SEMINAR REPORT

Reconsidering "Standard MR Images": What Are the Ideal MR Images for Diagnosing Lesions in the Central Nervous System?

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Introduction

MR imaging is routinely used for the diagnosis of lesions in the central nervous system. In this lecture, I would like to briefly discuss some key issues related to the acquisition of various types of MR images in terms of their diagnostic usefulness. At our hospital, a 3-T Vantage Centurian* MRI system (Canon) entered operation in November 2019. This system features a noise reduction reconstruction technology employing an advanced AI approach called Deep Learning Reconstruction (DLR) (product name: Advanced intelligent Clear-IQ Engine, AiCE). I would also like to show how this technology can be applied to images by presenting actual clinical images obtained at our hospital.

T2-weighted images

1. Image characteristics and the need to obtain coronal images

The main requirement for T2-weighted axial images is good contrast between various tissues, such as between the cortex and white matter, between white matter and central gray matter, between various nuclei in the brainstem, and between lesions and normal tissues. In order to clearly depict these structures, it is important to perform examinations using an appropriate scan sequence.

Obtaining T2-weighted coronal images is also essential. For example, the distribution of brain atrophy, enlargement of the inferior horn of the lateral ventricle, and widening of the collateral sulcus due to Alzheimer's disease can easily be identified in coronal images. The characteristic findings of normal pressure hydrocephalus, such as narrowing of the sulci in the parietal region (high convexity) and an increase in the callosal angle, can only be identified in coronal images. With regard to degenerative diseases, it is known that the normal cross-sectional area of the middle cerebellar peduncle is around 200 mm^2 in coronal images and that the angle of the superior cerebellar peduncle is significantly increased in patients with multiple system atrophy of the cerebellar type.

2. Shorter scan times with AiCE

The acquisition of coronal images is frequently omitted in routine clinical practice in order to shorten the examination time. Evaluation was conducted to determine whether AiCE can be used to shorten the scan time while maintaining an acceptable level of image quality for interpretation.

* Vantage Centurian is not commercially available in all countries.

Figure 1 shows a comparison of coronal images with and without AiCE. The images in rows c and d were obtained by applying AiCE to an image acquired in 50 seconds with NAQ 1 (a) and adjusting the strength and threshold. Extremely good image quality is obtained with a strength 5 and a threshold 1.2 (Figure 1d, center), but because AiCE only removes noise that contains high-frequency components,[1] CSF pulsation artifacts are still present in the image. In addition, the entorhinal cortex (arrow), which can be seen in the image acquired with NAQ 2 (Figure 1b), is not clearly visualized in the images acquired with NAQ 1, even with AiCE (Figure 1c, d). It is important to understand that structures which are not visible in the original image cannot be made visible by applying AiCE, therefore AiCE must be used appropriately.

T1-weighted images

1. Changes in visualization with different scanning methods

There are a variety of scanning methods for acquiring T1-weighted images, such as spin echo (SE), fast spin echo (FSE), and T1FLAIR. It is therefore important to take the scanning method into consideration during image interpretation. For example, the severe calcification in the basal ganglia and the deposition of gadolinium-containing contrast medium in the brain which are observed in patients with Fahr's disease may not be depicted by a scanning method that includes an inversion pulse. In contrast-enhanced MRI, the enhancement characteristics differ between sequences employing the inversion recovery (IR) technique and those employing the SE technique. Especially for the evaluation of metastasis, scanning using both SE and IR sequences reduces the risk of failing to detect lesions.

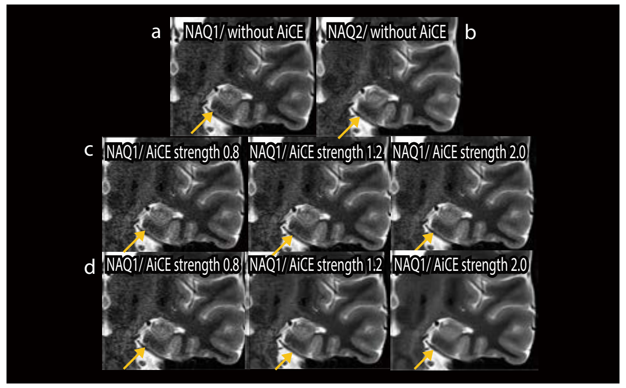

Figure 1 Shorter scan times for T2-weighted coronal images with AiCE.
a: NAQ1 / Without AiCE
b: NAQ2 / Without AiCE
c: NAQ1 / AiCE strength 1
d: NAQ1 / AiCE strength 5

2. Usefulness of AiCE in detecting pituitary microadenomas

Although pituitary microadenomas can be clearly depicted in dynamic examinations, there are some limitations related to the slice thickness and the number of slices. Evaluation was conducted to determine whether AiCE can be used to obtain high-resolution images in a short scan time (Figure 2).

When AiCE was applied to images acquired with a slice thickness of 2 mm and an imaging interval of 30 sec (Figure 2a), a microadenoma (arrow) was clearly depicted in the image acquired at 30 sec (Figure 2b, center), demonstrating improved diagnostic capabilities. AiCE allows acquisition with a thinner slice thickness, which is extremely useful.

FLAIR

1. Image characteristics and the need to obtain FLAIR images

When TE = 100 ms, excellent contrast can be obtained in FLAIR images at around TR/TI = 10000/2200 ms. Therefore, a longer TR is preferred. As TE is gradually increased, overall signal intensity is reduced, but the differences in contrast between tissues with different levels of water content are increased.

In recent years, with the introduction of Synthetic MRI, some have argued that FLAIR imaging is no longer necessary. However, due to partial volume effects, boundaries are not clearly depicted in Synthetic FLAIR, and separate FLAIR imaging may be required. For example, signals related to flow-related phenomena such as intravascular high signal intensity can be depicted only by 2D-FLAIR.

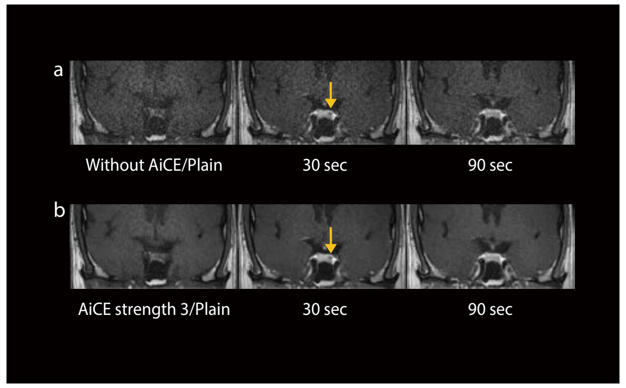

Figure 2 Application of AiCE in a dynamic pituitary examination (pituitary microadenoma).
a: Without AiCE
b: With AiCE

In addition, with regard to lesions located near CSF, it has been reported that a group of patients with sporadic neuronal intranuclear inclusion disease showed symmetric high-intensity signal in the paravermal area of the cerebellum in FLAIR images.[2] Synthetic FLAIR is not suitable for the depiction of such diseases.

High signal intensity in the sulci due to dilatation of the pial blood vessels in patients with cerebral infarction or migraine is also a characteristic finding in FLAIR images.[3]

2. Utilization of AiCE

Because it takes some time to perform FLAIR scanning, evaluation was conducted to determine whether it would be possible to shorten the scan time (Figure 3). At TR/TE = 5000/100 ms, T1 contrast was significantly reduced and the abnormal low-intensity signals in the pons were lost (Figure 3a, center). To compensate for the reduction in T2 contrast, TE was set to 150 ms. Although contrast was improved with these scan conditions, overall signal intensity was reduced, resulting in poor image granularity (Figure 3a, right). When AiCE was applied to this image, not only the SNR but also the image granularity was improved, providing a diagnostically useful image in only 1 min and 10 sec (Figure 3b, right).

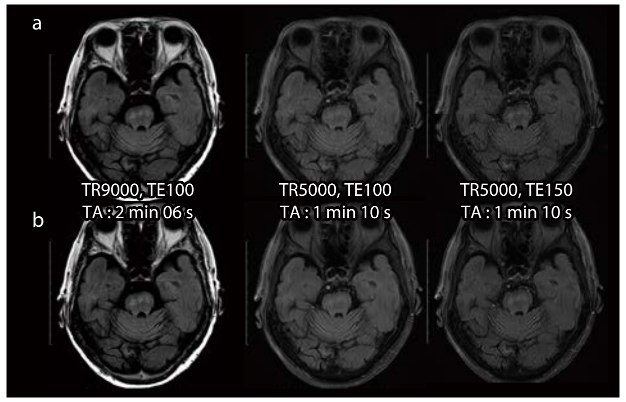

Figure 3 Shorter scan time in FLAIR with AiCE (multiple sclerosis).
a: Without AiCE
b: With AiCE

In contrast-enhanced T2-weighted FLAIR of the internal ear, the perilymph is usually enhanced about 4 hours after the injection of contrast. However, in patients with Meniere's disease associated with endolymphatic hydrops, the volume of non-enhanced endolymph is increased. Therefore, a subtraction image (HYDROPS image) was created from an image acquired with TI = 2250 ms (perilymph: high intensity, endolymph: low intensity) and an image acquired with TI = 2050 ms (perilymph: low intensity, endolymph: high intensity). When AiCE was applied to the subtraction image, enlargement of the endolymphatic space was clearly observed (Figure 4).

T2*-weighted images

Multi-echo T2*-weighted images, which are often used in the field of orthopedics, are obtained by acquiring and summing multiple echoes. These images feature high SNR and high T2*-weighted contrast. It has been reported that this method provides not only excellent contrast between white matter and gray matter but also superior detectability of multiple sclerosis compared to SE.[4] Evaluation was conducted to determine whether multi-echo T2*-weighted imaging is useful for visualizing nigrosome-1 (Figure 5).

In patients with Parkinson's disease, signals from nigrosome-1 are unclear due to degeneration of the dopamine-containing cells.[5] It is often difficult to visualize nigrosome-1 even using 3-T MRI. At our hospital, multi-echo acquisition was performed in a normal subject using Vantage Centurian. When AiCE was applied, nigrosome-1 was very clearly depicted (Figure 5, left).

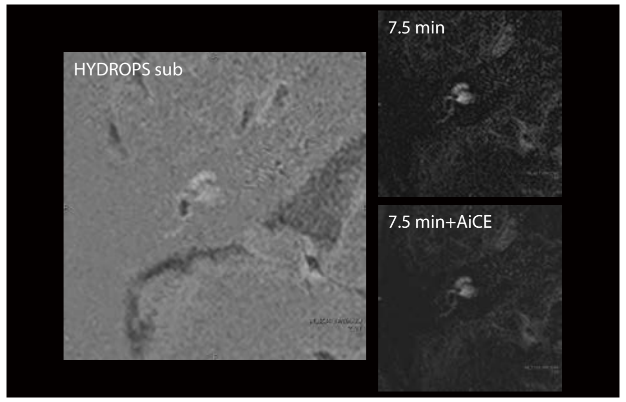

Figure 4 Depiction of an enlarged endolymphatic space in contrast-enhanced FLAIR of the inner ear (Meniere's disease)

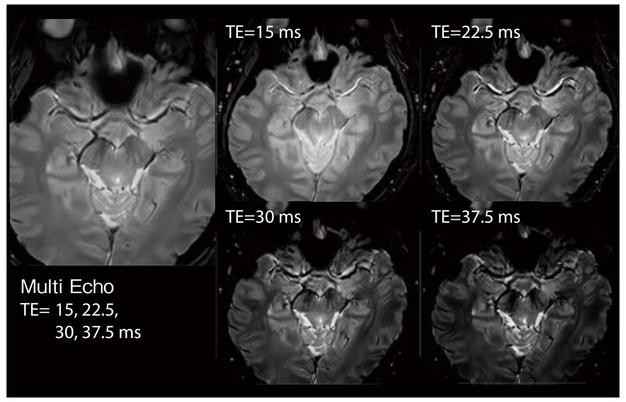

Figure 5 Visualization of nigrosome-1 in multi-echo T2*-weighted images (normal subject)

Diffusion-weighted images

1. Usefulness of imaging with high b-values

In diffusion-weighted imaging, the contrast in the normal cortex is reduced and the visualization of lesions is improved by employing a high b-value (b = approx. 1000 s/mm^2 in 1.5-T MRI, and b = approx. 2000-3000 s/mm^2 in 3-T MRI). With a high b-value, the visualization of lesions such as those associated with Creutzfeldt-Jakob disease (Figure 6) and cerebral infarction is improved, and some studies have even reported high detectability of acute-stage disease. In addition, because this method is not as strongly affected by T2 shine-through, the interpretation of diffusion is quite easy even in pathological conditions in which both increases and decreases in diffusion are observed, such as venous infarction. Scanning with a high b-value is considered to be extremely useful.

2. Effects of TE

The TE in diffusion-weighted imaging is related to the length of the diffusion time (TD). To obtain a higher b-value, a higher gradient or a longer TD is needed. However, a longer TD results in a lower SNR.

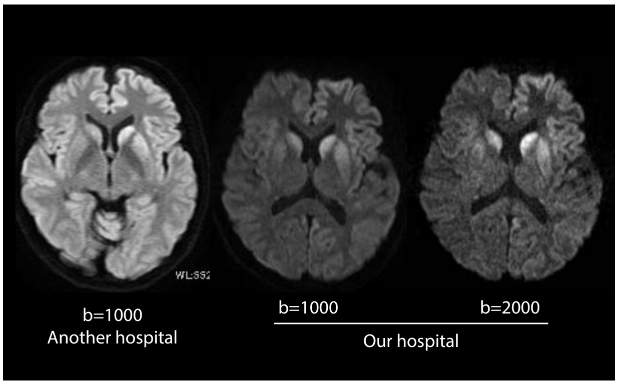

Figure 6 Depiction of Creutzfeldt-Jakob disease in diffusion-weighted images acquired with a high b-value.

In Vantage Centurian, TE can be reduced to the range of 60-70 ms in diffusion-weighted imaging thanks to the strong gradient magnetic field (G_{max}). If TE is too short, cerebral infarcts exhibit low signal intensity even though high-SNR images can be obtained. On the other hand, if TE exceeds 90 ms, the SNR falls. Flexible parameter setting is possible in systems with a high maximum gradient field strength. Based on a clear understanding of these characteristics, the optimal TE for the detection of lesions should be carefully considered in clinical applications.

Conclusion

In this lecture, I have briefly discussed MR imaging of the central nervous system. Even though coronal and FLAIR images are often not acquired in busy clinical settings, such images can provide very important clinical information and should therefore be acquired even if the contrast and SNR are reduced to some extent because a short scan time is employed.

AiCE can be applied to a variety of sequences and is useful for improving image quality in scanning with short scan times and for clearly depicting fine structures.

Acknowledgement

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References

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