Original Article

Advantages of Using Spin-Echo-Type Radial Scanning with Parallel Imaging of the Head

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ABSTRACT

Background: T1-weighted spin-echo (SE) imaging is generally used in contrast-enhanced imaging of the head. However, the posterior fossa cannot be clearly visualized with this method because of flow-related artifacts from blood vessels. Recent reports have described the use of radial scanning to address this problem. We investigated the characteristics of radial-acquisition regime (RADAR)-SE and the clinical advantages of this technique when combined with rapid acquisition through parallel imaging design (RAPID).

Methods: In a phantom study using diluted gadopentetate dimeglumine, contrast levels on RADAR-SE and SE images were compared. Each scan was repeated 5 times, mean contrast was calculated, and contrast levels on SE and RADAR-SE images were quantitatively evaluated. In a clinical study of 31 patients with intracranial disease, flow-related artifacts in RADAR-SE and SE were recorded and compared. Images acquired by SE and RADAR-SE were evaluated independently by 2 radiologists.

Results: In the phantom study, there was no significant difference between contrast levels on SE and RADAR-SE images. In clinical imaging, flow-related artifacts were suppressed on RADAR-SE ($p < 0.001$), but streak artifacts were observed in a few cases.

Conclusions: RADAR-SE suppressed flow-related artifacts during cranial imaging and thus may facilitate evaluation of intracranial lesions.

J Med Soc Toho 60 (4): 198–203, 2013

KEYWORDS: radial scan, brain, contrast-enhanced T1WI, MRI, artifact

T1-weighted spin-echo (SE) magnetic resonance imaging (MRI) is generally used for contrast-enhanced imaging of the head. However, the posterior fossa cannot be clearly visualized with this method because of flow-related artifacts from blood vessels. Even with flow compensation, it is difficult to eliminate artifacts completely.[1,2] In recent years, studies have attempted to solve this problem by using radial scanning, *i.e.*, periodically rotated overlapping parallel lines with enhanced reconstruction (PROPELLER/BLADE).[3,4] Most of these studies used T1-weighted fluid-attenuated inversion-recovery (FLAIR) BLADE, combining fast spin-echo with radial scanning.[5,6] In T1-weighted FLAIR BLADE, suppression of flow-related artifacts is greater than that achieved with flow compensation, but

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Received Mar. 11, 2013: Accepted June 14, 2013
Journal of the Medical Society of Toho University
60 (4), July 1, 2013. ISSN 0040–8670, CODEN: TOIZAG

scan time was longer as compared with SE, and contrast enhancement differed.[6] However, flow-related artifacts can be suppressed using T1-weighted radial-acquisition regime (RADAR)-SE, a method that combines RADAR[7] and SE.

In RADAR-SE, only 1 SE signal is collected per repetition time (TR). In addition, RADAR-SE arbitrarily determines whether to place a number of SE signals in parallel within each blade. However, unlike fast SE (FSE), each echo signal in the blade is collected with a separate TR. Therefore, RADAR-SE differs from previously reported radial-scan techniques in terms of points not arising in FLAIR or FSE. Moreover, by using RADAR-SE together with rapid acquisition through parallel imaging design (RAPID), the imaging time for RADAR-SE is less than that of conventional SE,[8] a method of parallel imaging.

In a phantom study, we examined the characteristics of RADAR-SE for contrast-enhanced imaging of the head. Then, we investigated the clinical advantages of using RADAR-SE in combination with RAPID.

Methods

MRI technique

All imaging was conducted using a 1.5-T MRI system (ECHELON Vega; Hitachi Medical Corp., Tokyo, Japan).

RADAR-SE is a method to fill the k-space using a trajectory rotated with the center of the k-space as its axis. RADAR-SE helps acquire a single echo signal within each TR, at which point a change occurs in the ratio of the readout gradient magnetic field pulses of the 2 axes within the slice, and the k-space fills up. It thus becomes possible to acquire an echo time (TE) of the same value in all echo modes.

RADAR-RAPID decreases the number of blades and shortens imaging time by thinning out the number of echo signals to be measured. During image reconstruction, an algorithm is used to generate aliasing for each blade.

Phantom study

Phantom studies were used to evaluate the contrast of RADAR-SE images. Phantoms were produced using gadopentetate dimeglumine (Gd-DTPA; Magnevist®; Bayer Yakuhin Ltd., Osaka, Japan) at concentrations of 10, 5, 1, 0.5, 0.2, and 0.1 mmol/l, with physiological saline as reference. Using a quadrature detection (QD) head coil, imaging was conducted to calculate contrast levels, for the purpose of comparing imaging techniques.

The imaging parameters for RADAR-SE were as follows: field of view (FOV), 24 x 24 cm; TR, 500 ms; TE, 12 ms; slice thickness, 5.0 mm; matrix, 320 x 264; number of signals averaged (NSA), 1; and RAPID, off. The parameters for SE were FOV, 24 x 24 cm; TR, 500 ms; slice thickness, 5.0 mm; matrix, 320 x 264; NSA, 1. The following equation was used to calculate contrast levels:

$$\text{Contrast} = (\text{Sla} - \text{Slb}) / (\text{Sla} + \text{Slb}) \quad [1]$$

where Sla is the signal value of the Gd-DTPA solution phantom and Slb is the signal value of physiological saline. Each scan was repeated 5 times, mean contrast was calculated, and SE and RADAR-SE contrast were quantitatively evaluated.

Clinical study

Patients were imaged using SE and RADAR-SE pulse sequences with equal imaging time. Images were then evaluated for contrast enhancement and quality of RADAR-SE images.

We examined contrast-enhanced cranial MR images of 31 consecutive cases, acquired from July 2011 to November 2011. The ethics committee of Toho University approved this study, and written informed consent was obtained from all patients (Ohashi12-7). The patients comprised 18 men and 13 women, ranging in age from 21 to 91 years (average: 62.4 ± 17.6 years).

Diagnoses were as follows: brain metastasis, n = 13 (from lung cancer, n = 11; esophageal cancer, n = 1; and bladder cancer, n = 1) ; glioma, n = 5; meningioma, n = 4; Beçhet's disease of the central nervous system, n = 2; angioma cavernosum, n = 2; multiple sclerosis, n = 1; malignant lymphoma, n = 1; angioblastoma, n = 1; symptomatic low cerebrospinal fluid pressure, n = 1; and germinoma, n = 1. Gd-DTPA, 0.2 ml/kg, was injected intravenously as contrast medium.

The imaging parameters for RADAR-SE were as follows: FOV, 24 x 24 cm; TR, 500 ms; TE, 12 ms; slice thickness, 5.0 mm; matrix, 320 x 264; NSA; 1; RAPID, 1.5; and scan time, 91 s. The parameters for SE were FOV, 24 x 24 cm; TR, 500 ms; TE, 12 ms; slice thickness, 5.0 mm; matrix, 256 x 200; NSA, 1; and scan time, 89 s, with flow compensation.

The images acquired by SE and RADAR-SE were evaluated independently by 2 radiologists, who were blinded to the imaging sequence used. Flow-related artifacts were evaluated using a 4-point scoring system: 0 = no artifacts, 1 = slight, 2 = moderate, 3 = severe.

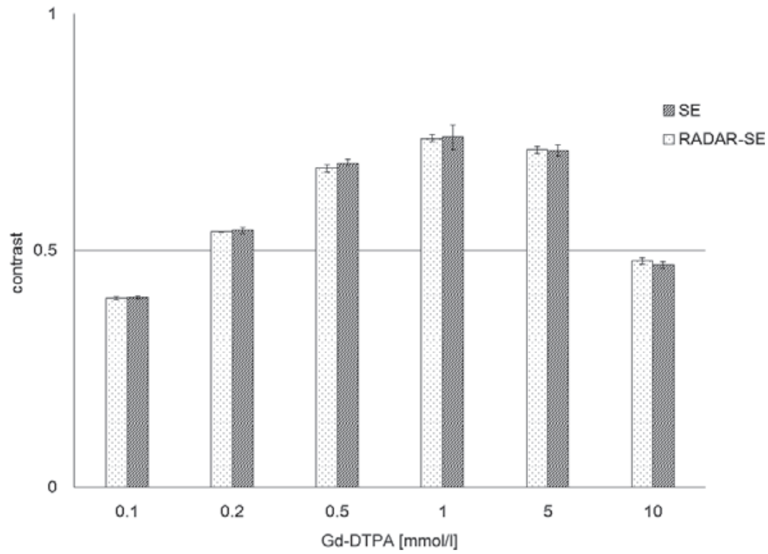

Fig. 1 Contrast evaluation using a gadopentetate dimeglumine (Gd-DTPA) phantom
A comparison of radial-acquisition regime (RADAR) spin-echo (SE) and SE shows no significant differences in contrast changes.
Error bars represent SD.

Table 1 Severity scores for artifacts on radial-acquisition regime (RADAR) spin-echo (SE) and SE images

	Reader	SE	RADAR-SE	p
Flow-related artifact	1	1.77 ± 0.76	0.03 ± 0.53	＜0.001
	2	2.29 ± 0.94	0.00 ± 0.00	＜0.001

Data are expressed as mean ± SD. Severity of artifacts was evaluated using a 4-point scoring system: 0 = no artifact, 1 = slight, 2 = moderate, 3 = severe.

Statistical analysis

We used the Wilcoxon signed-rank test to evaluate contrast of phantoms on SE and RADAR-SE and, in the clinical study, to compare the severity of flow-related artifacts on SE and RADAR-SE. A p value of less than 0.05 was considered to indicate statistical significance.

Results

Phantom study

Fig. 1 shows SE and RADAR-SE contrast in the phantom study using Gd-DTPA solution. There was no significant difference between the contrast on SE and that on RADAR-SE ($p = 0.0932$ at 0.1 mmol/l, $p = 0.0914$ at 0.2 mmol/l, $p = 0.0746$ at 0.5 mmol/l, $p = 0.2772$ at 1 mmol/l, $p = 0.0852$ at 5 mmol/l, and $p = 0.0823$ at 10 mmol/l).

Clinical study

In the clinical study, flow-related artifacts were rated as 0.03 ± 0.53 by Reader 1 and 0.00 ± 0.00 by Reader 2 for RADAR-SE, and as 1.77 ± 0.76 by Reader 1 and 2.29 ± 0.94 by Reader 2 for SE (Table 1). The severity of flow-related artifacts was significantly lower in RADAR-SE images (Fig. 2). RADAR-SE was thus useful for diagnosis, although streak artifacts were observed in a few cases (Fig. 3).

Discussion

In the phantom scans, no significant differences in contrast were seen on SE and RADAR-SE images, perhaps because RADAR-FSE, which combines FSE and RADAR, fills up the center of the k-space with multiple echoes of different TEs, resulting in decreased contrast,[9] whereas RADAR-SE fills up the k-space with SE signals with a single TE. Therefore, RADAR-SE and SE do not differ in contrast because both fill up the k-space with SE signals with identical TEs.

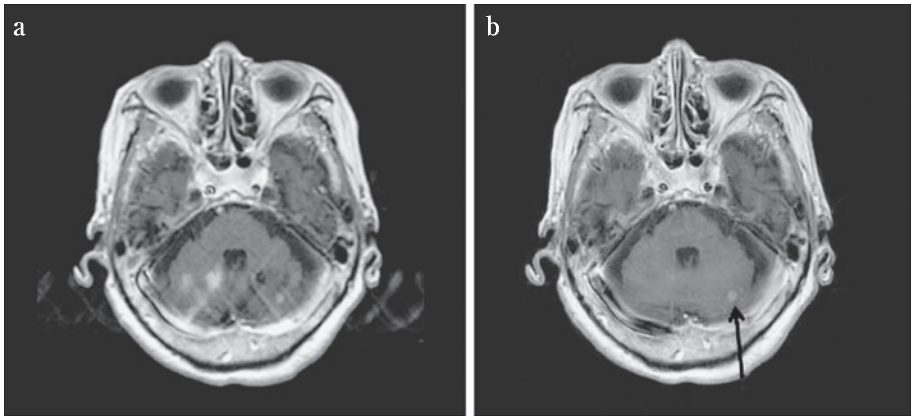

Fig. 2 (a) SE, (b) RADAR-SE
Flow-related artifacts on a spin-echo (SE) image are suppressed on a radial-acquisition regime (RADAR)-SE image. A cerebellar metastasis, which was unclear on SE, is clearly visualized (arrow).

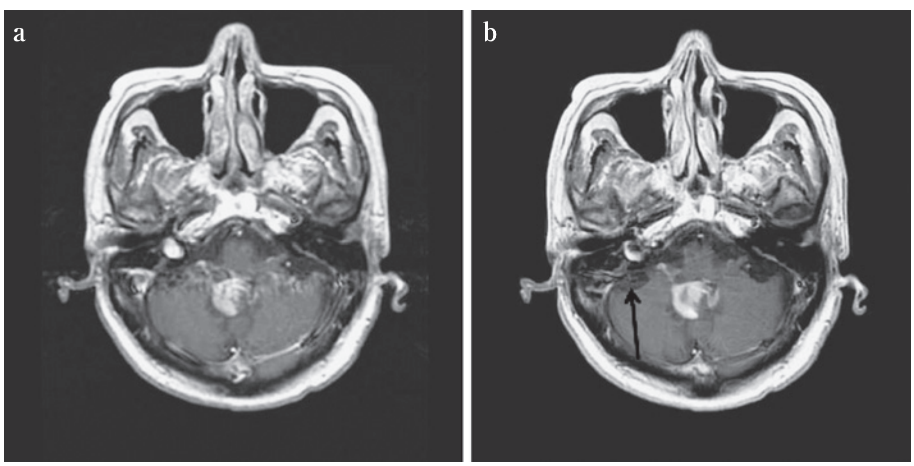

Fig. 3 (a) SE, (b) RADAR-SE
Flow-related artifacts on a spin-echo (SE) image are suppressed on a radial-acquisition regime (RADAR)-SE image; however, streak artifacts are visible (arrow).

As compared with conventional SE, T1-weighted FLAIR-BLADE changes peak contrast.[5] Conversely, in our comparison of RADAR-SE and SE, there were no significant differences in contrast changes, as shown in Fig. 1. Therefore, RADAR-SE is preferable to SE because it reduces the number of flow-related artifacts.

On clinical images, flow-related artifacts were significantly less severe on RADAR-SE as compared with SE images. Although flow compensation has been used as a countermeasure against flow-related artifacts in SE, it does not completely suppress such artifacts after injection of contrast medium.[1,2] Suppression of flow-related artifacts is also possible with T1-weighted FLAIR-BLADE,[5,6] but this technique has the disadvantage of drastically extending imaging time as compared with conventional SE.[6] Furthermore, the black-blood method and other methods of suppressing flow-related artifacts are limited with respect to number of slices and duration of imaging time.[10] It is also possible to decrease flow-related artifacts in high-resolution 3-dimensional (3D) T1-weighted images, such as those acquired using 3D volume-interpolated breath-hold examination (VIBE) and magnetization-prepared rapid-acquisition gradient-echo (MR-RAGE) imaging, but contrast enhancement is lower than that of SE imaging.[11] Motion-sensitized driven-equilibrium (MSDE) preparation has also been proposed as a means to suppress flow-related artifacts,[12] but deterioration in image uniformity and signal-to-noise ratio (SNR) was observed when MSDE was applied in combination.[13] It was also reported to yield false-positive results.[14]

By incorporating parallel-imaging techniques, RADAR-SE can acquire images with contrast equal to that of SE, in the same scan time. It can also suppress flow-related artifacts but has the disadvantage of producing streak artifacts. RADAR-SE might therefore be useful in cases prone to flow-related artifacts.

As mentioned above, streak artifacts were occasionally observed in RADAR-SE. These artifacts were not seen when using conventional methods and therefore require further study. In addition, since the number of cases in the current study was small, future studies should include a larger number of cases.

Conclusion

We studied the characteristics of RADAR-SE, a type of radial scan, and found that it suppresses flow-related artifacts without diminishing contrast or increasing scanning time. In addition, RADAR-SE had advantages when used in combination with RAPID for cranial imaging.

The authors would like to thank Yasuhiro Kamada, Masahiro Takizawa, and Masatomo Yokose of Hitachi Medical Corporation for their technical support.

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(J): in Japanese

頭部領域における Parallel Imaging を併用した Spin-Echo 型 Radial Scan の有用性

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要約

目的：造影剤投与後の magnetic resonance imaging（MRI）撮像において，フローアーチファクトが生じることが知られている．その対策として，radial scan が有用である．今回 spin-echo（SE）型 radial scan である radial acquisition regime（RADAR)-SE の有用性をファントムで評価し，parallel imaging を併用した RADAR-SE の有用性を臨床撮像において評価した．

対象および方法：ガドペンテト酸ジメグルミンを希釈したファントムを用いてコントラストの評価を行った．次に臨床 31 症例において RADAR-SE のフローアーチファクトの評価を行った．

結果：ファントム撮像において RADAR-SE は SE と同等のコントラストが得られた．臨床撮像において，RADAR-SE では SE よりもフローアーチファクトの低減が確認できた．

結論：RADAR-SE は頭部撮像において，フローアーチファクトの抑制に有用であった．

東邦医会誌 60(4)：198–203，2013

索引用語：radial scan，頭部，造影 T1WI，MRI，アーチファクト

1, 2, 3）〒153-8515　東京都目黒区大橋 2-17-6

東邦医学会雑誌　第 60 巻第 4 号，2013 年 7 月 1 日
ISSN 0040-8670，CODEN: TOIZAG