Poststenotic signal attenuation on 3D phase-contrast MR angiography: a useful finding in haemodynamically significant carotid artery stenosis

Abstract We performed blinded visual evaluation of MR angiography (MRA) films in 44 patients with unilateral carotid artery stenosis to determine whether a flow gap and poststenotic signal attenuation on 3D-PC MRA were useful signs of severe carotid artery stenosis. Although nine patients with a flow gap alone had various degrees of stenosis ranging from 22.2% to 77.3% without any decrease in regional cerebral blood flow (rCBF), 13 patients with both a flow gap and poststenotic signal attenuation had severe stenoses of 80% or more, with a definite decrease in baseline rCBF. The presence of both a flow gap and poststenotic signal attenuation on 3D-PC MRA appeared to be a reliable marker of severe carotid artery stenosis with a decrease in rCBF.

Key words Artery, carotid, stenosis • Angiography, intra-arterial • Angiography, magnetic resonance • Single-photon emission computed tomography

Introduction

Two-dimensional time-of-flight (2D-TOF) MR angiography (MRA) has been shown to be a useful for non-invasive detection of atherosclerotic narrowing of the common carotid artery bifurcation (CCB) because of its excellent sensitivity to slow flow. Complete loss of signal in the area of stenosis, i.e., a flow gap, is a reliable marker of stenosis of 60% or more [1–4]. However, because of the small field of view, 2D-TOF MRA cannot show other significant vascular pathology which might influence the decision to perform endarterectomy, such as tandem stenotic lesions.

We have used three-dimensional phase-contrast (3D-PC) MRA to examine both the CCB and intracranial circulation for pathology [5]. In the Japanese, because of the higher level of the CCB and the lower shoulders, a conventional head coil usually extends caudally enough to show the CCB. Therefore, using a single conventional head coil, with a short acquisition time, we can acquire MRA which will show the entire arterial system of the head and neck. This sequence can be used to detect not only a flow gap but also poststenotic signal attenuation in the extracranial internal carotid artery (ICA).

Our purpose was to determine whether a flow gap and poststenotic signal attenuation on 3D-PC MRA are useful signs of severe carotid stenosis and of use for identifying potential candidates for carotid endarterectomy.

Patients and methods

We reviewed 54 patients who underwent both 3D-PC MRA and intra-arterial digital subtraction angiography (DSA) on the suspicion of occlusive CCB disease. We excluded 10 because of ipsilateral CCB occlusion or bilateral CCB disease. In the first 2 years, after ethics committee approval and obtaining informed consent from the patients, we performed DSA on all patients who had definite signal attenuation at the CCB on MRA to confirm its clinical
significance and to decide whether to give antiplatelet therapy. We recommended endarterectomy to symptomatic patients when di-

meter stenosis was more than 70% or when angiography disclosed an irregular arterial lumen or ulceration. Antiplatelet therapy given to patients with CCB stenosis of more than 50% regardless of the presence of symptoms. The mean age was 68.4 years (range 36–83 years); there were 37 men and seven women, only 19 of whom were symptomatic; seven had a minor stroke, two amaurosis fugax and ten had hemisphere transient ischaemic attacks. In most cases, MRA was followed by DSA, although emergency DSA preceded MRA in cases of progressing stroke. The mean interval between MRA and DSA was 3.4 days (range 0–10 days). Single-photon emission computed tomography (SPECT) using 99mTc-N, N’-(1,2-

ethylenediyl) bis-L-cystein diethylester (99mTc-ECD) was per-

formed in 33 patients. The interval between SPECT and DSA ran-

ged from 0 to 7 days (mean 4.2 days).

MRA was performed on a 1.5 Tesla system with a commercially available head coil which extends caudally enough to show the CCB. Imaging parameters were repetition time (TR) 23 ms, echo time (TE) 9 ms, flip angle 20°, 25 cm field of view and 128×256 matrix. Slab thickness was 5.75 cm, which gave an effective section thickness of 1.25 mm. Velocity encoding was 30 cm/s. All MRA films were reviewed for a flow gap and poststenotic signal at-
tenuation by four neuroradiologists, blinded to the results of DSA and SPECT. A flow gap was recorded if a segment of the vessel was completely free of signal, with reappearance of signal distally, and poststenotic signal attenuation if the signal of the ipsilateral extra-

cranial ICA was definitely less than that of the contralateral extra-

cranial ICA. For confirmation of signal attenuation, the density of extracranial ICA on the MRA films were measured with a densi-
tometer; the area measured was 0.5°, the density range 0.00–4.00. Signal change in the extracranial ICA was estimated by a laterality index (LI), calculated as De/Di × 100 (%), where Di is the density of the ipsilateral straight portion of the ICA 3–4 cm above the CCB and Dc the density of the corresponding con-

tralateral portion.

In each DSA examination, we determined the image and viewing angle which best demonstrated the stenosis and measured the point of maximum narrowing at the carotid bifurcation directly from the angiogram, using mechanical Vernier-scale calipers, reading to 0.02 mm. The percentage diameter stenosis was calcu-

lated using the method employed by the North American Sym-

tomatic Carotid Endarterectomy (NASCET) [6, 7] and Asympto-
matic Carotid Atherosclerosis Study (ACAS) trials [8]: the di-

ameter of the stenosis on the view depicting the most severe nar-

rowing was compared to the diameter of the ICA beyond the bulb, where the vessel walls return to being parallel. When angiograms demonstrated reduction in the size of the distal ICA due to severe proximal stenosis, the narrowing was graded 5% by the NAS-

CET/ACAS convention.

SPECT was performed at a midscan time of 40 min after in-

travenous infusion of 20 mCi 99mTc-ECD, using dual-head gamma

camera with high resolution collimators (FWHM = 11 mm). Acquisition was in 64 steps through 360°, with a 128×128 matrix. Axial, sagittal and coronal images were reconstructed by filtered back-projection using both Butterworth and Ramp filters (cutoff frequency 0.45 cycle/cm) with attenuation correction (Sorensen 0.11 cm⁻¹). Regions of interest (ROI) were placed on the cerebral cortex (40 × 60 mm) in the middle cerebral artery (MCA) territory, avoiding any infarct seen on CT. Lassen’s linearisation correction algorithm for 99mTc-hexamethylpropyleneamine oxime [9, 10] was applied for backdiffusion correction for 99mTc-ECD. rCBF change was estimated by an asymmetry index (AI) [11, 12], calculat-

ed as Ca/Cb × 100 (%), where Ca is the mean reconstructed count for the ipsilateral ischaemic area and Cb the mean re-

constructed count for the corresponding contralateral area. Data were analysed using the Statview Macintosh program.

Results

The clinical and radiological characteristics of the 44 patients with unilateral CCB stenosis are shown in Table 1. The 13 patients with poststenotic signal atten-

uation on 3D-PC MRA had a mean LI of 38.4 ± 12.5% (maximum 60.2%), whereas the 31 pa-

tients with no poststenotic signal attenuation had a mean LI of 92.7 ± 8.4% (minimum 75.6%) (P < 0.0001). Visual identification of signal attenuation was con-

firmed by the LI. All 13 patients with poststenotic signal attenuation in the extracranial ICA had flow gap at the CCB.

The patients were classified into three groups: group I: 13 patients with both a flow gap and post-

stenotic signal attenuation; group II: nine patients with a flow gap alone; group III: 22 patients with neither. All patients in group I had severe stenoses measuring 80% or more (mean 92.3 ± 6.1). Those in group II had sten-

osis ranging from 22.2 to 77.3%; five with stenoses less than 60% had pocket formation due to ulcers on DSA. The mean percentage stenosis in group III was 35.1 ± 18.2% (range 10.0–67.0%). The degree of sten-

osis in group I was greater than in groups II or III (P < 0.0001). All patients in group I had no collateral flow via the anterior or posterior communicating artery and a lower baseline rCBF in the ipsilateral MCA terri-

tory than in the corresponding contralateral area. The mean AI in group I (84.3 ± 5.3%) was significantly less than in group II (99.38 ± 3.5%) or group III (98.9 ± 0.3%) (P < 0.0001). There was no significant difference in mean AI between groups II (99.38 ± 3.5%) and III (98.9 ± 0.3%), (P = 0.064). Ten patients in group I (76.9%), six patients in group II (66.7%) and three patients of group III (13.6%) were symptomatic. Illustrative cases are shown in Figs. 1 and 2.

Discussion

Masaryk and Obuchowski [13] argued that the goals of carotid artery imaging should be accurate quantification of the degree of stenosis, differentiation of severe ste-

nosis from occlusion, and detection of associated ab-

normalities, such as tandem lesions, which may affect the surgical procedure. Although selective carotid an-

giography accomplishes all of these anatomical goals, it has a small but definite risk of stroke [8, 14–16]. In Ja-

pan, because of the widespread availability of MR im-

agers, which are less operator-dependent than sonog-

raphy and do not need contrast medium, unlike CT an-

giography, MRA is the modality most widely used for