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FULL PAPER

Efficacy of the radial acquisition regime (RADAR) for acquiring head and neck MR images

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Objective: To investigate the efficacy of the radial acquisition regime (RADAR) for acquiring head and neck MR images.

Methods: 15 healthy volunteers underwent imaging with 4 sequences [fast spin echo T_2 weighted imaging (FSE-T2WI), RADAR T_2 weighted imaging (RADAR-T2WI), single-shot echo planar imaging diffusion-weighted imaging (SS-EPI-DWI) and RADAR diffusion-weighted imaging (RADAR-DWI)]. Both standard images and images during periodic mouth motion were acquired. Two radiologists scored the overall image artefacts and detectability of several anatomical structures without knowledge of sequence type. For each sequence, image distortion was quantitatively compared by the antero-posterior to right-left ratio of several anatomical structures. The mean scores of artefacts and distortion of

several anatomical structures were compared using the multiple comparison test. The detectabilities were compared using the Wilcoxon signed-rank test.

Results: Regardless of mouth motion, RADAR-T2WI was significantly superior to FSE-T2WI in artefacts and oral-area detectability ($p < 0.01$), and RADAR-DWI was significantly superior to SS-EPI-DWI in terms of artefacts ($p < 0.01$). In terms of image distortion, RADAR-DWI was significantly superior to SS-EPI-DWI ($p < 0.01$).

Conclusion: RADAR-T2WI could replace FSE-T2WI as a conventional T2WI protocol for the head and neck. For the RADAR-DWI sequence, validation studies are needed.

Advances in knowledge: RADAR-T2WI was superior to FSE-T2WI with regard to artefacts and detectability, and RADAR-DWI was superior in terms of artefacts compared with SS-EPI-DWI.

INTRODUCTION

The major problems in MRI of the head and neck include motion artefacts caused by breathing and swallowing, and magnetic susceptibility artefacts. These artefacts tend to degrade the quality of T_2 weighted imaging (T2WI) and diffusion-weighted imaging (DWI). DWI, in particular, is associated with many clinical problems due to image distortion. These artefacts cause loss of resolution and signal reduction, which can obscure anatomical detail and limit the detection of pathological findings.^{1–3} However, in recent years, modified sequences that reduce the influence of motion artefacts and magnetic susceptibility artefacts have been developed by various MR manufacturers (PROPELLER—GE Healthcare, Waukesha, Wisconsin 53188, USA; Multi Vane—Philips Healthcare, Best, the Netherlands; BLADE—Siemens Medical Systems, Erlangen, Germany; RADAR—Hitachi Medical Systems, Tokyo,

Japan; JET—Toshiba Medical Systems, Tochigi, Japan). In general, these sequences are known as periodically rotated overlapping parallel lines with enhanced reconstruction (PROPELLER). It is usually based on the fast spin echo (FSE), which achieves lower geometric distortion with radial k-space coverage than echo planar imaging (EPI) sequences.⁴ In PROPELLER, a set of parallel lines passing through the central portion of the k-space is acquired within one repetition time, referred to as a blade, which is then rotated around its centre to cover the entire k-space (Figure 1).^{5,6} The central region of the k-space that is sampled by each blade is used to correct rigid body motion between the blades. Although PROPELLER is not yet clinically used as a routine imaging procedure because of its relatively long scan time, we hypothesized that this sequence might reduce the artefacts in head and neck MR images. Although many

Figure 1. PROPELLER (GE Healthcare) k-space data acquisition. Data are acquired with a series of rotating blades. Each blade (brace) contains several phase-encoding lines.

investigators have reported the utility of PROPELLER, especially for imaging in the central nervous system,^{7–10} there have been only a few literature on PROPELLER imaging in the head and neck region.^{11–13} The differences between PROPELLER and the radial acquisition regime (RADAR) are as follows: the latter can correct every echo signal, and it can be applied to many sequences as well as FSE. However, there has been no work on the head and neck region using RADAR. Thus, the purpose of this study was to investigate the efficacy of RADAR for the acquisition of head and neck MR images.

METHODS AND MATERIALS

Subjects

The study group included 15 healthy volunteers (6 females and 9 males; age range, 21–23 years; mean age, 22.4 years). The inclusion criteria were as follows: no present illness for head and neck areas, no contraindication for MR examination including claustrophobia or person who had metallic biomedical materials or electronic device, and written informed consent. We excluded patients who had metallic artificial dentition or dental bridge because they would cause susceptibility artefacts in MR images. The study was approved by the institutional review board, and all volunteers provided written informed consent.

MR examination

All examinations were performed using a 1.5-T MR system (Echelon Vega; Hitachi Medical Corporation, Tokyo, Japan) with a 16-channel head coil. 15 healthy volunteers underwent image acquisition using 4 sequences [FSE-T2WI, RADAR-T2WI, single-shot EPI-DWI (SS-EPI-DWI) and RADAR-DWI]. In addition to images without mouth motion, images during periodic mouth motion were also acquired. Periodic motion was defined as repeated opening and closing of the mouth in 1 second. This motion was loaded every 15 s. Table 1 shows the parameters of FSE-T2WI and RADAR-T2WI. They were adjusted to match the imaging time. Table 2 shows the parameters of SS-EPI-DWI and RADAR-DWI.

MR image analysis

Qualitative evaluation

All image data sets (15 volunteers $\times$ 4 sequences $\times$ 2 motion status) were presented in random order and were evaluated independently by two experienced radiologists (one with 24 years of experience in head and neck radiology and the other with 7 years of experience in head and neck radiology). All images data sets were displayed in random order in each following two reading sessions for each observer to reduce reading-order effects. These randomizations were performed by one author who did not participate in the reading sessions using Excel-rand function. In the first reading sessions, the presence

Table 1. Measurement parameters for fast spin echo T_2 weighted imaging (FSE-T2WI) and radial acquisition regime T_2 weighted imaging (RADAR-T2WI)

	FSE-T2WI	RADAR-T2WI
TR/TE (ms)	4159/96	3849/80
Echo-train length	15	16
Number of blades	NA	37
Bandwidth (Hz/pixel)	43.5	62.5
Field of view (mm)	240 $\times$ 240	240 $\times$ 240
Section thickness/section gap (mm)	5/1	5/1
Acquisition matrix	288 $\times$ 256	320 $\times$ 380
Reconstruction matrix	512 $\times$ 512	512 $\times$ 512
Number of signals averaged	2	1
Acquisition time (min : s)	02 : 34	02 : 27

NA, not applicable; TE, echo time; TR, repetition time.

Table 2. Measurement parameters for single-shot echo planar imaging diffusion-weighted imaging (SS-EPI-DWI) and radial acquisition regime T_2 weighted imaging (RADAR-T2WI)

	SS-EPI-DWI	RADAR-DWI
TR/TE (ms)	4839/76	3915/111.6
Echo-train length	122	10
Number of blades	NA	20
Bandwidth (Hz/pixel)	250	43.9
Field of view (mm)	240 × 240	240 × 240
Section thickness/section gap (mm)	5/1	5/1
Acquisition matrix	128 × 128	128 × 128
Reconstruction matrix	256 × 256	256 × 256
b factor (s mm^{-2})	0, 500	0, 500
Rapid Acquisition through a Parallel Imaging Design (RAPID) (acceleration factors)	2	1
Number of signals averaged	4	1
Acquisition time (min : s)	1 : 03	5 : 18

NA, not applicable; TE, echo time; TR, repetition time.

and grade of image artefacts were assessed. The observers were blinded to the MR acquisition conditions. They were asked to rate the overall image artefacts using a four-point scale. They

scored each image with and without mouth motion as follows: 0 = free of artefacts; 1 = mild artefacts; 2 = moderate artefacts; and 3 = severe artefacts. Images with scores of 0 and 1 were

Figure 2. Axial T_2 weighted images of the oral cavity in a healthy volunteer. (a) Fast spin echo T_2 weighted imaging (FSE-T2WI; with mouth motion). Severe motion artefacts (arrow) from mouth motion degrade the image quality of FSE-T2WI. (b) Radial acquisition regime T_2 weighted imaging (RADAR-T2WI; with mouth motion) shows no motion artefact. (c) FSE-T2WI (without mouth motion). (d) RADAR-T2WI (without mouth motion) was superior to FSE-T2WI with regard to artefacts.

Figure 3. (a) Gray bar graphs demonstrate the artefact scores for fast spin echo T_2 weighted imaging (FSE-T2WI) and radial acquisition regime T_2 weighted imaging (RADAR-T2WI; $*p < 0.001$). For both images with and without mouth motion, RADAR-T2WI was significantly superior to FSE-T2WI with regard to the level of artefacts ($*p < 0.001$). (b) Gray bar graphs demonstrate the artefact scores for single-shot echo planar imaging diffusion-weighted imaging (SS-EPI-DWI) and RADAR diffusion-weighted imaging (RADAR-DWI) ($*p < 0.001$). RADAR-DWI was significantly superior to SS-EPI-DWI with respect to artefacts. m–, without mouth motion; m+, with mouth motion; n.s., not significant.

regarded as not having clinically significant artefacts. In the second sessions, the radiologists were asked to score the detectability of several anatomical structures (the pre-vertebral muscles, lingual muscles, palatine tonsils, retromandibular veins in the parotid gland, submandibular glands and sublingual glands) in both images with and without mouth motion as follows: 0 = clearly detectable; 1 = uncertain detectability; and 2 = difficulty in detection.

These scores of the rating artefacts and the detectability of anatomical structures were averaged separately for each sequence.

Quantitative evaluation

The anteroposterior to right-left distance ratio of several anatomical structures (the submandibular glands, palatine tonsils and spinal cord) were measured to evaluate the degree of distortion in all DWIs and FSE-T2WI. The measurements on

FSE-T2WI were used as standard values because CT data of our healthy volunteers were not available, and the repeated 180° pulses on FSE-T2WI could minimize the susceptibility effect and distortion of images. These measurements were averaged separately for each sequence. Two types of distances were also measured as an index of distortion of the overall image; the distance between the posterior border of the spinal cord and the anterior border of the oral floor (oral floor: spinal cord) and that between the lateral margins of bilateral palatine tonsils (right palatine tonsil: left palatine tonsil). These distances were also averaged separately for each sequence. Images without periodic mouth motion were used for all quantitative evaluations.

Table 3. Qualitative analysis results for artefacts compared with radial acquisition regime (RADAR) sequence

T2WI Sequence	Mean artefact score	p-value
Motion +		
RADAR-T2WI	1.23	NA
FSE-T2WI	2.27	<0.01
Motion –		
RADAR-T2WI	0.067	NA
FSE-T2WI	0.77	<0.01
DWI Sequence	Mean artefact score	p-value
Motion +		
RADAR-DWI	1.07	NA
SS-EPI-DWI	2.4	<0.01
Motion –		
RADAR-DWI	0.97	NA
SS-EPI-DWI	2.53	<0.01

DWI, diffusion-weighted imaging; FSE, fast spin echo; NA, not applicable; SS-EPI, single-shot echo planar imaging; T2WI, T_2 weighted imaging.

Figure 4. Gray bar graphs demonstrate the detectability score of the oral area with mouth motion for fast spin echo T_2 weighted imaging (FSE-T2WI) and radial acquisition regime T_2 weighted imaging (RADAR-T2WI). RADAR-T2WI was significantly superior to FSE-T2WI with regard to the level of detectability of oral area (lingual muscle and sublingual area) ($*p < 0.001$). There was no significant difference between the two sequences in the detectability score at other anatomical structures.

Table 4. Qualitative analysis results for the detectability of anatomical structures between radial acquisition regime T_2 weighted imaging (RADAR-T2WI) and fast spin echo T_2 weighted imaging (FSE-T2WI)

Anatomical structure, sequence	Mean detectability score	<i>p</i> -value
Motion+		
Pre-vertebral muscles		
RADR-T2WI	0.53	NA
FSE-T2WI	0.63	
Lingual muscles		
RADR-T2WI	0.8	<0.01
FSE-T2WI	1.57	
Palatine tonsils		
RADR-T2WI	0.77	NA
FSE-T2WI	0.9	
Retromadibular veins in the parotid gland		
RADR-T2WI	0.37	NA
FSE-T2WI	0.3	
Submandibular glands		
RADR-T2WI	0.73	NA
FSE-T2WI	0.9	
Sublingual glands		
RADR-T2WI	0.8	<0.01
FSE-T2WI	1.13	
Motion−		
Pre-vertebral muscles		
RADR-T2WI	0.03	NA
FSE-T2WI	0	
Lingual muscles		
RADR-T2WI	0.13	NA
FSE-T2WI	0.3	
Palatine tonsils		
RADR-T2WI	0.03	NA
FSE-T2WI	0.1	
Retromadibular veins in the parotid gland		
RADR-T2WI	0	NA
FSE-T2WI	0	
Submandibular glands		
RADR-T2WI	0	NA
FSE-T2WI	0.13	
Sublingual glands		
RADR-T2WI	0	NA
FSE-T2WI	0.07	

NA, not applicable.

Measurement of signal to noise ratio

Noise levels in the reconstructed images largely depend on the sensitivity profiles of the receiver coils and increase with the acceleration factors employed on parallel MRI; therefore, the signal and the noise vary spatially throughout the image. For this reason, noise levels are usually measured as standard deviation (SD) in close proximity to the lesion site or SD of normal parenchyma of the organ, not from the background.^{14,15} Therefore, we used SD of normal submandibular gland signal intensity as an estimate of local noise.^{14,15}

This method uses the following equation:

$$\text{SNR} = \text{SI}_m / \text{SD}$$

where SI_m indicates the mean of signal intensity of the region of interest, and SD indicates the SD of signal intensity of the region of interest.

Statistics

The mean scores of artefacts were compared among RADAR-T2WI, FSE-T2WI, RADAR-DWI and SS-EPI-DWI using the Steel-Dwass test for a multiple comparison of the four groups. As for detectabilities of anatomical structures, this score was

compared between RADAR-T2WI and FSE-T2WI and between RADAR-DWI and SS-EPI-DWI by the Wilcoxon signed-rank test. For quantitative analysis of MR image distortion, the mean anteroposterior to right-left ratio of several anatomical structures and the mean distance between the anterior margin of the oral floor and posterior border of the spinal cord and between palatine tonsils on both sides were compared between each DWI and FSE-T2WI. These mean values were compared using Steel's multiple comparison test between FSE-T2WI and each group. The signal-to-noise ratio (SNR) of the submandibular gland was compared between RADAR-DWI and SS-EPI-DWI by the Wilcoxon signed-rank test. Values of $p < 0.05$ were considered to indicate a significant difference in all statistical tests. Reader agreement was assessed using Cohen's kappa test. The following criteria were used: a value of 0.21–0.40 implied fair agreement; 0.41–0.60 implied moderate agreement; 0.61–0.80 implied substantial agreement; and 0.81–1.0 implied almost perfect agreement.¹⁶

RESULTS

Qualitative analysis results

For both images with and without mouth motion, RADAR-T2WI was significantly superior to FSE-T2WI with regard to artefacts and the detectability of anatomical structures in the oral

Figure 5. Axial diffusion-weighted images of the oral cavity in a healthy volunteer (b factor = 500 s mm^{-2}). (a) Single-shot echo planar imaging diffusion-weighted imaging (SS-EPI-DWI; with mouth motion); (b) radial acquisition regime diffusion-weighted imaging (RADAR-DWI; with mouth motion); (c) SS-EPI-DWI (without mouth motion); (d) RADAR-DWI (without mouth motion). RADAR-DWI was superior to SS-EPI-DWI with regard to artefacts.

area ($p < 0.01$), and the interobserver agreement was almost perfect ($k > 0.9$) (Figures 2–4, Tables 3 and 4). RADAR-DWI was significantly superior to SS-EPI-DWI with regard to artefacts ($p < 0.01$), and the interobserver agreement was almost perfect ($k = 0.90$) (Figures 3 and 5, Table 3). As for the detectability of several anatomical structures, significant differences were observed between SS-EPI-DWI and RADAR-DWI, and the interobserver agreement was almost perfect ($k > 0.81$) (Table 5).

Quantitative analysis results

In terms of the distortion of images, there was no significant difference between RADAR-DWI and FSE-T2WI in the horizontal-to-vertical ratio of all measured anatomical structures, whereas SS-EPI-DWI showed significant distortions compared with FSE-T2WI in all anatomical structures (Figure 6, Table 6). On the subject of the overall image analysis (oral floor to spinal cord, right to left palatine tonsils), SS-EPI-DWI and

RADAR-DWI showed no significant differences compared with FSE-T2WI (Table 6).

Measurement of signal-to-noise ratio

RADAR-DWI was significantly inferior to SS-EPI-DWI with regard to SNR (5.08 vs 9.66, $p < 0.01$) (Figure 7).

DISCUSSION

The results of our study indicate that RADAR-T2WI was significantly superior to FSE-T2WI in terms of both artefacts and the detectability of anatomical structures in the oral area and that RADAR-DWI was significantly superior to SS-EPI-DWI in terms of artefacts. As for the detectability, significant differences were observed between SS-EPI-DWI and RADAR-DWI in the detectability of anatomical structures. It was also revealed that RADAR-DWI was significantly superior to SS-EPI-DWI with regard to the distortion of DWIs.

Table 5. Qualitative analysis results for the detectability of anatomical structures between radial acquisition regime diffusion-weighted imaging (RADAR-DWI) and single-shot echo planar imaging diffusion-weighted imaging (SS-EPI-DWI)

Anatomical structure, sequence	Mean detectability score	<i>p</i> -value
Motion+		
Palatine tonsils		
RADAR-DWI	1.43	NA
SS-EPI-DWI	1.4	
Retromadibular veins in the parotid gland		
RADAR-DWI	1.73	NA
SS-EPI-DWI	1.7	
Submandibular glands		
RADAR-DWI	1.83	<0.05
SS-EPI-DWI	1.47	
Sublingual glands		
RADAR-DWI	1.13	NA
SS-EPI-DWI	1.6	
Motion−		
Palatine tonsils		
RADAR-DWI	0.6	<0.01
SS-EPI-DWI	1.13	
Retromadibular veins in the parotid gland		
RADAR-DWI	0.83	<0.01
SS-EPI-DWI	1.63	
Submandibular glands		
RADAR-DWI	1.6	<0.01
SS-EPI-DWI	1.1	
Sublingual glands		
RADAR-DWI	0.63	<0.01
SS-EPI-DWI	1.36	

NA, not applicable.

Figure 6. Gray bar graphs show the differences in anteroposterior to right-left ratio of several anatomical structures between each diffusion-weighted imaging (DWI) and fast spin echo T_2 weighted imaging (FSE-T2WI; $*p < 0.01$). Radial acquisition regime DWI (RADAR-DWI) showed no significant differences compared with FSE-T2WI, whereas single-shot echo planar imaging DWI (SS-EPI-DWI) showed significant differences compared with FSE-T2WI in terms of artefacts. T2 = FSE-T2WI; SS = SS-EPI-DWI; RADAR = RADAR-DWI. n.s., not significant.

The previous investigations have shown that the radial k-space acquisition scheme is beneficial for reducing motion-inducing artefacts during data sampling and image distortion in brain and parotid gland images.^{8,14,17} The present study also shows that the acquisition by rotating blades to cover the k-space can be significantly superior to standard rectilinear data sampling with regard to artefacts and detectability of anatomical structures. If the patient moves when the Cartesian scan acquires the centre of k-space, which determines the imaging contrast, it results in an extremely large motion artefact. On the other hand, the radial scan reduces the motion artefacts, since it always acquires k-space data for the central portion and averages them.¹⁶ In the radial scan, insufficient data sampling of the periphery of k-space corresponding to the high spatial frequency components can theoretically cause the reduction of spatial resolution. For this reason, imaging time of PROPELLER requires $\pi/2$ times as the Cartesian scan to obtain an equivalent spatial resolution.¹⁸ In our study, data sampling of the high spatial frequency components might be insufficient because we have intended to equalize the imaging time of RADAR and other sequences. As for T2WI, phase-encoding matrix of FSE-T2WI was 256; therefore, the ideal matrix of RADAR-T2WI corresponded to 402 ($256 \times \pi/2$), but the actual matrix was 380. We speculate that the reduction of motion artefacts could exceed the degradation of spatial resolution by insufficient sampling of the peripheral zone of k-space and the superiority of RADAR in artefact, and detectability scores in our study could support this speculation.

In terms of the lesion detectability and characterization, previous reports have suggested that PROPELLER/BLADE (PROPELLER in MR systems from Siemens Healthcare) acquisition improves lesion characterization.^{18,19} Our study also

shows that RADAR-T2WI was significantly superior to FSE-T2WI with regard to the detectability of anatomical structures in the oral area. We speculate that these results may have been attributable to RADAR, which would have reduced the artefacts by its radial k-space scanning. As for DWI, significant differences were observed between SS-EPI-DWI and RADAR-DWI with regard to the detectability of several anatomical structures. Regarding the high detectability score (low detectability) of the submandibular glands in RADAR-DWI, we speculate that this was due to the reduction in the signal-intensity-to-noise ratio (SNR) on RADAR-DWI, which had only a single number of signal averaged in order to control imaging time for clinical practice. Our results showed that RADAR-DWI was significantly inferior to SS-EPI-DWI with regard to SNR (5.08 vs 9.66 , $p < 0.01$), and these results could support our speculation (Figure 7).

Table 6. Quantitative analysis results for the distortion of anatomical structures and overall image compared with fast spin echo T_2 weighted imaging (FSE-T2WI)

Anatomical structure, sequence	Horizontal to vertical ratio, mean $\pm$ SD	p-value
Submandibular gland		
FSE-T2WI	1.44 $\pm$ 0.31	NA
SS-EPI-DWI	2.35 $\pm$ 0.49	<0.01
RADAR-DWI	1.43 $\pm$ 0.26	0.91
Palatine tonsil		
FSE-T2WI	1.13 $\pm$ 0.24	NA
SS-EPI-DWI	1.85 $\pm$ 0.52	<0.01
RADAR-DWI	1.07 $\pm$ 0.24	0.61
Spinal cord		
FSE-T2WI	0.64 $\pm$ 0.06	NA
SS-EPI-DWI	0.87 $\pm$ 0.14	<0.01
RADAR-DWI	0.63 $\pm$ 0.09	0.7
Anatomical structure, sequence	Measured distance (mm), mean $\pm$ SD	p-value
Overall image (oral floor: spinal cord)		
FSE-T2WI	94.0 $\pm$ 6.2	NA
SS-EPI-DWI	97.5 $\pm$ 8.0	0.45
RADAR-DWI	92.8 $\pm$ 6.7	0.59
Overall image (right palatine tonsil: left palatine tonsil)		
FSE-T2WI	45.5 $\pm$ 4.7	NA
SS-EPI-DWI	43.9 $\pm$ 4.2	0.22
RADAR-DWI	45.3 $\pm$ 4.8	0.96

NA, not applicable; RADAR-DWI, radial acquisition regime diffusion-weighted imaging; SD, standard deviation; SS-EPI-DWI, single-shot echo planar imaging diffusion-weighted imaging.

Figure 7. Gray bar graphs show signal-to-noise ratio (SNR) of submandibular gland between single-shot echo planar imaging diffusion-weighted imaging (SS-EPI-DWI) and radial acquisition regime diffusion-weighted imaging (RADAR-DWI; $*p < 0.01$). SS-EPI-DWI was significantly superior to RADAR-DWI. SS = SS-EPI-DWI; RADAR = RADAR-DWI.

Concerning the distortion of images, previous reports have suggested that the distortion was eliminated at PROPELLER-DWI in head and neck MR image.¹¹ Our study also shows that only RADAR-DWI showed no significant differences compared with FSE-T2WI with regard to the distortion of all measured anatomical structures, whereas SS-EPI-DWI revealed significant differences. We presume that RADAR-DWI could reduce the distortion under the condition not using EPI but FSE. EPI collects the raw data without using 180° pulses, and therefore it accumulates the phase difference, which distorts the images in the phase-encoding direction. Especially in DWI, motion probing gradient pulses repeated in a short time affects the phase difference. For this reason, we speculate that RADAR-DWI was able to minimize the distortion, whereas the radial k-space scanning itself could not reduce the image distortion.

Our study has some limitations. First, we applied this technique for normal volunteers only and did not test it using clinical images. Thus, it is possible that the method may not yield reliable results for the depiction of actual head and neck lesions. For example, the motion artefacts in our study might not reflect the actual artefacts in a clinical setting. Therefore, a future validation study will be required to determine whether RADAR would be useful for clinical imaging. Second, we have excluded the patients who had metallic artificial dentition or dental bridge. As a result, the study group was limited to younger healthy subjects. Thus, our study population is significantly different compared with patients examined in a clinical setting. Third, our quantitative analysis of the degree of distorted images by measuring the anteroposterior to right-left ratio of anatomical structures might not reflect the true skewness. For example, when the structure was elongated in the x -axis and elongated in the y -axis, the skewness could be cancelled out in the ratio measurement. Thus, testing for a more suitable method of analyzing skewness will be needed. Finally, a potential performance bias could not be completely eliminated, since the type of MR sequence being used was identifiable by the radiologists. Although the observers were blinded to the MR acquisition conditions, the experienced radiologists may distinguish most sequence types looking at the images. Despite these limitations, however, this is the first study to demonstrate the utility of RADAR in head and neck MR images.

In conclusion, RADAR-T2WI could replace FSE-T2WI as a conventional T2WI protocol for the acquisition of head and neck MR images. For DWI sequences of the head and neck region, RADAR-DWI was superior at reducing artefacts and distortion image, but equivalent to SS-EPI-DWI, which is routinely used in a clinical practice, in terms of the detectability of anatomical structures, although validation studies are needed.

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