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MR Imaging in Moyamoya Disease*: Utility of Partial Flip Angle T2-weighted Spin-Echo Imaging

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— **Abstract** —

In order to assess the utility of partial flip angle (PFA) spin-echo (SE) imaging in moyamoya disease, the authors compared conventional long TR axial images (SE 2500/30,80/1) with and without flow compensation (FC) and PFA SE axial images (1200-1300/30, 80/1-2) with a flip angle of 45° in 8 patients of angiographically- proven moyamoya disease. In all 8 patients the multiple collateral vessels were demonstrated better as signal voids on both PFA SE and conventional images without FC, whereas they were much less conspicuous on the conventional images with FC. This is thought to be secondary to refocusing of the signal from the collateral vessels of slow flow by FC. The flow artifacts frequently seen on conventional images without FC were reduced on PFA SE images with 2 excitations. Total imaging time, contrast characteristics, and image quality of the PFA SE were comparable with those of conventional images. In conclusion, PFA SE imaging proved to be useful in the evaluation of moyamoya disease, demonstrating the collateral vessels better and reducing flow- related artifacts.

Index Words: Cerebral blood vessels, MR studies 17.1214.
Cerebral blood vessels, Stenosis 17.72134
Carotid arteries, Stenosis 172.72134

Introduction

MR diagnosis of moyamoya disease has relied on observation of the signal void collateral vessels in the basal ganglia as well as of the narrowing or occlusion of the intracranial internal carotid artery (ICA) (1-6). Vascular abnormalities are not always demonstrated on routine MR images, however (1-2). With implementation of flow-compensation (FC) techniques, such as gradient moment nulling for routine brain imaging, some or all of the collateral vessels have not been detected as a signal void on conventional long TR spin-echo (SE) images, often making a correct diagnosis of moyamoya disease difficult. Without FC, the collateral vessels have been much better depicted, but significant flow artifacts were produced.

Many investigators have suggested that partial flip angle (PFA) double-echo SE imaging has some advantages over conventional long TR SE imaging, including reduction of the imaging time and suppression of flow artifacts (7-12). In this study, we evaluated the utility of PFA SE imaging in moyamoya disease to determine if it can be used as an alternative to conventional long TR SE imaging.

Materials and Methods

Eight patients with angiographically-proven moyamoya disease were studied with MR imaging. Five male and 3 female patients were 3 to 43 years old (mean, 16.3 years). MR imaging was performed on a 2.0T superconducting unit (Spectro-20000,

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Goldstar, Seoul, Korea) with multi-slice SE sequences in all patients. T1-weighted images were obtained in a sagittal plane in all patients, covering the middle two-thirds of the brain from the right sylvian fissure through the left one. Three kinds of proton density- and T2-weighted images using dual echoes were obtained in an axial plane in all patients; the conventional long TR images with using FC, followed by those without using FC, and PFA SE images without FC within 2 days. The imaging parameter were 500-600/30/2 (TR/TE/number of excitation) for T1-weighted images and 2500/30, 80/1 for conventional proton-density- and T2-weighted images in all patients, while they were 1200-1300/3, 80/1-2 with a flip angle of 45° for PFA SE images (1 excitation in 3 and 2 excitations in the remaining 5 patients). The other imaging parameters were the same in each sequence of all patients. The slice thickness was 5mm with an interslice gap of 2mm. The acquisition matrix varied from 180×256 to 256×256. The MR images of each patient were comparatively evaluated side by side in terms of ability to demonstrate vascular narrowing and collateral vessels, contrast for normal structures vs lesions, and absence or presence of significant flow artifacts.

Results

Narrowing or occlusion of the intracranial ICAs and proximal middle cerebral arteries (MCA), noted in all patients, were equally well visualized on all 3 kinds of axial images, although a PFA SE image with single excitation revealed poor image quality (Fig. 1). The multiple signal void collateral vessels were well visualized on the conventional long TR images without FC and on the PFA SE images, but they were much less conspicuous on the conventional long TR images with FC in each of the 8 patients (Fig. 2,3,4). In 6 patients the collateral vessels were not identified in 1 or more areas on the images with FC. Most of the collateral vessels appeared isointense, slightly hypointense or rather hyperintense relative to the brain parenchyma on the conventional long TR images with FC (Fig. 2,3), unlike those seen as a signal void on the images without FC and PFA SE images.

The contrast for normal structures vs lesions such as ischemic infarct or hemorrhage appeared almost identical among the 3 kinds of axial images in all patients (Fig. 3).

Significant flow artifacts were demonstrated in the

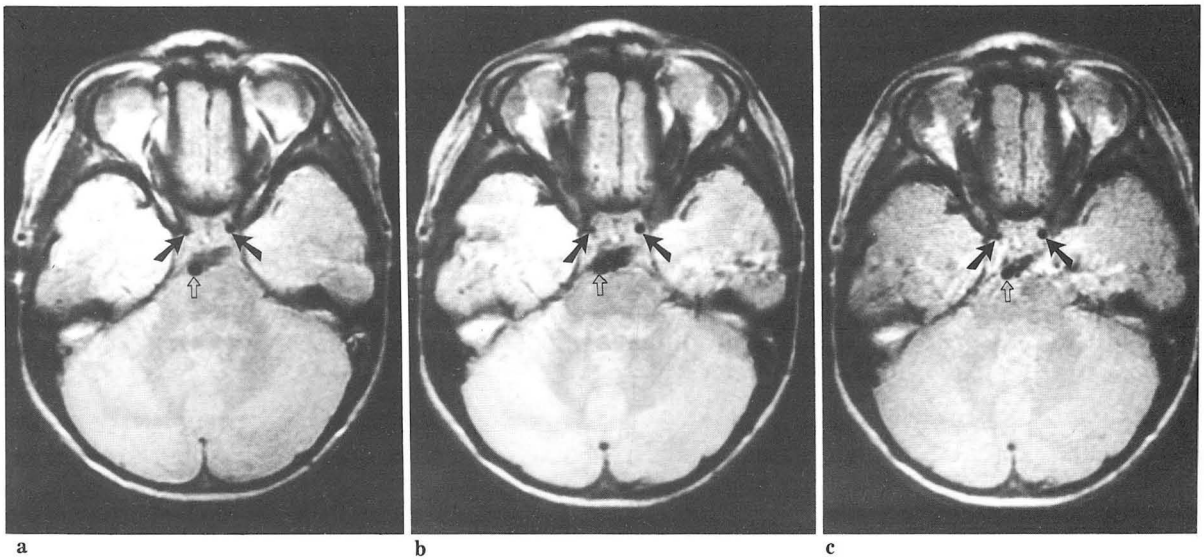
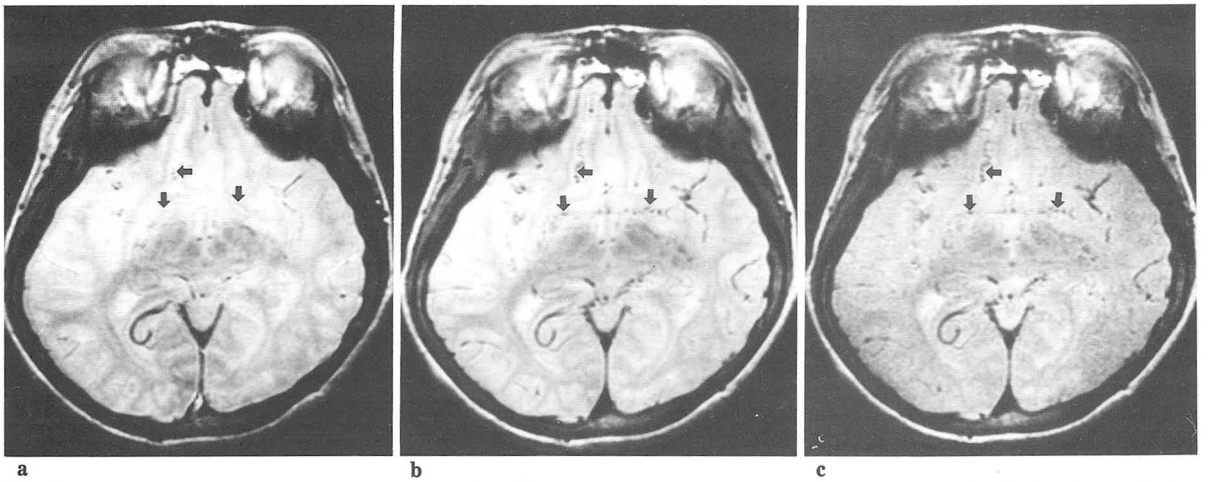


Fig. 1. Axial images of 3-year-old girl with moyamoya disease. The conventional images (2500/30/1) with (a) and without flow compensation (b), and partial flip angle spin echo (PFA SE) image (1200/30/1) with flip angle of 45° (c) all demonstrate narrowing of both internal carotid arteries well (arrows) compared with the basilar artery (open arrow), although PFA SE shows poorer image quality, due to lower SNR. Imaging time of c is approximately half a and b.

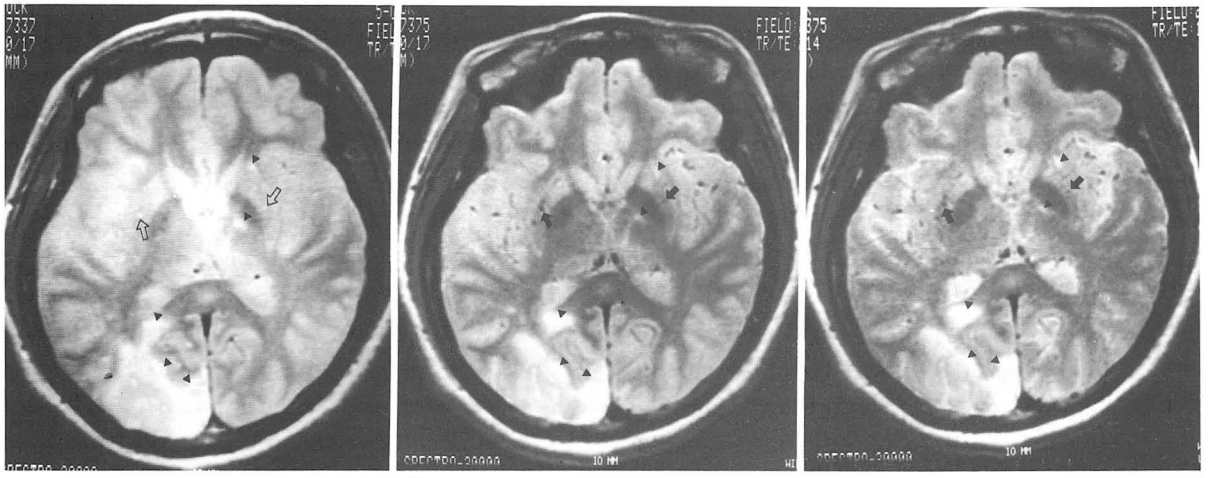
temporal lobes, basal ganglia, and/or brain stem in 7 out of 8 patinets on the images without FC, even though they did not prevent from making correct diagnosis of moyamoya disease, while they were not seen on the images with FC in any patient (Fig. 4). On the PFA SE images, significant flow artifacts were demonstrated only in the 3 patients, in whom the images were obtained with single excitation (Fig. 1).

Although the signal void of vascular abnormalities and the contrast characteristics identical to conventional images were preserved with the PFA SE images, regardless of the number of excitations, there was a considerable sacrifice of image quality with



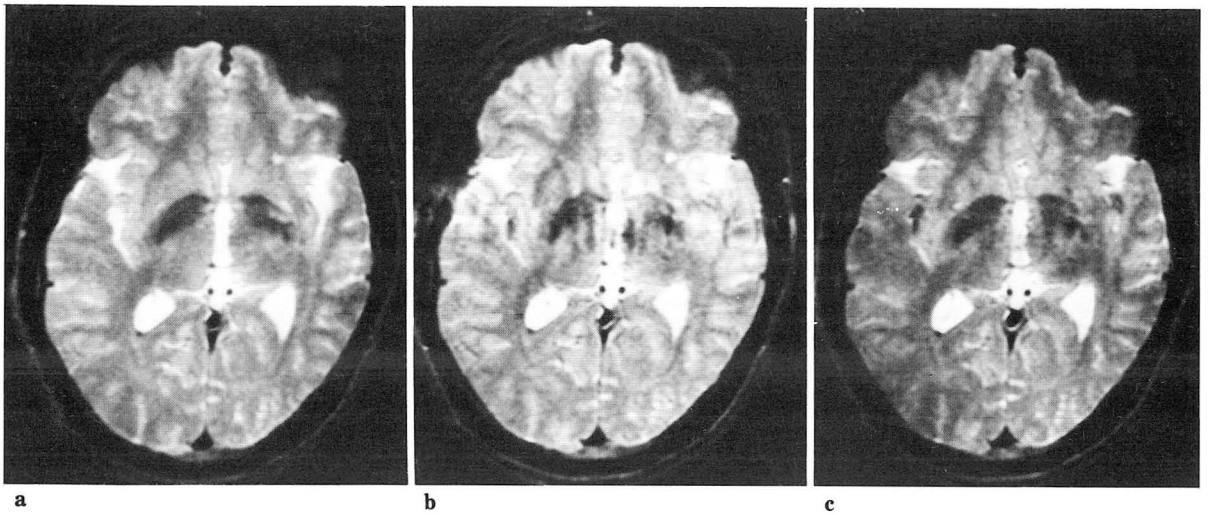
a b c

Fig. 2. Axial MR images of a 17-year-old male with moyamoya disease. Multiple signal void collateral vessels (arrows) are well visualized on the conventional image (2500/30/1) without flow compensation (FC) (b) and partial flip angle (PFA) spin echo (SE) image (1300/30/1) with flip angle of 45° (c), but not conspicuous on the conventional image (SE 2500/30/1) with FC (a). The image quality of PFA SE image is poorer than the others, because of lower SNR secondary to small flip angle and shorter imaging time.



a b c

Fig. 3. Conventional images (2500/30/1) with (a) and without using flow compensation (FC) (b) and partial flip angle (PFA) SE images (1300/30/2) (c) of a 35-year-old woman with moyamoya disease. Multiple collateral vessels in the basal ganglia (arrows in b, c) are well seen as signal void on the conventional images without using FC and PFA SE images, whereas they are less conspicuous and appear isointense or hyperintense (open arrows in a) on the conventional images with using FC, secondary to refocussing of the signals from slow flow. Note multiple ischemic infarcts of high intensity in the left basal ganglia and right occipital lobe (arrowheads) demonstrating almost identical contrast on all images of three kinds. The image quality of PFA SE image with two excitations is nearly comparable with the conventional images.



a b c

Fig. 4. T2-weighted axial images of a 15-year-old male with moyamoya disease. The conventional images (2500/80/1) with flow compensation (FC) (a) and partial flip angle spin echo images (1300/80/2) with 45° flip angle (c) reveal little flow artifacts, whereas the conventional image (2500/80/1) without FC (b) shows significant flow artifacts in temporal lobes and basal ganglia.

PFA SE imaging with single excitation due to low-signal-to-noise ratio (SNR) (Fig. 1,2). However, the image quality of the PFA SE images with 2 excitations, which represents an imaging time almost identical to conventional long TR imaging, was comparable with that of conventional images, even though the PFA SE images appeared slightly coarser (Fig. 3,4).

On the T1-weighted sagittal images, narrowing or occlusion of the ICA and MCA could hardly be identified in all the patients. Signal void collateral vessels were demonstrated in the basal ganglia, around the lateral ventricle, and around ambient or quadrigeminal cisterns in only 5 patients.

Discussion

Moyamoya disease is a rare cerebrovascular disease of unknown etiology consisting of a progressive nar rowing or occlusion of the supraclinoid portion of the ICA and proximal portions of the anterior cerebral artery and MCA in association with extensive parenchymal, transdural, and leptomeningeal collateral vessels, most often reported from Japan (13, 14). Because of its ability to demonstrate arterial blood flow as a signal void, MR imaging is capable of detecting abnormal vascularities, including narrowing of the ICA and MCA, and collateral vessels that are suggestive of moyamoya disease (1, 2).

Currently, FC software has been almost routinely implemented in cranial MR imaging for reducing flow artifacts. However, imaging with FC has some draw backs, including suppression of the signal void from slowly flowing blood such as cortical veins or from CSF passing through an aqueduct (15, 16). On the angiography of the present cases, many of the collateral vessels proved to have a slow flow, persisting up to the venous phase. Isointensity or hyperintensity of the collateral vessels seen on the images with FC in the present study is considered to be mainly due to the signals refocused by FC. Increased intravascular signals can also be secondary to flow-related enhancement, diastolic pseudogating, and even-echo rephasing (5,15,16). But these are not believed to contribute to the increased signals of the collateral vessels on the images with FC, because both the first and asymmetric second echo images without FC well demonstrated the collateral vessels as a signal void in the same patients. The present study indicated that axial conventional long TR images without FC and PFA SE images are better than conventional long TR images with FC and sagittal T1-weighted images in demonstrating vascular abnormalities.

PFA double-echo SE imaging with shorter TR and a smaller flip angle has been reported to permit im-

age contrast characteristics identical to those obtained with conventional SE imaging with long TR, as well as reduction in imaging time and suppression of flow artifacts at the expense of SNR (7-12). In the PFA SE imaging of the present study, we used a TR of 1200 to 1300 msec and a flip angle of 45° for reducing SNR sacrifice and obtaining enough slice numbers for axial scanning in one acquisition. The PFA SE images with single excitation obtained in 3 patients permitted a shorter imaging time (approximately one-half of the conventional imaging) and good demonstration of signal void collaterals but revealed poor image quality due to low SNR, as we expected. PFA SE imaging with 2 excitation numbers, however, which represnets almost the same imaging time as that of convention imaging, demonstrated an image quality comparable with conventional images. The advantage of PFA SE imaging in the present study was that it was nearly identical to conventional imaging without FC in demonstrating the collateral vessels and the contrast characteristics, and if the 2-excitation is used, it is comparable to conventional imaging with FC in image quality and in reducing the flow artifacts, although PFA SE images appeared slightly coarser than conventional images.

The exact mechanism of suppression of the flow artifacts in PFA SE imaging remains uncertain. Both relatively short TR (compared with conventional long TR imaging) and 2 excitations seem to contribute mainly to the suppression of flow artifacts in PFA SE imaging. The flow artifacts regarded as "noise" can be suppressed with an increase of the excitation number since SNR increases by the square root of the excitation number (12). Our results suggest that double-echo PFA SE imaging without flow-compensating gradients may be useful as either a primary or an auxiliary technique in patients suspected of moyamoya disease.

T1-weighted sagittal images, of course, can demonstrate the collateral vessels, but they have a limitation in convering the whole brain and in demonstrating ICA and MCA abnormalities, as in the present series. An axial or coronal T1-weighted sequence may better visualize ICA and MCA abnormalities and the collateral vessels with thin-slice thickness, but the whole brain is not included in the 1-acquisition imaging. T1-weighted images (axial, sagittal or coronal images) are necessary mainly for the evaluation of possible hemorrhage of the subacute stage.

In summary, the collateral vessels were much less conspicuous with conventional long TR images with FC, while the flow artifacts were frequently seen with those without FC. PFA SE imaging (1200-1300/30, 80/2/45°) proved to demonstrate the collateral vessels well and to reduce the flow artifacts, which suggests that PFA SE imaging can be used as an alternative to conventional long TR imaging in patients suspected of having moyamoya disease.

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〈국문요약〉

모야모야병의 자기공명영상 : Partial flip angle T2 강조 스핀에코 영상의 유용성

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모야모야병에서 경동맥 협착에 의해 부측 순환 혈관(collateral vessels)인 소위 "모야모야" 혈관은 뇌 기저부 혹은 기저핵 부위에 경동맥 협착 소견과 함께 자기공명(MR)영상에서 signal void로 잘 나타나며, 이러한 소견은 모야모야병의 특이적 소견으로 알려져 있다. 그러나 최근의 대부분의 MR 장치에는 flow artifact 를 보정하는 flow compensation(FC)의 software를 내장하여 T2 강조영상을 얻기 때문에 모야모야 혈관, 피질정맥(cortical vein), 수도관(aqueduct)의 CSF 등과 같이 속도가 낮은 flow는 T2 강조영상에서 signal void로 나타나지 않는 단점 때문에 모야모야병의 MR진단에 어려움이 있는 경우가 적지 않다.

저자들은 혈관조영술로 확진된 8례의 모야모야병 환자를 대상으로 새로운 영상기법의 하나인 partial flip angle(PFA) T2 강조 스핀에코(SE) 영상이 flow artifact를 줄이면서도 모야모야 혈관을 잘 나타낼 수 있는지의 여부를 알기 위하여, 각각의 환자에서 PFA SE기법을 포함한 3가지 SE 영상의 유용성을 평가하였다. 3가지 영상기법은 2.0T 장치하에서 ① PFA T2 강조 SE 영상(1200−1300/30, 80, flip angle 45°) ② FC를 이용하지 않은 재래식 T2 강조영상(2500/30, 80), ③ FC를 이용한 T2 강조 SE 영상(2500/30, 80) 이었다. 그 결과, PFA SE 영상에서는 FC를 이용하지 않은 재래식 T2 강조영상에서와 같이 모야모야 혈관이 signal void로 나타났으며, flow artifact면에서는 FC를 이용한 T2 강조 SE 영상에서와 같이 flow artifact가 거의 나타나지 않았다. 영상시간, 영상의 대조도는 3가지 방법이 모두 비슷하였고, 영상의 질은 PFA SE 영상이 재래식 영상에 비해 약간 떨어졌으나 진단에는 지장을 주지 않을 정도였다. 따라서 PFA SE기법은 모야모야 혈관을 잘 나타낼 뿐만아니라 flow artifact도 감소시키는 장점이 있기 때문에 모야모야병의 MR진단에 T2 강조영상 대신에 이용될 수 있는 가치가 있다고 사료된다.