies.

Introduction

Despite recent advances in magnetic resonance imaging (MRI) and computed tomography (CT), digital subtraction angiography (DSA) remains the standard imaging technique for determining the angioarchitecture of brain arteriovenous malformations (BAVM) [1]. However, selective DSA has a few technical limitations. The projection of numerous vascular elements in a definite anatomical plane may lead to marked reading difficulties. Risky superselective catheterization may be required to better understand the three-dimensional (3D) structure of BAVM and to depict points of weakness in the lesion [2]. Interobserver agreement in the characterization of radioanatomical features may also vary [3,4]. In the present study, a method of complementary selective 3D rotational angiography (3DXA) was evaluated, using digital flat-panel technology to depict the angioarchitecture and spatial conformation of BAVM. The aim of the study was to evaluate 3DXA and the new-generation flat panel to determine whether or not it can improve characterization of the anatomical features of BAVM.

Patients and methods

The study was carried out in accordance with our institutional privacy policy. Prospectively included were 72 patients who underwent conventional DSA and 3DXA to assess BAVM as part of their ongoing planning of treatment by radiosurgery, whether or not the patient had already been partially treated. For these 72 patients (39 men and 33 women; mean age: 37 ± 1 years), there were 75 BAVM because three patients had multiple BAVM. The overall incidence of hemorrhage was 54.2% (39/72) and, of seizure, 27.8% (20/72). Twenty-six patients were de novo cases with no previous treatment, while 46 patients had already been partially treated—by surgery in four cases, embolization in 35 and radiosurgery in 10.

3DXA acquisition protocol

The Innova 3100IQ angiographic system with the Revolution flat-panel detector (GE Healthcare, Waukesha, WI, USA) was used in all procedures. The patient's head was immobilized within a radiosurgery stereotactic frame, and a 5-F diagnostic catheter was introduced *via* the femoral route into the carotid and/or vertebral artery from which the feeding arteries originated. All patients first underwent conventional DSA (posteroanterior and lateral views), using a 1024^2-pixel matrix system, followed by an arterial-phase 3DXA acquisition performed through a 200° rotation of the C arm at 30 images/s. A 5-s acquisition protocol was used in 27 patients during the first part of the study, and a 10-s protocol was performed in the last 45 patients, who thus benefited from an upgrade of the sequence. A 20-mL dose of the non-ionic iso-osmolar contrast medium Visipaque (iodixanol, 320 mg/mL, GE Healthcare) was infused at a rate of 4 mL/s, using an automatic injector, for the 5-s acquisition protocol, whereas a 34-mL dose was injected at 3 mL/s for the 10-s acquisition protocol. The 3DXA acquisition started 2 s after initiation of the contrast infusion to obtain 3D images of the entire BAVM. Data were acquired in a 512^3-pixel matrix with a field of view of 20^2 cm^2 on automatic exposure. Spatial resolution was 0.2 mm for all acquisitions. No complications occurred following 3DXA.

Superselective catheterization was not performed, as all of the patients were evaluated under stereotactic conditions with subsequent gamma-knife treatment on the same day as the angiography.

Raw data for image-processing were transferred to an Advantage Windows Workstation 4.2 running the Innova 3D application (GE Healthcare). 3D reconstructions were obtained using a sharp filter with a 512^3-pixel matrix. Multiplanar reconstructions (MPR), 2D and 3D maximum intensity projections (MIP), 3D volume rendering and 3D manipulation tools were used for the analysis. In addition, T_2-weighted MRI, post-gadolinium T_1-weighted magnetic resonance imaging (MRI) and post-contrast computed tomography (CT) were performed in all patients on the same day as the 3DXA.

Data collection

Data-acquisition terminology and radiological features were inspired by the literature [5], and all examinations were performed and read by the same experienced neuroradiologist, who collected the following data.

BAVM location

The location of the lesion was categorized, using a combination of the MRI, CT and angiography acquisitions, and the following criteria: side (53.3% left-sided; 46.7% right-sided); supratentorial lobar ($n = 40$; 53.3%); supratentorial deep ($n = 14$; 18.7%); supratentorial and both deep and lobar ($n = 9$; 12%); and infratentorial ($n = 12$; 16%).

General aspect and dimensions

The type of BAVM was categorized as either nidus ($n = 66$) or fistula (AVF, $n = 9$) [6]. Nidus was defined as a tangled bundle of abnormal vessels linked by one or more fistulae (Fig. 1) [7]. The maximum nidus diameter and internal carotid artery or basilar artery width were measured and assessed by pixels on the angiogram (maximum nidus diameter in pixels = Sp; diameter of artery in pixels = Ap), and in