Magnetic resonance angiography (MRA) of the circle of Willis: a prospective comparison with conventional angiography in 54 subjects

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Abstract. We prospectively correlated the findings of magnetic resonance angiography (MRA) with those of transfemoral four-vessel angiography in 54 patients to investigate the direction of flow within the circle of Willis. Our primary goal was to assess the direction of flow using the size of the vessel and signal intensity, without saturation techniques. Analysis of the circle of Willis, especially the communicating arteries, was performed double-blind by two groups of two radiologists. Three types of arteries were identified: high flow or cross-cerebral circulation, patent and nonvisualised arteries. Cerebral angiography was the standard for comparison between the two methods. MRA did not reveal any arteries invisible on angiography, thus providing a specificity of 100%. The sensitivity of MRA was 89.2% for the anterior and 81.3% for the posterior communicating arteries, and 100% for the anterior, middle and posterior cerebral arteries. MRA was shown to be a useful technique for the assessment of patency of the circle of Willis.

Key words: Circle of Willis, functional studies – Circle of Willis, anatomy – Cerebral angiography – Magnetic resonance angiography – Brain, ischaemia

Knowledge of the direction of flow in the circle of Willis is of concern to the neurosurgeon, vascular surgeon and interventional neuroradiologist [1–3] if any procedure upon cervical and/or cerebral arteries is to be attempted. The possibility of temporary or definitive occlusion of an artery supplying the circle of Willis raises the issue of its collateral capabilities. These are usually assessed by means of selective arteriography of internal carotid and vertebral-basilar arteries [1, 3]. This is however invasive and can be difficult, especially in atherosclerotic patients. Duplex and colour Doppler sonography, including the transcranial approach [4–6] and magnetic resonance angiography (MRA) are potentially noninvasive alternatives to cerebral angiography [7–18], although they use different physical bases for demonstrating flow phenomena.

Several papers have described the advantages and drawbacks of the different MRA sequences (phase contrast versus time-of-flight [TOF], two- versus three-dimensional acquisitions) [7, 14–16]. TOF has the advantages of short acquisition times, but is relatively insensitive to slow flow; phase contrast is far more sensitive to various flow velocities and can be used to define the direction of flow using three acquisition planes, at the price of long acquisition times, unacceptable in routine examinations. Other reports have emphasised the clinical utility of MRA in the diagnosis of cerebral aneurysms, arteriovenous malformations, ischaemic disease and cerebral venous thrombosis. Only two studies [17, 18] have, to our knowledge, focussed on the circle of Willis, using time-of-flight sequences with presaturation slabs (selective MRA).

Our purpose was to determine prospectively whether both patency and the direction of flow could be determined merely by single nonselective three-dimensional TOF MRA sequences, by comparing it with cerebral angiography (CA).

Materials and methods

We studied 54 consecutive patients (24 female, 30 male), aged 13 to 71 years (mean 44), referred for pancerebral angiography. The final diagnoses are summarised in Table 1. All patients underwent MRA

Table 1. Final diagnosis in the 54 patients studied

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number</th>
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<tbody>
<tr>
<td>Intracranial aneurysm</td>
<td>13</td>
</tr>
<tr>
<td>Subarachnoid or intracerebral haemorrhage with normal angiography</td>
<td>8</td>
</tr>
<tr>
<td>Arteriovenous malformation</td>
<td>11</td>
</tr>
<tr>
<td>Ischaemic cerebrovascular disease</td>
<td>16</td>
</tr>
<tr>
<td>Midline tumour</td>
<td>5</td>
</tr>
<tr>
<td>Dural fistula</td>
<td>1</td>
</tr>
</tbody>
</table>
Fig. 1. A Axial MRA reconstruction illustrating the patency of an anterior communicating artery with a berry aneurysm; the signal intensity of the two pericallosal arteries is identical to that of the A1 segment of the right anterior cerebral artery, indicating a spontaneous blood supply from right to left, confirmed on right (b) and left (c) common carotid arterigrams.

Fig. 2. Anterior communicating artery considered as functional on MRA with blood flow from left to right because the A1 segment of the left anterior cerebral artery is missing, in a subject with a dissection of the right carotid artery.

Fig. 3. Identification of two patent posterior communicating arteries joining the intracranial carotid and posterior cerebral arteries.

Fig. 4. The two posterior communicating arteries have the same diameter and signal intensity of the P2 segment of the ipsilateral posterior cerebral artery. The invisibility of the P1 segments indicates that the posterior communicating arteries are functional, and that the direction of flow is from front to back.

Fig. 5. MRA displays no collateral flow between the carotid and basilar arteries around the circle of Willis. There is little or no flow in the three communicating arteries. No communicating artery was seen on angiography.

and CA within 3 days of each other: MRA was performed first in 28 cases, and CA in 26.

MR images were obtained on a 1.0 T system. Examinations were performed with a circularly polarised head coil operating in the transmitting-receiving mode.

Standard MRI was performed first. MRA was then performed, using the midsagittal slice as scoutview for positioning the volume to explore. The principles of TOF angiography have been described elsewhere [7, 8, 10-13]. Angiographic sequences were acquired in the axial plane, by means of three-dimensional (3D) acquisitions. Gradient-echo acquisitions with linear flow velocity compensation and gradient spoiling (3D FLASH) with TR/TE flip angle of 40/10 20° were employed. Other parameters were number of excitations 1, field of view 200-250 mm, matrix size 256 x 256, 32 slices with 1 mm effective thickness. In 15 patients, additional acquisitions with a sagittal (in 11) and/or coronal (in 10) presaturation slab were performed, to better understand flow patterns in the anterior and posterior communicating arteries, respectively. The slab was used to ensure a saturation of one carotid or basilar axis. To obtain angiogram-like images, reconstructions of the data sets were made using a maximum intensity projection (MIP) algorithm.

The mean time for one individual acquisition was 5.3 min, and approximately 5 min for reconstruction.

Transfemoral four-vessel CA was performed in all cases. In cerebro-occlusive disease, the tip of the catheter was placed proximal to the carotid bifurcation; the amount of contrast medium was 12 ml for each series and the injection rate 5 ml/s. In patients with aneurysms or arteriovenous malformations, the catheter tip was placed in the