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MR Signal Intensity of the Optic Radiation

Mika Kitajima, Yukunori Korogi, Mutsumasa Takahashi, and Komyo Eto

PURPOSE: To determine whether a hyperintense layer adjacent to the lateral ventricle on T2-weighted MR images represents the optic radiation. **METHODS:** We reviewed 11 brain specimens from patients with nonneurologic diseases and MR images from 43 healthy volunteers. The MR images in a patient with cerebral infarction involving the lateral geniculate body were also reviewed to evaluate wallerian degeneration of the optic radiation. **RESULTS:** The external sagittal stratum, composed of the optic radiation, showed a pale layer in specimens stained by Bodian's method. On high-power microscopic views of the specimens, the axons of the external sagittal stratum were large and separated by wide translucent spaces. In the volunteers, the external sagittal stratum appeared hyperintense on T2-weighted MR images and hypointense on T1-weighted images. The MR images in a patient with cerebral infarction showed hyperintensity within the layer corresponding to the external sagittal stratum. **CONCLUSIONS:** The hyperintense layer on T2-weighted images represents the external sagittal stratum, or optic radiation. The signal intensity of the external sagittal stratum reflects histologic characteristics of low axonal density.

Index terms: Brain, anatomy; Brain, magnetic resonance

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The optic radiation occupies almost the entirety of the external sagittal stratum. It begins at the lateral geniculate body, passes through the temporal and parietal lobes, and terminates in the calcarine area. Many pathologic conditions involve the optic radiation and cause various abnormalities of the visual field. It has been reported that a thin hypointense layer on T2-weighted magnetic resonance (MR) images represents the optic radiation (1).

We noted a discrete layer that appeared hypointense on T1-weighted images and hyperintense on T2-weighted images; therefore, we undertook this study to determine whether this thin hyperintense layer represents fibers of the optic radiation. To address this issue, we compared MR images of the optic radiation in healthy control subjects with pathologic specimens of corresponding regions of the brain.

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Materials and Methods

Eleven brain specimens from patients with nonneurologic diseases (seven women and four men; mean age, 73 years; range, 57 to 88 years) were evaluated. Coronal sections were prepared at the level between the trigone and posterior horn of the lateral ventricle. Specimens were stained by the Klüver-Barrera method for the myelin sheaths and Bodian's method for the axons. The optic radiation was defined as the external sagittal stratum (2). The degree of staining of the tapetum, internal sagittal stratum, external sagittal stratum, and adjacent white matter was assessed with the unaided eye or with low-power microscopy in both stained specimens. With specimens stained with Bodian's method, the thickness of the external sagittal stratum and the distance from the wall of the lateral ventricle to the medial border of the external sagittal stratum was measured on the low-power photomicrographs. In three patients, the caliber and density of the axons and density of the myelin were assessed for the four layers described above with high-power magnification. The histologic findings were evaluated by a neuropathologist.

The brains of 43 healthy volunteers (36 men and 7 women; mean age, 58 years; range, 39 to 75 years) were

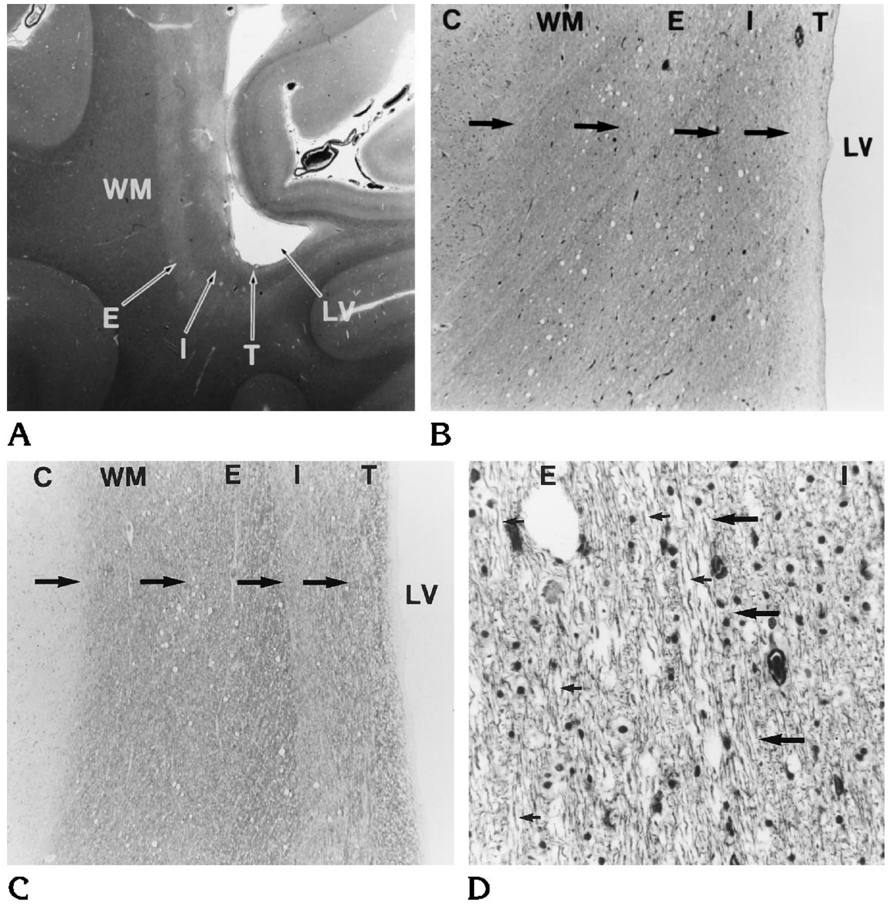

Fig 1. Coronal sections of the brain from a patient with a nonneurologic disease at the level of the posterior trigone.

A, Tapetum (*T*), internal sagittal stratum (*I*), external sagittal stratum (*E*), and adjacent white matter (*WM*) are clearly seen as four layers parallel to the wall of the lateral ventricle (*LV*) (Bodian's method, original magnification ×4).

B, The external sagittal stratum (*E*) is recognized as the pale layer demarcated medially and laterally by the strongly stained internal sagittal stratum (*I*) and adjacent white matter (*WM*). *C* indicates occipital cortex; *T*, tapetum; *LV*, lateral ventricle; and *arrows*, borders between each structure (Bodian's method, original magnification ×20).

C, The external sagittal stratum (*E*) is more strongly stained than the internal sagittal stratum (*I*). *C* indicates occipital cortex; *T*, tapetum; *LV*, lateral ventricle; and *arrows*, borders between each structure (Klüver-Barrera method, original magnification ×20).

D, High-power photomicrograph of the specimen shows that the axons of the external sagittal stratum (*E*) are large and separated by wide translucent spaces. *I* indicates internal sagittal stratum; *large arrows*, borders between the external sagittal stratum and the internal sagittal stratum; and *small arrows*, wide translucent spaces (Bodian's method, original magnification ×200).

examined with a 1.5-T MR unit. Coronal T1-weighted MR images were obtained using a spin-echo sequence with parameters of 550/13/2 (repetition time/echo time/excitations), and T2-weighted images were obtained with 2500/80/1. The section thickness was 6 mm, with a 1.2-mm intersection gap. The field of view was 25 cm, and the matrix size was 256 × 256. The findings on MR images of both hemispheres at the level between the trigone and posterior horn of the lateral ventricle were evaluated consensually by two radiologists, with emphasis on the signal intensity of the optic radiation and adjacent structures. The distance of the optic radiation from the lateral ventricle was also assessed.

The MR images obtained from a 50-year-old man who had left hemiplegia and hemianopsia due to cerebral infarction were reviewed to evaluate the finding of wallerian degeneration of the optic radiation. The duration from ictus to MR examination was 15 months. This patient was examined on a 0.5-T MR unit. T1-weighted images were obtained using a spin-echo sequence with 383/16/4, and T2-weighted images were obtained with 3500/110/2 in axial and coronal planes. The section thickness was 8 mm, with a 2-mm intersection gap. The field of view was 23 cm, and the matrix was 224 × 256.

Results

With the unaided eye or with low-power microscopy of the specimens stained by Bodian's method, we clearly observed the tapetum, internal sagittal stratum, external sagittal stratum, and adjacent white matter as four layers parallel to the wall of the lateral ventricle (Fig 1A). The external sagittal stratum was recognized as a pale layer demarcated medially by the strongly stained internal sagittal stratum and laterally by adjacent white matter (Fig 1B). In myelin-stained specimens, the external sagittal stratum was more strongly stained than the internal sagittal stratum in most cases (Fig 1C). However, in some cases, the external sagittal stratum could not be distinguished from the internal sagittal stratum on the myelin-stained specimen. The thickness of the external sagittal stratum ranged from 0.9 to 1.4 mm (mean, 1.1 mm). The distance from the lateral ventricle to the medial border of the external sagittal stra-

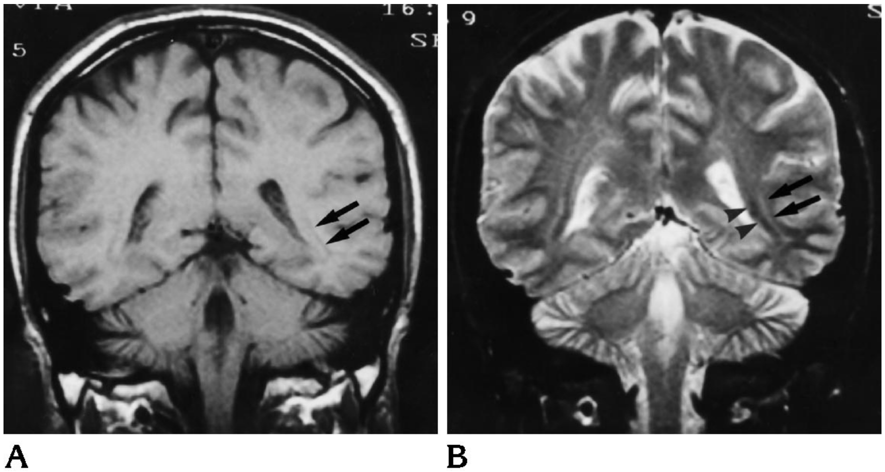

Fig 2. Coronal MR images from a healthy volunteer.

A, T1-weighted image (550/13) shows a hypointense layer parallel to the lateral ventricle (*arrows*).

B, On T2-weighted image (2500/80), a layer corresponding to that seen on the T1-weighted image appears hyperintense (*arrows*), and a hypointense layer (*arrowheads*) is seen just medial to this hyperintense layer.

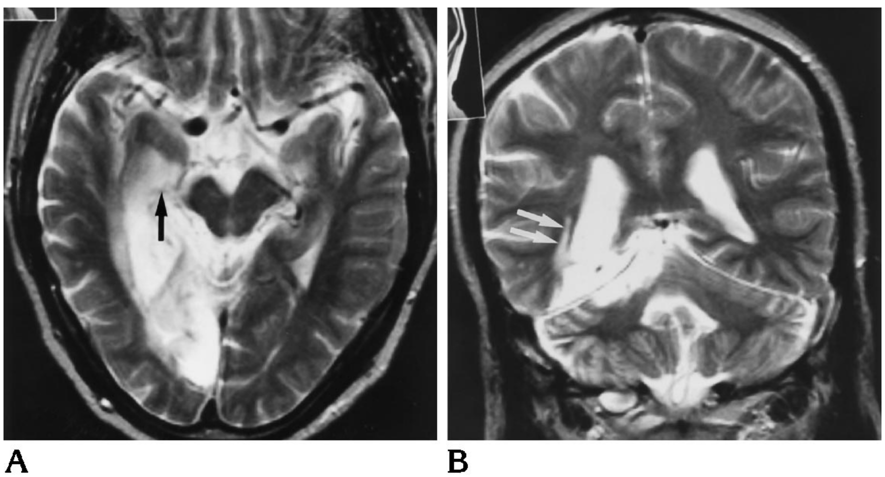

Fig 3. T2-weighted MR images from a 50-year-old man with hemiplegia and hemianopsia due to cerebral infarction.

A, In the axial section (3500/110), the infarct extends from the right temporal lobe to the occipital lobe, and the ipsilateral lateral geniculate body (*arrow*) is also involved.

B, In the coronal section (3500/110), a thin but well-defined band of marked hyperintensity (*arrows*) extends posteriorly around the trigone through the course of the right optic radiation.

tum ranged from 2.8 to 4.1 mm (mean, 3.2 mm).

High-power photomicrographs of specimens showed that the axons of the external sagittal stratum were large and separated by wide translucent spaces (Fig 1D). In contrast, both axons and myelin sheaths of the internal sagittal stratum were small with narrow translucent spaces. When the density of axons of the external sagittal stratum, internal sagittal stratum, tapetum, and adjacent white matter were compared, the external sagittal stratum showed the lowest density and the internal sagittal stratum showed the highest density.

T1-weighted images showed a hypointense linear layer parallel to the lateral wall of the lateral ventricle on both sides in all volunteers (100%) (Fig 2A). On T2-weighted images, a corresponding layer was seen as hyperintense, and a hypointense layer was seen just medial to this (Fig 2B). On T2-weighted images, the medial hypointense layer was recognized in all cases, but the lateral hyperintense layer was not recognized in three sides of two cases (83 [96.5%] of 86).

On MR imaging, the distance from the wall of the lateral ventricle to the medial border of the hyperintense layer on T2-weighted images ranged from 1.7 to 6.0 mm (mean, 2.9 mm), which corresponded to the distance from the wall of the lateral ventricle to the external sagittal stratum on histologic specimens.

In the patient with an old cerebral infarction, the lesion extended from the right temporal lobe to the occipital lobe, and the ipsilateral lateral geniculate body was also involved on MR images (Fig 3A). On T2-weighted coronal images, a thin but well-defined layer of increased signal intensity extended posteriorly around the trigone through the course of the right external sagittal stratum. The intensity of this layer was higher than that of the contralateral external sagittal stratum (Fig 3B).

Discussion

The optic radiation is the fiber tract connecting the lateral geniculate body and striate cortex. Many of the fibers of this bundle are first directed forward and lateral from the lateral geniculate body above the inferior horn of the lateral ventricle, and then, bending laterally through the sublenticular part of the internal capsule, they finally run backward through the external sagittal stratum of the temporal and occipital lobes to the striate area of the occipital cortex (2). The internal sagittal stratum, which contains fibers from the colliculus, lies medial to the external sagittal stratum. The tapetum, which contains fibers of the corpus callosum, lies medial to the internal sagittal stratum. In most cases, these three layers stain differently from the surrounding fibers with Klüver-Barrera staining, and can be identified easily (3).

Curnes et al (1) reported that the optic radiation was represented by an area of decreased signal intensity on T2-weighted MR images, which was explained by heavily myelinated fiber density. In contrast, the optic radiation was presented as a hyperintense line on T2-weighted images in the figures of MR atlases by Naidich et al (4) and Hayman et al (5). The decreased area of signal intensity was interpreted as the tapetum in their figures. They explained the high signal intensity of the optic radiation as the result of less deposition of iron (4). The signal intensity of the optic radiation on T1-weighted images was not discussed in these publications.

In our study, the external sagittal stratum appeared hypointense on T1-weighted images and hyperintense on T2-weighted images. In the brain specimen, the areas less densely stained with Bodian's staining were occupied by large axons, thick myelin sheaths, and wide translucent spaces between axons, indicating that the external sagittal stratum has lower axonal density than adjacent layers, such as the internal sagittal stratum, tapetum, and adjacent white matter (Fig 4).

Yagishita et al (6) reported that the area of high signal intensity in the posterior limb of the internal capsule corresponded to the corticospinal tract, and that this finding reflected histologic characteristics of large axons, thick myelin sheaths, and wide translucent spaces. Jolesz et al (7) have indicated that proton MR relaxation characteristics of body tissues are related to water-surface interactions, and tissues with shorter relaxation times contain an abundance of surfaces, primarily in the form of membranes or large macromolecular surfaces, such as axonal and myelin membranes. The corticospinal tract, which has low axonal and myelin densities, has less abundant axonal and myelin membrane, which may explain the T1 and T2 prolongation (6). T1 and T2 prolongation of the external sagittal stratum is probably caused by histologic characteristics similar to the corticospinal tract. With myelin staining, the external sagittal stratum was stained more strongly in most cases. In general, heavy myelination causes decreased signal intensity on T2-weighted images. Because the external sagittal stratum appeared hyperintense on T2-weighted images, myelination may not be related to the difference in signal intensity. The hypointense layer on T2-weighted images was considered to be the internal sagittal stratum plus the tapetum, and this region was occupied by small axons, thin myelin sheaths, and narrow translucent spaces (see Fig 1D).

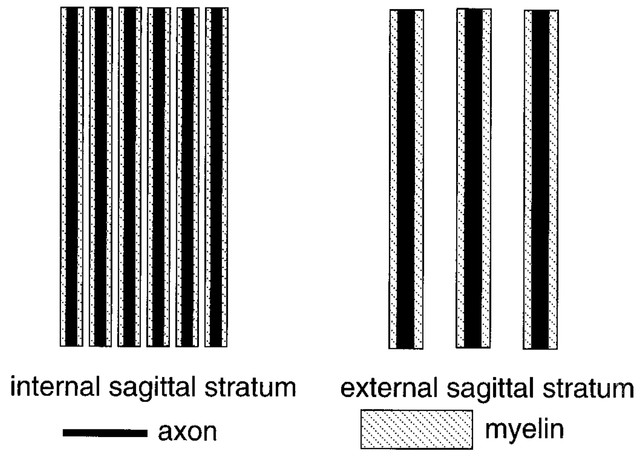

Fig 4. Histologic characteristics of the external sagittal stratum and the internal sagittal stratum. The external sagittal stratum has large axons, thick myelin sheaths, and wide translucent spaces. In contrast, both axons and myelin sheaths of the internal sagittal stratum are small and associated with narrow translucent spaces.

Ebeling and Reulen (8) estimated the thickness and width of the optic radiation by studying consecutive coronal sections in formalin-fixed hemispheres of human brain. They studied the topography of the optic radiation by using Klingler's fiber dissection method. However, the thickness of the optic radiation seemed to be measured as the total thickness of the external sagittal stratum, internal sagittal stratum, and tapetum. According to them, the total thickness was 1 to 2 mm at the tip of the temporal horn, 2 to 4 mm at the trigone, and 3 to 5 mm at the posterior limit of the posterior horn of the lateral ventricle. Wahler-Lück et al (9) reported that the optic radiation maintains a distance of 3 to 4 mm from the lateral ventricle. In our study, the thickness of the external sagittal stratum ranged from 0.9 to 1.4 mm (mean, 1.1 mm), and the thickness of the internal sagittal stratum plus the tapetum (the distance from the lateral ventricle to the medial border of the optic radiation) ranged from 2.8 to 4.1 mm (mean, 3.2 mm). Our results corresponded to the previous reports.

Savoiardo et al (10) reported two cases in which MR imaging revealed wallerian degeneration of the optic radiation caused by lesions of the lateral geniculate body. These authors showed that the optic radiation with wallerian degeneration appeared hyperintense on T2-weighted images. In our case, a markedly hyperintense lesion representing wallerian degeneration of the optic radiation corresponded to the external sagittal stratum. This finding supports the hypothesis that the optic radiation lies within the external sagittal stratum.

In summary, this study demonstrated that the optic radiation appears hypointense on T1-weighted images and hyperintense on T2-weighted images. These signal intensities correspond to a low density of fibers, large axons, thick myelin sheaths, and wide translucent spaces.

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