Magnetic Resonance Angiography in Childhood Arterial Brain Infarcts
A Comparative Study With Contrast Angiography

Béatrice Husson, MD; Georges Rodesch, MD; Pierre Lasjaunias, MD, PhD; Marc Tardieu, MD, PhD; Guillaume Sébire, MD, PhD

Background and Purpose—Contrast angiography (CA) is the reference examination for the diagnosis of cerebral arterial abnormality, but this procedure is invasive. In childhood, ischemic strokes are being increasingly investigated by means of MRI, including MR angiography (MRA). Very few data are available about the accuracy of MRA compared with CA in the specific context of acute pediatric stroke. We sought to compare the results of MRA with those of CA for the study of cerebral arteries in children with arterial infarction in an arterial distribution.

Methods—Twenty-four children presenting with 26 infarcts were studied. All were examined with cerebral MRI and MRA and with CA. The interval between CA and MRA was <3 days for most of the patients.

Results—Arterial lesions were detected in all but 2 children. They were located in the major cerebral arteries, predominantly in the anterior circulation (85% of cases). All lesions shown by CA were present on MRA (19 cases). Patients with no lesion on MRA had normal CA (2 cases). Associated distal vascular lesions and degree of arterial stenosis were more accurately detected with CA.

Conclusions—MRA is sensitive enough to provide an adequate initial evaluation of arterial brain disease in childhood.

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Key Words: angiography ▪ child ▪ magnetic resonance angiography ▪ stroke

The incidence of strokes in children is approximately 8/100 000.1 In contrast to adulthood, etiologies are more protean. Treatment and prognosis depend on the specific underlying condition. Therefore, the exploration of the cerebral circulation is essential to determine the mechanism and the cause of stroke. However, the strategy of investigation remains open to discussion. Contrast angiography (CA) is the reference technique for the examination of brain vasculization, but the need for arterial catheterization, the injection of contrast agents, and the potential risk of embolus, although minimal, make this procedure invasive. In contrast, MR angiography (MRA) provides accurate images of the intracranial and cervical circulation less invasively.2–6 There is little information about the comparative value of MRA versus CA in childhood.7,8 In this study we compared MRA with CA in analyzing vascular lesions and underlying etiologies in childhood arterial ischemic strokes.

Subjects and Methods
We studied 24 children admitted consecutively for arterial ischemic strokes between 1995 and 1998. Twenty-two children had had 1 stroke, and the other 2 patients presented with a recurrence. Our patients met the following diagnostic criteria for infarction: (1) prolonged neurological deficit with sudden onset and (2) MRI showing brain parenchymal lesions corresponding to an arterial territory. We systematically performed MRA and CA in all patients with arterial infarcts in whom the indication for conventional cerebral angiography was not clear-cut. Thus, patients with conditions classically not requiring CA, namely, previously known cardiac thromboembolism or sickle cell disease, were not included in this study. Our study group consisted of 13 boys and 11 girls aged between 6 months and 14 years (mean, 7 years). Twenty-one patients were previously in good health. The 3 patients who had antecedents suffered from human immunodeficiency virus 1 infection (patient 1), autoimmune hepatitis (patient 2), and Down syndrome (patient 3). Twenty children had neuroradiological investigations within 10 days of presentation with the neurological deficit and 4 within the first month. The interval between CA and MRA was <3 days in 19 strokes, between 3 and 7 days in 5 strokes, and 2 or 4 weeks in the other 2 strokes.

To determine the accuracy of MRA in the analysis of large, medium, and small arteries, MRA and CA were interpreted by 2 investigators who were not aware of each other’s results. On the basis of CA data, the following terms were used to describe the various vascular lesions: occlusion was defined as a total obstruction of a vessel, focal stenosis as a short and regular narrowing of a vessel, severe stenosis as a succession of tight stenoses leading often to a “string of beads” appearance, irregular stenosis as nonocclusive...
segmental irregularities of the arterial wall, endoluminal defect as a segmental lack of blood flow, and ectasia as arterial enlargement.

CA was performed under general anesthesia by transfemoral selective catheterization of internal carotid arteries (ICA) and vertebral arteries after informed consent was obtained from the parents. We did not observe any complications. MRI and MRA were conducted with a 1.5-T Siemens Magnetom unit. Light sedation (sodium pentobarbital, 5 mg/kg, rectal administration) was required only for children younger than 6 years. MRI was performed with T1- and T2-weighted axial and coronal sequences. MRA of the intracranial circulation was performed with the use of a 3-dimensional time-of-flight fast imaging with steady state precession sequence with repetition time/echo time/flip angle = 35/6 ms, 20°, and axial volume with 50 slices 0.8 mm in thickness. Transfer of magnetization was used with a 256 × 256 matrix and field of view of 200 mm. The data sets were reconstructed with a maximum intensity projection algorithm. In addition, cervical MRA (5 patients) was performed with a 3-dimensional time-of-flight sequence with the use of multiple overlapping thin-slab acquisition when cervical trauma was suspected or when flow was not visualized in the ICA with MRA.

Results
The locations of parenchymal lesions and the etiologies of the 26 brain infarcts are listed in Table 1. In 18 cases (70%) the strokes involved only the territory of the middle cerebral artery (MCA). Ten patients (42%) had parenchymal lesions limited to the deep gray nuclei and internal capsule.

Detection of Arterial Lesions
The MRA and CA data for the large arteries were similar in the 26 strokes. These patients had either anomalies of the large cerebral arteries (anterior cerebral artery [ACA], MCA, posterior cerebral artery [PCA], ICA, and basilar artery; n = 24) or normal examinations (n = 2 [patients 11 and 12]). Two patients had anomalies involving all major vessels of the circle of Willis (patients 1 and 9). Nine had abnormalities involving the supraclinoid ICA (distal ICA) extending to the initial segment of the MCA (n = 9) and ACA (n = 5) (Figure 1). Nine children had focal lesions, located in the cervical ICA (n = 1), in the horizontal segment of the MCA (n = 5), in the initial segment of the PCA (n = 1), and in the basilar artery (n = 2). In 3 cases (patients 17, 20, 24) with a distal occlusion of a supraclinoid ICA, MRA as well as CA showed a severe decrease of flow in the cervical segment of the ICA (Figure 2).

For all 10 patients with parenchymal infarcts limited to the region of the deep gray nuclei, MRA gave the same result as CA in detecting the arterial lesions. Both techniques showed either focal anomalies of MCA (n=4; patients 7, 10, 22, 23), dissection of cervical ICA (n=1; patient 4), or extended lesions of ICA and MCA (n=3; patients 14, 18, 20). Two patients had normal MRA and CA.
In 9 children (34%) CA detected anomalies of small arteries not visible on MRA. These anomalies were located on distal MCA branches and were associated in all the patients with lesions of the horizontal portion of the MCA detected with MRA.

**Characterization of Arterial Lesions**
Among the 24 infarcts with intracranial or cervical vascular lesions, MRA and CA provided identical information in 18 cases (75%). Arteriographic occlusions, endoluminal defects (Figure 3), and multiple ectasia were diagnosed with MRA as well as CA.

In 6 cases (25%), MRA and CA were discordant (Table 2). In all of these cases arteriographic stenosis was overestimated with MRA. Irregular (patient 18) and focal stenosis (patient 22) appeared as severe stenosis on MRA. In 4 patients, a severe stenosis appeared as an occlusion on MRA (patients 13, 17, 21, 24).

The characteristics of arterial lesions studied by MRA were specific enough to pinpoint the common etiopathological conditions. Two of our 24 patients (8%) had moyamoya syndrome with bilateral ICA lesions and a basal neovascular network that was diagnosed by MRA as well as by CA. Dissection of the vertebral or cervical carotid arteries was detected in 2 patients (8%). For these 2 patients a pseudoaneurysm was present, one seen on CA and MRA at days 20 and 21, respectively, after the stroke (patient 5), the other detected...
by MRA performed 6 days after CA, which showed a severe stenosis of the cervical segment of an ICA (patient 4, Figure 4). Nineteen strokes (73%) remained idiopathic; 5 of the children had recently had chickenpox.

**Discussion**

In this series of 26 brain infarcts, MRA was concordant with CA in detecting defects in large cerebral vessels. We did not observe any false-positive result while investigating intracranial arterial lesions with MRA. However, there was some discordance between MRA and CA, mainly overestimation of stenosis and underdiagnosis of distal arterial lesions with MRA.

Some studies have already assessed the value of MRA for the visualization of the intracranial circulation in childhood. In a series of 31 pediatric brain infarcts confirmed by MRI, Zimmerman et al observed MRA anomalies in 62% of cases. Using MRA in a series of 24 children with parenchymal infarcts, Wiznitzer and Masaryk reported abnormalities in the corresponding arteries in 75% of cases. None of these studies compared CA and MRA. Lee et al performed such comparison, but the interval between the 2 explorations was not specified. In this series of 13 children with stroke, the authors showed that MRA was concordant with CA in 100% of cases for the localization of vascular lesions in large- to medium-caliber intracranial arteries. Rollins et al also compared MRA and CA and found that the positive predictive value of MRA for arteriopathy was 100%. MRA was as
TABLE 2. Comparison of CA and MRA for Discordant Cases

<table>
<thead>
<tr>
<th>Patient</th>
<th>CA</th>
<th>MRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Fusiform aneurysms of L distal ICA, L MCA, L ACA, irregular enlargement of both PCA, distal occlusion</td>
<td>No visualization of distal occlusion</td>
</tr>
<tr>
<td>4</td>
<td>Occlusion of R cervical ICA</td>
<td>Suspicion of dissecting pseudoaneurysm of R cervical ICA</td>
</tr>
<tr>
<td>13</td>
<td>Severe stenosis of L distal ICA, L MCA, and L ACA, distal occlusion</td>
<td>Occlusion of L distal ICA, L MCA, no visualization of distal occlusion</td>
</tr>
<tr>
<td>14</td>
<td>Irregular stenosis of R MCA, distal occlusion</td>
<td>No visualization of distal occlusion</td>
</tr>
<tr>
<td>15</td>
<td>Irregular stenosis of L distal ICA and L MCA, distal occlusion</td>
<td>No visualization of distal occlusion</td>
</tr>
<tr>
<td>16</td>
<td>Severe stenosis of R distal ICA, R MCA, and R ACA, distal occlusion</td>
<td>No visualization of distal occlusion</td>
</tr>
<tr>
<td>17</td>
<td>Severe stenosis of R distal ICA and R MCA</td>
<td>Occlusion of R MCA, signal void of flow in extracranial ICA</td>
</tr>
<tr>
<td>18</td>
<td>Irregular stenosis of L distal ICA, L MCA, and L ACA, distal emboli</td>
<td>Severe stenosis of L MCA, signal void of distal emboli</td>
</tr>
<tr>
<td>19</td>
<td>Severe stenosis of R distal ICA and R MCA, distal occlusion</td>
<td>No visualization of distal occlusion</td>
</tr>
<tr>
<td>20</td>
<td>Occlusion of L distal ICA, L MCA, irregular stenosis of L ACA</td>
<td>Signal void of flow in extracranial ICA</td>
</tr>
<tr>
<td>21</td>
<td>Severe stenosis of L distal ICA and L MCA, distal occlusion</td>
<td>Occlusion of L MCA, no visualization of distal occlusion</td>
</tr>
<tr>
<td>22</td>
<td>Focal stenosis of R MCA</td>
<td>Severe stenosis of R MCA</td>
</tr>
<tr>
<td>24</td>
<td>Occlusion of L distal ICA, focal stenosis of L MCA and L ACA</td>
<td>Occlusion of L MCA and L ACA, signal void of flow in extracranial ICA</td>
</tr>
</tbody>
</table>

L indicates left; R, right.

reliable as CA in the detection of stenotic or occlusive diseases of the ICA and MCA. Our findings confirm an excellent correlation between CA and MRA for the detection and location of intracerebral arterial lesions, although the characterization of the type of lesion remains somewhat limited with MRA (circumferential clefts, intimal flaps, intraluminal thrombi, or tapering of MCA branches). As previously shown, in several series of strokes in childhood investigated with CA, the most common sites of arterial disease are the distal ICA or the proximal MCA. In our series, the same locations were observed in 74% of the cases. The study of Rollins et al16 of distal ICA lesions raised doubts concerning the precision of MRA compared with CA. This suspected limitation is apparently due to a well-recognized artifact caused by signal loss in a large vessel in regions of complex flow such as the internal carotid siphon or the bifurcation of the common and internal carotid arteries. The use of 3-dimensional time-of-flight sequences with thin slices (<1 mm) and a 512 matrix to decrease voxels, combined with analysis of the source images, enables differentiation between an artifact and a vascular lesion. Taking into account these technical considerations, we improved the images in our patients, leading to the elimination of any discordant results by MRA compared with CA in exploring the distal ICA.

Ten children of our series (42%) had infarcts limited to the basal ganglia. Brower et al13 described the characteristics of this entity, which is a frequent association with arterial stroke in childhood. In our study both MRA and CA showed the same lesions in this subgroup. It is therefore inerable that MRA is comparable to CA in detecting one of the most frequent intracranial arterial lesions associated with stroke in children. Furthermore, MRA was as efficient as CA in detecting the main etiologies of arterial diseases of the brain in childhood, particularly moyamoya, extracranial dissection, and idiopathic arteriopathy, such as transient cerebral arteriopathy.10 These data are in agreement with several studies reporting the usefulness of MRA in the diagnosis of cervical dissection, although confident diagnosis or exclusion may require CA.17 Likewise, Yamada et al11 reported accurate diagnosis and evaluation of moyamoya by MRA. CA was reserved for cases in which surgical revascularization was planned. However, in particular cases, such as intracranial dissection, the spatial resolution of MRA, which is inferior to CA, can lead to an imprecise description of the nature of the lesion. Furthermore, the extent of collateral flow via leptomeningeal anastomoses cannot be judged by MRA.

Other pitfalls, limitations, and technical points must be considered when MRA is used. In 3 patients from our series, a signal void on the cervical ICA proximal to a severe intracranial lesion raised some difficulties concerning the precise diagnosis. It is known that slow blood flow is difficult to visualize with a 3-dimensional time-of-flight sequence. In situations in which the underlying mechanism is doubtful, such as slow blood flow proximal to a distal stenosis or an intraluminal defect, a Doppler examination of the cervical vessels may resolve the diagnostic problem. If this sonographic exploration fails, CA should be considered. Another known limitation of MRA is its lack of sensitivity in the detection of small-vessel diseases. Some authors have noted the utility of the technique of magnetization transfer with increased signal-to-noise ratio, which improves small-vessel detection. Additionally, the use of intravenous paramagnetic contrast to increase the signal of blood in vessels may allow better definition of small vessels. Furthermore, the sensitivity of MRA may be enhanced when a 512 matrix is used. However, the indication for investigation of the small cerebral vessels in children is restricted to a small fraction of patients because most ischemic strokes in childhood are related to lesions involving large arteries. CA is indicated for the investigation of lesions distal to small vessels, for instance, to make the distinction between embolic disease and inflammatory processes, such as isolated angiitis of the central nervous system. Another widely noted limitation of MRA is the overestimation of stenosis, observed in 25% of our patients. A precise quantification of
stenosis, for instance, in carotid artery lesions, is important in adulthood in making therapeutic decisions. In childhood, such quantification currently seems to be less important since the degree of stenosis is not recognized as a determinant parameter in therapeutic decisions.

In conclusion, within the diagnostic framework we studied, MRA is sensitive enough to provide an adequate and most often sufficient evaluation in the initial stage of arterial brain diseases in childhood. However, CA should be considered in situations in which MRA is normal, small-artery diseases are suspected, or uncertainties about the differential diagnosis of ICA lesions persist and for an accurate assessment of the effect of therapeutic trials on the arterial wall.

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References
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