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Fast Inversion Recovery Magnetic Resonance Imaging with the Real Reconstruction Method: A Diagnostic Tool for Cerebral Gliomas

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Abstract

The fast inversion recovery (IR) technique was evaluated for the localization of gliomas. Fast IR imaging with real reconstruction and T_1-weighted spin echo (SE) imaging before and after contrast administration were performed in 20 patients with gliomas. The tumor-to-white matter contrast ratio (TWCR), tumor-to-gray matter contrast ratio (TGCR), tumor-to-white matter contrast-to-noise ratio (TWCNR), and tumor-to-gray matter contrast-to-noise ratio (TGCNR) were calculated and compared. Fast IR imaging visualized tumors with significantly higher TWCR, TGCR, TWCNR, and TGCNR values ($p < 0.01$) than those for T_1-weighted SE imaging. In particular, fast IR imaging clearly revealed seven non-enhanced tumors that were poorly visualized on T_1-weighted SE imaging. Fast IR imaging showed a similar TGCR and significantly higher TWCR ($p < 0.01$) compared to T_1-weighted SE imaging with contrast medium in 13 enhanced tumors. However, fast IR imaging showed similar TWCNR and lower TGCNR compared to T_1-weighted SE imaging with contrast medium. The fast IR technique can discriminate tumors from normal cerebral tissues with high contrast and without the use of contrast medium. This technique is extremely useful for the localization of non-enhanced tumors.

Key words: glioma, magnetic resonance imaging, fast inversion recovery technique

Introduction

Gliomas develop in the cerebral parenchyma and invade the adjacent tissues. Conventional T_1-weighted spin echo (SE) magnetic resonance (MR) imaging visualizes gliomas as low- or iso-signal intensity areas, but the margins of the lesions are not clearly delineated in many cases.[5] Some gliomas, such as glioblastomas and anaplastic astrocytomas, are enhanced by contrast medium, so the margins are clearly visualized. However, gliomas that do not show contrast enhancement, such as low-grade astrocytomas, cannot be clearly delineated by conventional T_1-weighted SE MR imaging methods.

The inversion recovery (IR) technique is another pulse sequence for obtaining T_1-weighted images.[9] The IR technique is excellent for the visualization of anatomical structures, providing good white-to-gray matter contrast.[4] The IR technique has had a number of limitations such as long acquisition times, but acquisition times have been significantly reduced by the combined use of fast scan techniques such as fast or turbo SE imaging, and the IR technique is now widely employed for imaging of lesions of the head and neck[13] and the central nervous system.[1,7,16]

The present study acquired images of gliomas using fast IR, which is a pulse sequence combining the IR and fast SE techniques and the real reconstruction method, to compare the usefulness of fast IR with conventional T_1-weighted SE MR imaging techniques for the evaluation of patients with gliomas.

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Materials and Methods

Twenty patients with gliomas (16 men and 4 women) aged from 25 to 68 years (mean 48.8 years) were examined. The histological diagnosis was glioblastoma in 11 patients, anaplastic astrocytoma in two, astrocytoma in five, and oligoastrocytoma in two.

All patients underwent MR imaging using the fast IR and T_1-weighted SE techniques using a 1.5-T MR imaging system (VISART; Toshiba Corporation,

Tokyo). The images were acquired in the axial plane parallel to the anterior commissure-posterior commissure line. Informed consent was obtained from the patients before gadolinium-diethylene-triaminepenta-acetic acid (DTPA) (Magnevist; Nihon Schering, Osaka) 0.1 mmol/kg was injected intravenously and T_1-weighted SE images with contrast medium were acquired.

Scanning parameters used for all techniques were matrix size = 224 × 256 pixels, field of view = 22 × 22 cm, number of signal averagings = 2, slice thickness = 5 mm, slice gap = 1 mm, and number of slices = 19. Repetition time (TR) = 500 msec, echo time (TE) = 15 msec, and scan time = 3 min 44 sec were used for T_1-weighted SE MR imaging. TR = 2500 msec, TE = 18 msec, echo train length = 4, inversion time = 400 msec, and scan time = 4 min 48 sec were used for fast IR MR imaging. The image reconstruction method was the real reconstruction method, which displays images while maintaining the positive and negative signal values of the acquired fast IR data.

The tumor-to-white matter contrast ratio (TWCR), tumor-to-gray matter contrast ratio (TGCR), tumor-to-white matter contrast-to-noise ratio (TWCNR), and tumor-to-gray matter contrast-to-noise ratio (TGCNR) were measured to compare the images acquired using each pulse sequence. The region of interest (ROI) for obtaining the signal intensity within the tumor was selected in an area of uniform signal intensity at the center of the tumor. The ROI was selected in an area of uniform contrast enhancement for enhanced tumors. In addition, the ROI for obtaining the white matter signal intensity was selected in the normal-appearing white matter near the tumor, and the ROI for obtaining the gray matter signal intensity was selected medial to apparently normal cortical tissue of the frontal lobe. The standard deviation (SD) of the image noise was measured in the phase-encoding direction in the background air around the patient's head, avoiding areas showing motion artifacts.

TWCR was calculated using the following formula: TWCR = (tumor signal intensity − white matter signal intensity)/white matter signal intensity. TWCNR was calculated using the following formula: TWCNR = (tumor signal intensity − white matter signal intensity)/image noise SD. TGCR and TGCNR were calculated in similarly. The TWCR, TWCNR, TGCR, and TGCNR values were converted to absolute values to compare the conventional T_1-weighted SE and fast IR images. The Wilcoxon signed-rank test was used for statistical analysis. Values of $p < 0.05$ were considered statistically significant.

Results

The mean and SD values of the TWCR, TGCR, TWCNR, and TGCNR are shown in Table 1.

TWCR and TGCR values in fast IR images were significantly higher ($p < 0.01$) than those in T_1-weighted SE images, and the tumors could be clearly distinguished from the normal-appearing white matter and gray matter with better contrast. There were no significant differences in TGCR, but TWCR was significantly higher ($p < 0.01$) in fast IR images compared to T_1-weighted SE images with contrast medium in the 13 enhanced tumors.

TWCNR and TGCNR were significantly higher ($p < 0.01$) in fast IR images than in T_1-weighted SE images. There were no significant differences in TWCNR, but TGCNR was significantly higher ($p < 0.01$) in T_1-weighted SE images with contrast medium compared to fast IR images in the 13 enhanced tumors.

Representative Case Reports

Case 1: A 25-year-old man presented with a left frontal astrocytoma. Fast IR imaging easily detected the

Table 1 Comparison of ratios measured by fast inversion recovery and T_1-weighted spin echo imaging

	T_1-weighted spin echo (n = 20)	Fast inversion recovery (n = 20)	Probability	T_1-weighted spin echo with contrast medium (n = 13)	Fast inversion recovery (n = 13)	Probability
TWCR	0.23 ± 0.09	3.96 ± 1.05	< 0.01	0.48 ± 0.34	3.72 ± 0.86	< 0.01
TGCR	0.1 ± 0.07	1.14 ± 0.69	< 0.01	0.9 ± 0.42	1.13 ± 0.78	n.s.
TWCNR	17.86 ± 6.68	38.89 ± 9.07	< 0.01	35.77 ± 21.85	39.91 ± 9.11	n.s.
TGCNR	6.45 ± 4.5	14.31 ± 5.13	< 0.01	53.01 ± 21.13	13.73 ± 5.03	< 0.01

Values are mean ± standard deviation. Statistical analysis used Wilcoxon's signed-rank test. n.s.: not significant, TGCNR: tumor-to-gray matter contrast-to-noise ratio, TGCR: tumor-to-gray matter contrast ratio, TWCNR: tumor-to-white matter contrast-to-noise ratio, TWCR: tumor-to-white matter contrast ratio.

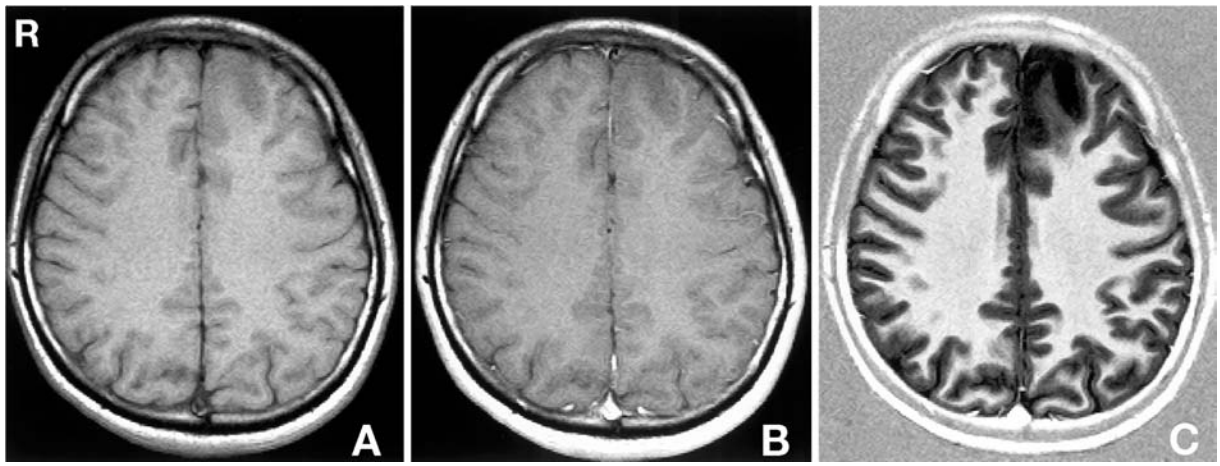

Fig. 1 T_1-weighted spin echo magnetic resonance images before (A) and after (B) contrast administration, and fast inversion recovery image (C) of a 25-year-old man with a histological diagnosis of left superior frontal gyrus astrocytoma. The tumor is not enhanced, and the localization is not clearly shown by the T_1-weighted spin echo images. The fast inversion recovery image shows the tumor arising in the cortex with excellent contrast, and also clearly shows the part of the lesion extending into the white matter, which is not clearly seen in the conventional images.

tumor in the left superior frontal gyrus as an area of low signal intensity (Fig. 1). The affected portion of the cortex appeared swollen and the lesion in the white matter was clearly shown. T_1-weighted SE imaging delineated the lesion less clearly and the lesion in the white matter was not clearly visualized. The tumor was not enhanced by contrast medium.

Case 2: A 35-year-old man presented with a right frontal astrocytoma. T_1-weighted SE imaging showed a faint area of low signal intensity in the right frontal lobe, which was not enhanced by contrast medium, and the margins of the lesion were not clearly delineated (Fig. 2). Fast IR imaging clearly detected the lesion extending from the cortex to the white matter with high contrast, and the margins were also clearly visualized. Fast IR imaging showed that the lesion was located in the left superior frontal gyrus.

Case 3: A 44-year-old woman presented with a left parietal glioblastoma. T_1-weighted SE imaging showed a tumor associated with surrounding edema in the white matter of the left parietal lobe, which was enhanced by contrast medium (Fig. 3). The edema was visualized more clearly by fast IR imaging than by T_1-weighted SE imaging. Fast IR imaging delineated the tumor lesion separately from the surrounding edema without the use of contrast medium.

Discussion

The present study shows that fast IR MR imaging is an effective method for the evaluation of patients with gliomas. In particular, fast IR imaging is considerably more helpful for evaluating non-enhanced tumors.

Fast IR images showed significantly higher TWCR, TGCR, TWCNR, and TGCNR values compared to conventional T_1-weighted SE imaging. Therefore, the fast IR technique can depict tumor lesions clearly with high contrast. Fast IR imaging can also clearly depict tumors that are not enhanced by contrast medium, mostly astrocytomas. This study included five astrocytomas and two oligoastrocytomas that were not clearly enhanced on T_1-weighted SE imaging, but fast IR imaging clearly showed these tumors. The information obtained from fast IR imaging will be very useful in the treatment planning for patients with gliomas, in which the extent of the lesion must be accurately determined and tumor resection performed to the greatest extent possible.[2,6,14] Furthermore, the fast IR technique can distinguish the white matter and gray matter with high contrast.[4,11] Therefore, this technique is useful for the morphological evaluation of the affected cortex and for discriminating between the normal cortex and white matter and astrocytomas, which generally arise near the cerebral surface and then extend into the cortex and deep white matter.[3,12]

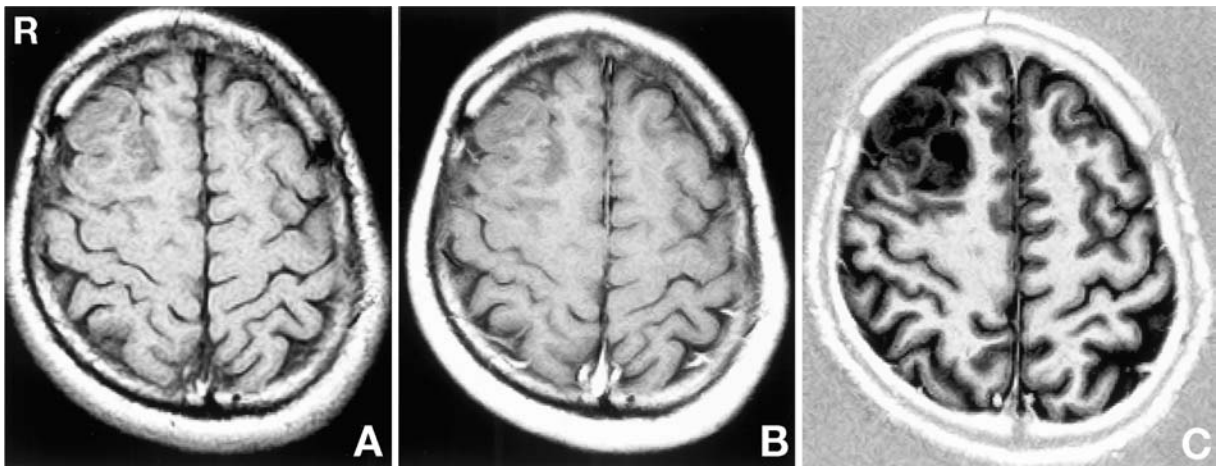

Fig. 2 **T_1-weighted spin echo magnetic resonance images before (A) and after (B) contrast administration, and fast inversion recovery image (C) of a 35-year-old man with a histological diagnosis of right middle frontal gyrus astrocytoma. The tumor is not enhanced, and appears as a faint area of low signal intensity and the margins are not clearly delineated by the T_1-weighted spin echo images. The fast inversion recovery image clearly shows the lesion and delineates the margins.**

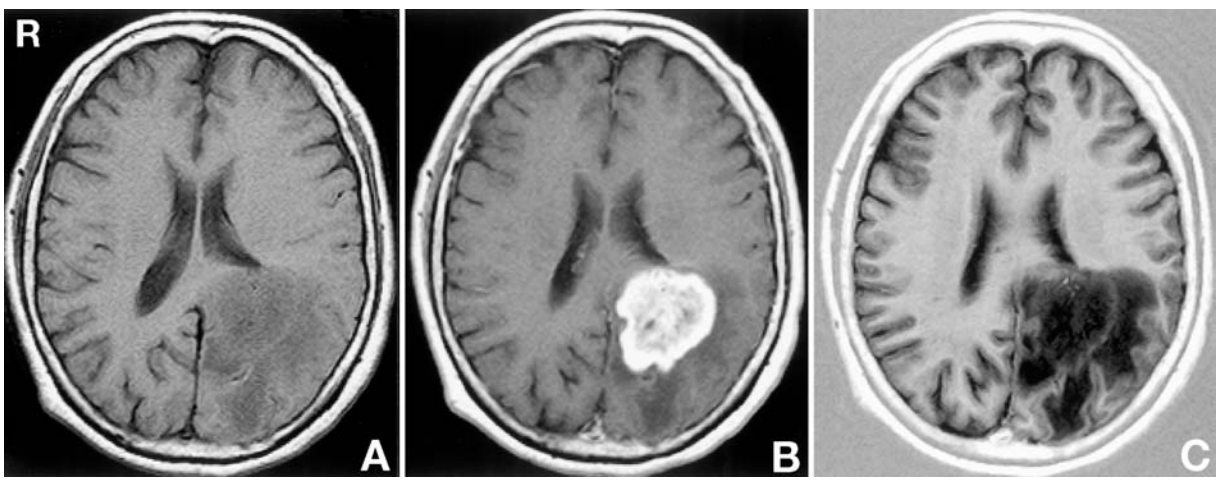

Fig. 3 **T_1-weighted spin echo magnetic resonance images before (A) and after (B) contrast administration, and fast inversion recovery image (C) of a 44-year-old woman with a histological diagnosis of left parietal glioblastoma. The fast inversion recovery image shows the tumor, including the edematous area, more clearly than the conventional images, and the tumor lesion is distinguished from the surrounding edema without the use of contrast medium.**

Fast IR imaging showed TGCR values as high as and TWCR values significantly higher than those in T_1-weighted SE imaging in the 11 glioblastomas and two anaplastic astrocytomas enhanced by contrast medium. This suggests that the fast IR technique can show tumors enhanced by contrast medium as well as or better than the conventional method. Anaplastic astrocytomas and glioblastomas often arise in the deep white matter and rarely extend to the cerebral surface,[3,15] so fast IR imaging with a high TWCR provides even greater advantages. Tumor lesions with a higher water content than normal cerebral tissues show large negative magnetization and appear as areas of low signal intensity on fast IR imaging. In contrast, such tumors are visualized as areas of high signal intensity due to contrast enhancement on conventional imaging. Therefore, T_1-weighted SE imaging with contrast medium is likely to depict

such tumors more clearly. However, the fast IR technique can distinguish tumor lesions from the surrounding edema not by contrast medium, but by the differences in T_1 values. Therefore, fast IR can provide images that are as clinically useful as those obtained by T_1-weighted SE imaging with contrast medium.

The fast IR technique is based on a 180° inversion pulse applied prior to a fast SE pulse sequence. Application of the 180° inversion pulse doubles the T_1 factor range due to the inclusion of the positive and negative values. In contrast, T_1-weighted SE imaging employs only the positive T_1 values. The real reconstruction method employed in the present study maintains the positive and negative signal values and thus accurately reflects the differences in T_1 relaxation times between tissues, whereas conventional magnitude reconstruction displays positive and negative signal values as absolute values. The high TWCR and TGCR values obtained in the present study are attributable to this characteristic of fast IR. Fast IR provided higher TWCNR and TGCNR values than conventional T_1-weighted SE imaging, but not higher than conventional imaging with contrast medium. Such differences are related to the effects on longitudinal magnetization strength of the differences between the fast IR and SE pulse sequences and also of the signal increase resulting from the administration of gadolinium-DTPA. Nevertheless, fast IR has advantages for clinical diagnosis, as demonstrated by the representative cases. A TE as short as 18 msec, as employed in the present study, avoids the signal decrease due to the T_2 factor and produces T_1-weighted images heavily affected by T_1 relaxation.

The present study focused on the contrast between the tumor and normal cerebral tissues, and did not compare the range of signal changes between fast IR imaging and T_1-weighted SE imaging with or without contrast medium, or T_2-weighted fast SE imaging. However, the relationships between histological findings and the signal intensity changes according to the scanning technique employed must be clarified to determine the extent of tumor resection. For example, areas of neovascularization and endothelial proliferation appear as regions enhanced by gadolinium-DTPA,[8] and tumor cell infiltration is located within the area of high signal intensity on T_2-weighted fast SE imaging.[10] Such issues have not yet been fully investigated.

The fast IR technique can depict tumor lesions with higher contrast compared with the conventional T_1-weighted SE technique due to the excellent T_1 contrast characteristics, and provides contrast comparable to or higher than T_1-weighted SE imaging with contrast medium. Consequently, this technique is extremely useful for the localization of nonenhanced tumors such as astrocytomas, as the extent of tumor resection can be determined. The fast IR technique has limitations. T_1-weighted SE imaging with contrast medium can provide information regarding blood-brain barrier, which is essential for the preoperative estimation of tumor grading, and to detect intracranial tumor dissemination. Fast IR imaging cannot provide such information. However, fast IR imaging can show the tumor lesion with high contrast, so is useful for brain tumor screening examinations and evaluation of patients with brain tumors in whom gadolinium-DTPA cannot be used (due to allergy to gadolinium-DTPA, asthma, renal dysfunction, etc.). The present study indicates that the fast IR technique is a useful addition to the standard diagnostic imaging protocols for the clinical evaluation of patients with brain tumors.

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Commentary

There have been very few advances in the MRI analysis of cerebral gliomas that have been truly helpful to the practicing neurosurgeon. The authors of this paper demonstrate a novel technique using fast inversion recovery and a reconstruction method that certainly highlights unenhanced tumors in a very precise and effective fashion. This sort of analysis, particularly when combined with image-guided surgery, should provide for the opportunity for more complete resection of cerebral gliomas. It will be interesting to see how this technique can be applied to recurrent tumors and the postoperative situation.

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The authors report that fast IR MR imaging can depict tumor lesions clearly with high contrast, and that it is useful for evaluating non-enhanced tumors such as cerebral astrocytomas in adults which usually appear as non-enhanced low-signal areas on standard T_1-weighted imaging. As the fast IR technique can also distinguish tumors from the surrounding edema, it is also useful for detecting the border between non-enhanced astrocytomas and the surrounding edema. The most important point for this new imaging technique is availability at all neurosurgical clinics.

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The fast inversion recovery (IR) technique provides high contrast MR images with reduced acquisition time and can identify various neuronal diseases. The authors evaluated the possibility of localizing glioma by MR imaging, using the IR technique. Especially for astrocytoma, the image obtained with this technique could discriminate the tumor lesion from surrounding cortex more clearly, compared with the conventional T_1-weighted SE MR image. The clinical significance is obvious and this method may contribute to achieving complete tumor resection. On the other hand, the authors demonstrated that other image techniques with contrast medium may be complementary to evaluate the tumor grading and dissemination in the case of high grade glioma.

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